EVALUATING THE PEDESTRIAN LEVEL OF SERVICE FOR THE CITY OF PANCHKULA

A Thesis Submitted in Fulfillment of the Requirement for the Award of the Degree of

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Submitted By

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DECLARATION

I hereby declare that this work which is being presented in the thesis entitled "Evaluating The Pedestrian Level of Service for the City of Panchkula" in partial fulfilment of the requirement for the award of degree of Master of Engineering in the field of Civil Engineering with specialization in Infrastructure Engineering submitted at Thapar Institute of Engineering & Technology (Patiala) is an authentic record of my own work carried out during the period from 14.08.2018 to 14.08.2019 under the guidance of Dr. Mansha Swami, and Mrs. Neena Garg.

The matter embodied in this thesis has not submitted by me for the award of any other degree or diploma.

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This is to certify that the above declaration made by the student concerned is correct according to the best of my knowledge and belief.

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ABSTARCT

Pedestrians are the most vulnerable population of road users because their movement is restricted to the physical boundary of walkways and sidewalks. Therefore, it is necessary to assess the walkability of the pedestrian networks and consider pedestrians' needs when designing transportation facilities to motivate walking in safe, accessible, and pleasant environments. 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 environmentally friendly facilities increasing, pedestrians are getting more and more attention.

Though there are different ways to measure walking conditions of sidewalks, the most common approach is calculating pedestrian level-of-service.

However, qualitative factors that strongly influence the pedestrian perception and experience are not addressed in standard level-of-service calculation (Jaskiewicz,2000). The assessment methods should not be limited to data collection and measurement which can be easily satisfied quantitatively, but it also should reflect the qualitative walking experience of the pedestrian (Singh & Jain, 2011).

In this research, twenty-four street sections have been selected in Panchkula, Haryana. For each pedestrian segment, the level-of-service (LOS) has been calculated individually by using the Highway Capacity Manual (HCM) 2010 & INDO-HCM 2017. In addition to the quantitative research, pedestrians on the segments were surveyed in order to assess the qualitative factors. A questionnaire sheet was created and Responders were requested to record their perceptions on the ease of walking on the sidewalks.

The pedestrians perception of comfort and safety while walking on sidewalks is comprehensively studied by the evaluating from the survey data. From the Various Surveys performed it was stated that existence of sidewalks on both sides, infrastructure, protection against to weather, and etc. had an important effect on ease in walking.

To encourage a greater modal shift towards walking on the streets, Firstly, it is important to understand and evaluate walkability and walking concepts. While walkability assessment studies mainly deal with perception and built environment aspects, engineering studies focused on evaluating pedestrian level of service (PLOS) based on flow and infrastructure capacity measures. PLOS evaluations for Panchkula walkways are performed using Highway Capacity Manual (HCM) 2010, Indo-HCM 2017, which resulted in contradicting ratings. Comparison of the results revealed insights about the strength and weaknesses of each method, and led to a series of recommendations to improve walkability assessments, which was the main goal of this study. At the end, the results of both methods were analyzed to compare how quantitative measurements can differ from peoples' real-world experiences. Comparing and contrasting the results revealed that the quantitative results for pedestrian LOS are one level higher than the qualitative results in most selected pedestrian segments in Panchkula. Further various recommendations have been suggested in order to enhance the LOS of a corridor based on Best Practices from across the world. A small re-design of sidewalk has also been done for 2031. This Research work is an attempt to enhance the Understanding & Evaluation of PLOS for an Urban area in a developing country like India.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Pedestrian form a very important component of our Transportation System. Walking is a full- ledged mode which is non-motorized, sustainable, promote good health, zero fuel consumption, zero pollution. Walking becomes an important part of urban transport in many large cities in developed countries, but most people in developing countries prefer driving and riding than walking. Weather conditions (heat, dust, and air pollution), sidewalk conditions, and distance of a trip are among many reasons unfavorably affecting the decision to walk. Pedestrians are an inseparable part of transport system.

However, analyzing and simulating pedestrians' behavior is a complex phenomenon compared to vehicular movement. Generally, sidewalk characteristics in developing countries are different compared with those in developed countries. For instance, most of sidewalk obstructions commonly found in developed countries are utility tools, such as telephone boxes, post boxes, billboards, shelters etc. In developing countries, however, on street vendors exist as obstruction along the sidewalk, which are commonly found in commercial area. Street vendors commonly occupy space inside the sidewalk width. Reduction in total width due to vendor's existence leads to obstructions for pedestrian movements. Encroachments like this need to be removed.

The term “pedestrian” refers to someone who is standing, sitting, and walking on a road; or a walking facility on foot; or in any mobility device that hasn’t been designed to surpass a speed of 10 kph. Provision of walking facilities can satisfy psychological, physiological and social needs of travellers on foot (Rastogi, R. *et al.* 2014).

The Shimla road users and pedestrians (Public Safety and Convenience) Act, 2007. Received the assent of the President on the 13th February, 2008. An act to restore the sanctity of the Shimla Mall Road by preventing its use as a thoroughfare and to provide for

regulation of vehicular traffic in the interest of public safety and convenience on the sealed and restricted roads of Shimla town to prevent annoyance and injury to pedestrians and to provide for matters connected therewith or incidental thereto.

Right to walk is further proposed to be included in one of the fundamental rights as per a petition filed in the High Court of Punjab and Haryana. Choosing to move on foot—to work, school, or the market should be safe and easy for urban residents. Yet city streets are increasingly being built for high-speed, personal vehicles, with hazardous intersections and narrow or non-existent sidewalks. In many cities, simply getting anywhere by foot has become a dangerous: thousands of pedestrians are killed on the world's roads each week. Pedestrians, wheelchair users, children, and the elderly deserve the right to walk safely and comfortably to their destinations. Reshaping our cities to encourage walking is part of building a sustainable future, and avoiding the high costs to build and maintain urban highways. Building better spaces for walking saves lives, emissions, and promotes urban equity.

According to the Centres for Disease Control and Prevention (CDC), More than 145 million adults now include walking as part of a physically active lifestyle. More than 6 in 10 people walk for transportation or for fun, relaxation, or exercise, or for activities such as walking the dog. The percentage of people who report walking at least once for 10 minutes or more in the previous week rose from 56% in 2005 to 62% in 2010 (CDC, 2012).

Physical activity helps control weight, but it has other benefits. Physical activity such as walking can help improve health even without weight loss. People who are physically active live longer and have a lower risk for heart disease, stroke, type 2 diabetes, depression, and some cancers. Improving spaces and having safe places to walk can help more people become physically active. Aerobic activities like brisk walking, running, swimming and bicycling make you breathe harder and make your heart and blood vessels healthier.

Designing communities that are more walkable, mixed-use, and compact will add more physical activity into our daily routines and promote healthier lifestyles.

Furthermore, pedestrianized environments are a common approach to reduce carbon footprints in cities because walking is a zero-carbon activity and involves zero costs. Recently, redevelopment of urban areas has moved toward sustainability and building walkable environments to release less pollution into the air.

Walking is the most desirable mode of transportation in sustainable communities. It is prudent to consider pedestrian friendly designs for urban streets that promote walking. This doesn't occur unless decision makers and engineers plan and build safer and more pleasant urban sidewalks which could help the pedestrians to feel more comfortable when walking than driving.

Walking should not be limited only to young people, but also should be treated as beneficial physical exercise for the senior citizens, disabled and young children. Providing safe and comfortable walkable facilities inspire different ages with different levels of abilities to walk. Quality of walking conditions defines the walkability of a facility.

Growing motorization has also led to a dramatic increase in the pedestrian fatalities and accidents, and high levels of air pollution particularly exposing pedestrians who walk to access public transport to reach their destinations. According to statistics provided by the Ministry of Road Transport & Highways, Government of India, the annual rate of growth of motor vehicle population in India has been increase about 10 percent during the last decade. In contrast to the more global perspective of walkability, engineers have used old measurement techniques in an attempt to establish some quantitative assessment of what might constitute a friendly walking environment in terms of pedestrian comfort and measures of congestion.

The WHO (2009) study that examines policies around the world related to road safety suggests that: Our roads are particularly unsafe for pedestrians, motorcyclists and cyclists who, without their protective shell of a car around them, are more dangerous. These road users need to be given increased attention. Measures such as building sidewalks, separate lanes for two wheelers; reducing drink-driving, raised crossings and excessive speed;

increasing the use of helmets and improving trauma care centre are some of the intervening places that could save hundreds of thousands of lives every year. While progress has been made for protecting people in cars, the needs of these vulnerable groups of road users are not being met. In 2013, 185 million vehicles were playing on Indian roads.

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.

1.2 PERCENTAGE SHARE OF PEDESTRIAN AT GLOBAL AND INDIA LEVEL

More than 270,000 pedestrians lost their lives on the world's roads in 2013, accounting for 22% of the total 1.24 million road traffic deaths. In 2013, a pedestrian was killed every 2 h and injured every 8 min in traffic crashes on an average in USA. Pedestrian deaths accounted for 14% of all traffic fatalities in road accidents. This share was 23% in 2014 in the UK. In India, 8.8% of total road accident fatalities in 2014 has been reported to be pedestrians. Although the percentage share is lower compared to other countries, the actual number of pedestrian fatalities was 12,291. This is equivalent to losing a fully loaded Boeing 777 aircraft every week. In India, upon classifying the road accident fatalities according the place of occurrence, it was found that 10.3% of all the road accident fatalities took place at pedestrian crossing locations. In USA, 69% of the pedestrian fatalities occurred at non-intersection locations, 20% at intersections and 10% at other locations like sidewalks and bicycle lanes. The absence of pedestrian crossing facilities also leads to a large number of pedestrian road accidents at mid-block locations. In the UK, 75% of

pedestrian accidents occurred where pedestrian crossing facilities were not present at the crossing location. According to the data provided by Department of Transport, UK, pedestrians have the second highest fatality rate (deaths per billion passenger miles) after motorcyclists among all other road users. To prevent such crashes and ensure safe pedestrian crossing movements, appropriate facilities should be provided at crossing locations. (U Jain, R Rastogi, 2016)

1.3 MODAL SHARE OF PEDESTRIAN IN INDIAN CITIES

Pedestrians facilities & Infrastructure are very improper and lacking in developing countries like India because of which the Quality & LOS are going down and is a big discourage for the pedestrians. Walking is a mode of transport which is commonly used for short trips. Walking mode provides the fundamental interface between the various types of land-use and other transport modes. Pedestrians are more flexible than vehicular traffic. Ministry of Urban Development Report (MoUD, 2008) has remarked out that the walk mode share is declining and is projected to decline further over the next 20 years; particularly in cities having less than 2 million populations. Pedestrian fatality share at the national level is 9.5 % (MORT&H, 2015). The modal share of pedestrians across seven Indian cities is given in Table 1.1 (MoUD, 2008). (*Source: INDO-HCM 2017)*

Table 1.1 Modal Share in Indian Cities

Description	Modal Share by Walk (%)
< 5 lakh Population, Plain Terrain	34
< 5 lakh Population, Hilly Terrain	57
5-10 lakh Population	32
10-20 lakh Population	24
20-40 lakh Population	25
40-80 lakh Population	25
>80 lakh Population	22

(Source: INDO-HCM 2017)

1.4 STATEMENT OF THE PROBLEM

Although, urbanization brings opportunities of jobs and affluent life style but it has its drawbacks as well. Even pedestrian facilities are not spared from the ill effects of urbanization, due to which the operating condition of road deteriorates with each passing day. Today various problems such as speed limitation, increased congestion, increase travel time and poor level of service are being faced by on the road networks. The requirement of the pedestrian, like the need of the motor vehicles, is prerequisite in designing transportation facilities. Their safety, comfort, convenience and mobility should be kept well in mind.

A national level review has shown that nearly 60 percent of deaths and injuries on national highways are among pedestrians and hospital-based studies indicate that pedestrian death varies from 22% to 35% and population-based studies of road deaths are among pedestrians. Although it is impossible to ascertain the precise number of pedestrians injured and killed, however it is estimated to be around 40000 deaths annually in India. Collision with heavy vehicles and mid-sized vehicles results in higher death.

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 indicatives which represents quality of given intersection in terms of perceived safety, convenience and comfort in terms of pedestrian perspective.

1.5 NEED OF STUDY

Due to the above discussed issues faced by the Pedestrians in Developing Countries, a need arises to study, evaluate & enhance the metrics that govern the Pedestrian Behavior. The Pedestrian LOS is one such parameter which breaks down the speed, density, volume &

Capacity values of a pedestrian stream. Once these Parameters are evaluated, further study can be done to enhance the metrics. So, there is a need to evaluate the Level of Service criteria of pedestrians for the betterment & the safety of Pedestrians.

1.6 OBJECTIVES OF STUDY

1. Evaluation of Pedestrian Walkability Parameters to assess the current scenario in Panchkula city.
2. To Calculate PLOS for the Selected Locations as per Highway Capacity Manual (HCM-2010) for the Panchkula City based on Geometric Design.
3. To Calculate PLOS for the Selected Locations as per INDO-HCM 2017 for the Panchkula City based on Geometric Design.
4. To Evaluate the Walkability Scores based on PLOS model using metrices from Pedestrian Perception responses.
5. Comparison of Results with respect to Methodologies and results obtained from the current study and Redesigning the Problematic Segment
6. Sidewalk Redesign & Recommendations for Enhancing Level of service on Urban roads.

1.7 LAYOUT OF THESIS

The thesis is planned into ten chapters. The first chapter introduces the topic, defines the problem, explains the need of the study, provides the objectives of the present work study area. In the second chapter presents the review of literature on pedestrian level of service analysis and. The third chapter is about the study area and the methodology dealing with it and the data collection technique. Fourth Chapter presents the walkability parameters of the current scenario including all the figures of the pedestrian response on the qualitative questionnaire survey and also the Pilot and volume survey details. The fifth chapter presents the level of service concepts & the detailed procedure for evaluation of the Pedestrian LOS for the off-street Pedestrian and the analysis of the results with the help of HCM 2010. The sixth chapter presents detailed procedure for the evaluation of the Pedestrian LOS for the selected locations with the help of INDO-HCM 2017. The seventh chapter presents the procedure for the evaluation of the Walkability Scores based on the PLOS Model using the

response of the Pedestrian Perceptions and further evaluating the PLOS Scores and the LOS. The eighth chapter presents summary of the research work, Comparisons of the Results. The Ninth chapter deals with the Policy Recommendation. The Tenth Chapter deals with the Conclusion and future scope in this research area.

CHAPTER 2

LITERATURE REVIEW

2.1 RESEARCH PUBLICATIONS

1. Kodavanti V.R. Ravishankar *et al.* (2017). Studied the risk of pedestrian's safety at uncontrolled midblock and unsignalized intersections. They conducted a video graphic study to further extract data and study parameters like crossing time of pedestrians, speed, different stages of crossing, number of interruptions while crossing and also the type of vehicle for which the pedestrians accept the gap. The results reveal a correlation between the size of the vehicle and the gap acceptance by the pedestrian and crossing behavior of the pedestrian. Also, based on gender Male pedestrians were found to take more risk than the female pedestrian while crossing the unsignalized intersections.

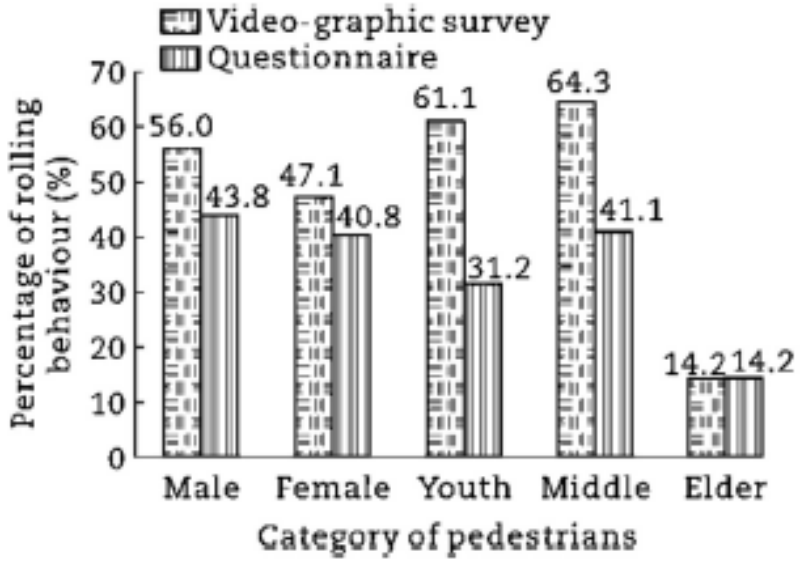

Figure 2.1 Comparison of Rolling Gap behaviour from surveys

Figure 2.1 Shows a comparison of the results of rolling gap behavior across different age brackets from the questionnaire-based survey and the video graphic survey. As can be seen in the most cases it is matching the video graphic result but in the case of young and middle-aged pedestrians the risk-taking tendency is way more than reported.

2. Pelin Onelcin *et al.* (2017) tried to optimize the signal timings in accordance with the pedestrians crossing speeds and delays. They also explored the pedestrian perception on safety.

Pedestrians are the vulnerable part of the road users worldwide. Their study was carried out at signalized intersections in Izmir, Turkey. They selected several intersections for the study where pedestrian density was high. The peak hours were identified as afternoon peak (12.30-13.30) and evening peak (17.00-18.00) hours using video-based survey. The mean crossing speed was found to be 1.31 m/s & the average 15th percentile crossing speed was found to be 1.07 m/s.

3. Jain Udit & Rastogi Rajat (2016) published a review paper on pedestrian crossing warrants from across the world. Pedestrian Crossing Warrants or PCW's help in identifying the type of facility to be provided at a location to make sure pedestrians have an ease of walking in that area. The following figure shows all types of pedestrian crossing facilities in a classified manner.

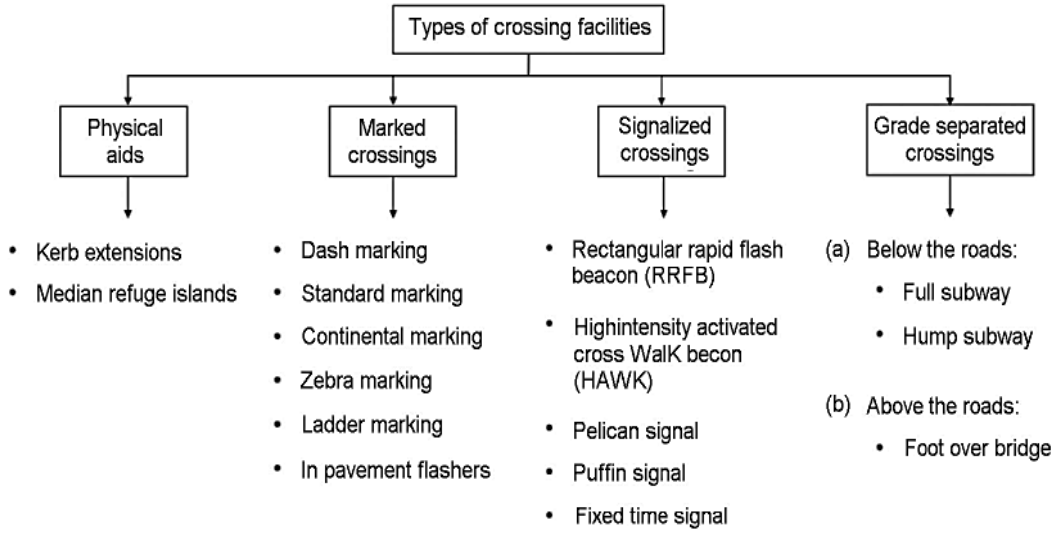

Figure 2.2 Types of Pedestrian Crossing Facilities.

Based on the comprehensive literature review done by these authors, there was one thing that merged in the conclusions. In India, very old systems of PCW were being followed. Further, in developing countries like India and Iran very limited research has been done on the Pedestrian Crossing Warrants.

4. Jain, Akash, *et al.* (2014), they analyzed the provision of enhancement in the pedestrian facilities with the help of a study conducted in Roorkee city. The effect of pedestrian age, gender, luggage, crossing patterns were examined on pedestrian flow characteristics. In the figure below, as can be seen is the variation of pedestrian walking speed on various location in Roorkee city.

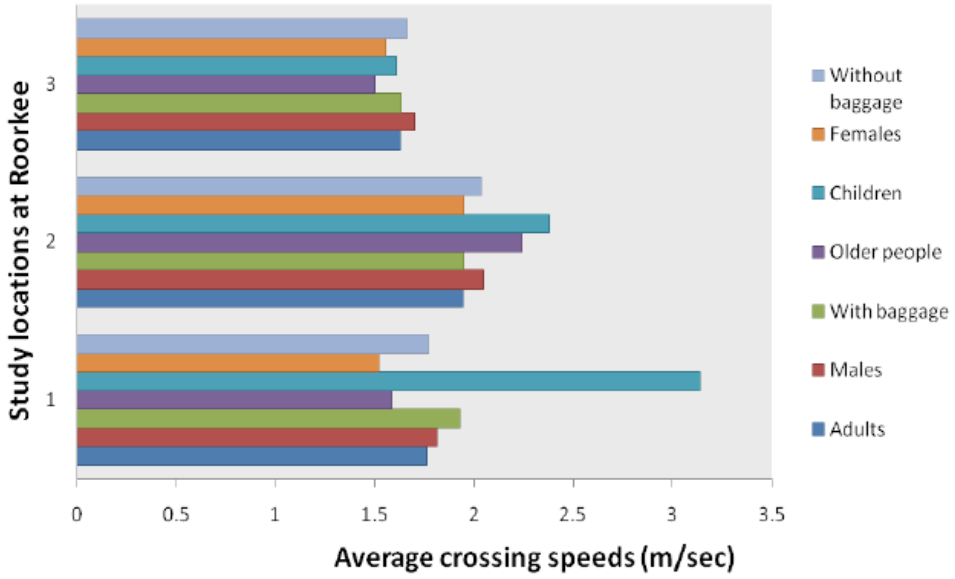

Figure 2.3 Variation of Pedestrian Crossing Speeds at study area.

Also, the following figure shows the average values of gap accepted across various age groups for both the genders. The average gap values are shown in terms of safety margins (seconds) and in average time gap (seconds)

Category	Average Safety Margins (sec)	Average Time Gap (sec)
Males	1.75	3.7
Females	2.25	4.0
Adults	1.85	3.95
Olders	2.4	3.0
Children	2.0	4.35

Figure 2.4 Average gaps for males and females.

5. Sheng Jin *et al.* (2013) studied the vehicle pedestrian interaction at the crosswalk in three scenarios as shown in figure below. First Scenario represents the vehicle j as the nearest upstream vehicle from the stop line. The second Scenario shows thaat the pedestrian is crossing the crosswalk and the virtual vehicle is assumed to be on the road while the

pedestrain is crossing so vehicle j will have to wait till virtual vehicle gets moving or till when the pedestrian completes the crossing of the crosswalk. Third scenario is when the vehicle j notices the pedestrians on the sidewalk waiting to cross the road and the waiting angle of these pedestrians is used to model the lateral discomfort.

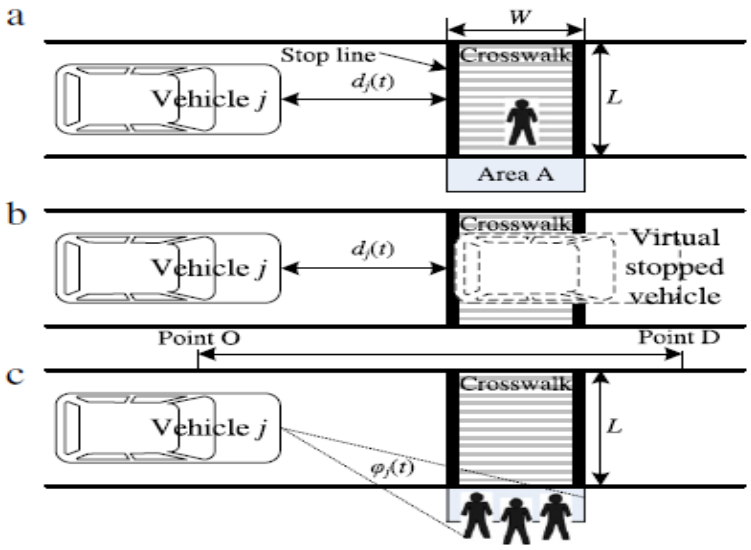

Figure 2.5 Illustration shows 3 scenarios of the study

The result of this study showed that there was significant delay to the pedestrian as well as the vehicle in the case of vehicle pedestrian interaction and further such interaction reduced the traffic capacity drastically.

6. Eleftherios Sdoukopoulos (2011) did a study to assess the Pedestrian Level of Service methodologies followed worldwide and compared them for the Greek city Thessaloniki. He compared around 18 methods from across the world. The summary of all these methods are as given below.

Method	Country	Spatial level						Primary factors			
		Area	Roadway corridor	Roadway segment	Intersection	Pedestrian crossing	Sidewalk	Design	Environmental	Traffic	Delays
Kansas Walkability Plan (2004)	U.S.A.	✓						✓	✓		
Jaskiewicz F. (2000)	U.S.A.			✓					✓		
Gallin N. (2001)	Australia			✓				✓	✓		
Landis B. et al (2001)	U.S.A.			✓				✓		✓	
Mozer D. (1997)	U.S.A.			✓				✓		✓	✓
Jensen S. (2007)	Denmark			✓				✓	✓	✓	
FDOT (2002)	U.S.A.			✓				✓		✓	
Dixon L. (1996)	U.S.A.		✓					✓	✓	✓	
Landis B. et al (2005 -2006)	U.S.A.		✓			✓				✓	✓
HCM 2000 (TRB)	U.S.A.		✓			✓	✓	✓		✓	✓
Steinman N., Hines K. (2003)	U.S.A.				✓			✓		✓	
Chu X., Baltes M. (2001)	U.S.A.					✓		✓		✓	
Muraleetharan T. et al (2004)	Japan					✓	✓	✓	✓		✓
Tan D. et al (2007)	China						✓	✓		✓	

Figure 2.6 Comparison of 18 Methods by Eleftherios Sdoukopoulos

He further compared these methods based on their components and separate locations. For Greek cities till then they were following the HCM 2000 method. They concluded that LOS values will vary with variation in the method and also, the methods that take into consideration mainly the qualitative parameters reported a lower LOS when compared to the quantitative methods. The author suggested to develop a new model for calculating LOS in the Greek Environment.

7. Johanna Eidmann et al. (2011) They did a study for walkability of the North Adams area of Massachusetts. They used the Rubric's method to do a quantitative ranking of the neighborhoods. Separate Rubrics were used for commercial and residential streets. Apart from this field notes, inventory observations, questionnaire-based interviews with community users and pedestrian surveys were used to study the walkability of the area. Most of the streets nearer to downtown ranked well were pleasant to walk on, with complete and unharmed sidewalks, well-marked crosswalks, and grass-buffers separating the pedestrian from the rest of the street. However, the sections farther from downtown scored

poorly, mainly due to sidewalks that were either absent or in poor condition. These streets hampered the overall neighborhood connectivity and dissuade their residents from walking.

8. Inger Marie Bernhoft *et al.* (2008) studied the preferences of senior pedestrians which revealed that the senior pedestrians were appreciative of the pedestrian infrastructure such as the pedestrian crossing, cycle paths, signalized pedestrian intersections etc. They felt highly unsafe while crossing the street in the absence of these facilities. They also insisted on a pavement surface on their pedestrian route instead of a fast passage. These differences between the behaviors of the older users and the younger users were mainly due to their health condition and activity levels.

9. Zhenzhong Cui and Nambisan, Shashi (2003) studied the spatial as well as the temporal characteristics of the midblock pedestrian crashes, which they also names as MBPC's. They studied all possible combinations of time and places where these crashes could occur. All existing databases pertaining to crashes were used. They also studied all relevant geometric characteristics of roadways along with the study of pedestrian and driver behavior patterns. The results expressed a lower possibility of conflict if the pedestrian chooses to cross at an intersection as compared to a midblock location.

10. V.P. Sisiopiku *et al.* (2003) conducted an observational study of pedestrian behaviors at various urban crosswalks in Michigan USA along with a pedestrian user survey next to a university campus. The various facilities studied by them included signalized and unsignalized intersection crosswalks, physical barriers like landscaping and vegetation, unsignalized marked and non-striped midblock crosswalks, midblock crosswalk shelters, coloured paving at medians and curbs, and pedestrian warning signs. Videography study was done to record pedestrian movement. Majority of the users were willing to cross the road over a midblock crosswalk which was unsignalized. The location of the crosswalk, with respect to the origin and destination of the pedestrian was a major factor influencing the choice of pedestrian. Pedestrians also stated that if proper traffic control would be placed in the scene, they shall have more motivation to cross road. The other important feedback was the presence of natural vegetation barrier in terms of bushes and hedges and concrete

wall coming in the way of their vision to cross was observed. In low traffic conditions the passengers were less likely to comply with the signal indications for pedestrians and would rather prefer to cross the road through unsignalized midblock locations. The pedestrian's quality and convenience were understood by their jaywalking behaviors. Also, they would discourage use of unnecessary warning signals placed at the midblock and also mentioned that motorized vehicles gave very less priority to their presence on the crossings. To counter this, they suggested revising of the pedestrian intervals during heavy traffic conditions.

GD RIVER AVE (M-43) PEDESTRIAN CROSSWALKS (ABBOTT - BOGUE STS)

Date: 2/23/98, Monday, 35 °F, cold, partly sunny **Time:** 2:46pm

1- Abbott St. Signalized Intersection Crosswalk

Pedestrian counts-30 min	On-crosswalk	Partial Jaywalkers	Jaywalkers around CA	Total
RU + PS (VS)	47	2	0	**49**
PS (VR)	14	1	0	**15**
S	32	2	2	**36**
LS	9	1	0	**10**
Total 102		**6**	**2**	**110**

RU: Regular users **S: Sneakers**

PS (VS): Partial sneakers (vehicles stopped) **LS: Late starters**

PS (VR): Partial sneakers (vehicles running)

Jaywalkers from west side of the crosswalk = 5 peds in 30 min

Jaywalkers from east side of the crosswalk = 3 peds in 30 min

Total pedestrians in the Crosswalk Area = 102 + 6 = 108 peds in 30 min

Total pedestrians in the Crosswalk Influence Area = 110 + 5 + 3=118 peds in 30min

Vehicular Volume (VV) = 2427 veh/hr, L_{CIA} = 38.4 m (126.0 ft)

$$\text{Overall Crossing Compliance Rate} = \frac{\textit{No of RUs + no PS(VS)s on-crosswalk}}{\textit{Total peds in the crosswalk influence area}} = \frac{47}{118} = 39.8\%$$

Total Pedestrian Volume in the Crosswalk Area = 108 * 2 = 216 peds / hr

Total Pedestrian Volume in the Crosswalk Influence Area = 118 * 2 = 236 peds / hr

Spatial Compliance Rate =102 / 118 = 86.4%, Violation of flashing red signal = 10/108=9.3%

Temporal Compliance Rate= 49/108 = 45.4%.

Figure 2.7 Data summary sheet for signalized crosswalks

(Source: V.P. Sisiopiku *et al.*, 2003).

Figure 2.7 shows the summary of data collected at the signalized crosswalks. This research consolidated the relevance of survey-based results as the results were very much in accordance with the movement data extracted from video graphic survey.

Bivina *et al.* (2018) They Studied Qualitative Pedestrian Level of Service is given in the Table 2.1 from 1993 to 2016. The Table illustrates the methods used by various authors and the factors considered for the study. Followed by The Factors considered for the study and their description is given below in Table 2.2

Table 2.1 Summary of Previous Qualitative Pedestrian Level of Service (PLOS) studies

Author	Methods	Factors considered
Sarkar (1993)	Scoring System	Convenience, comfort, safety, security, continuity, system coherence and attractiveness
Khisty (1994)	Scoring System	Comfort, convenience, continuity, attractiveness, system coherence, safety, security
Dixon (1996)	Scoring System	Path conflicts, amenities, motor vehicle LOS, maintenance problems, provision of basic facilities and provision for multiple modes.
Landis et.al. (2001)	Ordinary Least Regression	Lateral separation factors, traffic volume, speed of the vehicle, driveway access frequency and volume
Gallin (2001)	Scoring System	Sidewalk width, sidewalk surface, comfort, walk environment, potential for vehicle conflict, crossing facilities and pedestrian volume,
Muraleetharan et.al. (2005)	Ordinary Least Regression	Sidewalk width & separation, pedestrian volume, flow rate and bicycle events
Jaskiewicz (2005)	Scoring System	Enclosure, Complexity of Path Network, Building Articulation, Complexity of Spaces, Overhangs, Buffer, Shade Trees, Transparency, Physical Components/Condition

Jensen (2007)	Cumulative Logit Model	Sidewalk width, walking environment, pedestrian volume, parked vehicle, bicycle track width, buffer area and landscape
Parida et.al. (2007)	Scoring System	Footpath width, footpath surface, continuity, comfort, safety, encroachment, potential to vehicle conflict, crossing facilities, walking environment and pedestrian volume.
Sheikari et.al. (2014)	Scoring System	Footpath surface, footpath, corner island, width of footpath, tactile pavement (guiding), tactile pavement (warning), signal, seating area, drinking fountain, curb ramp, ramp, grade, signal, bollards, lighting, driveway, traffic speed, buffer, traffic lanes, crossing, facilities, furniture
Garcia & Lara (2015)	Scoring System	Sidewalk width, sidewalk surface, walking distance
Aghaabbasi et. al. (2016)	Scoring System	Sidewalk width, sidewalk surface, ramps, tactile pavements, utilities and landscape

(Source: Bivina *et.al*, 2018)

Table 2.2 Factors considered for the study and its summary

Factors	Description
Sidewalk surface	Sidewalk surface is defined as the floor on which a person walks in the pedestrian environment. Sidewalk surface types often determine how difficult an area is to negotiate. An accessible sidewalk surface should be firm, stable, slip-resistant and free from cracks and bumps.
Sidewalk Width	The sidewalk's width not only affect pedestrian serviceability, but also determines the types of access and other pedestrian elements that can be installed. Pedestrian travel tendencies also affect the width of sidewalks. Sidewalks should be sufficiently wide so that pedestrians can walk and separate themselves from road traffic and avoid street furniture, obstructions and also other pedestrians.

Obstructions	The obstruction can be anything or in any form like garbage bin, hoardings, trees or electric pole present on the sidewalk. The sidewalk should be such that the comfort of pedestrian should not be affected by any obstructions.
Potential for vehicle conflict	Sometimes pedestrians on sidewalks are prone to vehicle conflict if sidewalks are unseparated or not having any guard rails. Grade-separated facilities or raised footpath are facilities that segregate pedestrians from motor vehicles. They can significantly reduce pedestrian-vehicle conflicts and potential collisions.
Continuity	A continuous sidewalk are those sidewalks that don't have any frequent up and downs throughout. Sidewalks should be continuous to provide comfort while walking, especially for disabled pedestrians and old age ones. Discontinuous sidewalks can make them uncomfortable and can drive pedestrians to walk on the carriageway.
Encroachment	Encroachments are the structures, objects or merchandise that comes along the sidewalk. Presence of encroachment can affect the comfort level of pedestrians while using sidewalks. The extent of encroachment should be limited to a certain level that doesn't affect accessibility of pedestrians to footpath.
Availability of crossing facilities	Zebra crossings, pedestrian bridges, underpass, etc. are the common types of crossing facilities. Enough crossings facilities along sidewalks should be available that allow pedestrians and motor vehicles to cross safely.
Security	The feeling of being safe and secure is one of the important factors governing the decision to walk. Pedestrians should feel safe during any time of the day. Safety and security can be ensured by providing adequate street lighting, police patrolling during the night time, etc.
Comfort	Pedestrian needs to be protected from harsh weather and environmental conditions. The trees can act as a protective shield, but they can also act as obstructions if they are planted unplanned.

	Facilities like chair/benches and rest rooms are other provisions that can add comfort to pedestrians.
Walk Environment	Walking should always be a pleasant experience. Walking environment is governed by the surrounding and the condition of sidewalks. Therefore, sidewalks should be clean and free from garbage.

(Source: Bivina *et.al*, 2018)

2.2 GOVERNMENT POLICY BASED GUIDELINES (INDIA)

1. NRSP, National Road Safety Policy (2018)

In 2018, the government of India had formulated a National Road Safety Policy, according to which the safety of vulnerable road users shall be considered important. Pedestrians are considered as vulnerable road users, since their cognitive skills to react to complex traffic situation are not fully developed. Further, the design and construction of all road spaces and movement areas (rural and urban) will be done keeping in mind their safety.

2. Road safety audit (IRC SP 88- 2010) a manual of Road Safety Audit by Indian Road Congress has suggested some principles for Road design to make the road safer for road user as well as for pedestrian. Vehicles parked on sidewalk affect the safety of Pedestrian. Pedestrian should be segregated from the vehicles as pedestrian are significant group of vulnerable road users, therefore they should be given detailed attention for their safety. Certain guidelines are given related to crossing, junction, road width, curve, road signs, and Parking space.

3. Indo-HCM some guidelines are given related to pedestrian facilities which should be considered to make a safe pedestrian environment. According to Indo-HCM the minimum space required for a pedestrian to walk freely on road is 0.35m x0.51m (total area of 0.18m^2) without baggage and with baggage it is 0.52m x 0.51m (0.26m^2). Different crossing facilities are mention for pedestrian safety such as zebra crossing, signalized crossing, pelican crossing, puffin crossing, and toucan crossing. Stairways can also be use were ever necessary to reduce the conflict between the vehicles and the pedestrian while crossing.

4. IRC 103-2012 "Guidelines for Pedestrian facilities" the Indian Road Congress has given guideline related to improvement to make a safer environment for the Pedestrian. The minimum width of the footpath at various locations depending upon the land use. These guidelines cover engineering design and planning aspects of pedestrians' facilities on road sides and at road crossing in urban and semi-urban areas. Pedestrian facilities at special location like school, parking and transit areas are also covered. These guidelines are framed to serve the objectives of universal accessibility and social equity for sustainable transportation.

CHAPTER 3

STUDY AREA & METHODOLOGY

3.1 ABOUT PANCHKULA

Panchkula is a District of State Haryana having the population of 561,293 of which 261,614 were Female and 299,679 were Male (Census,2011). It has an Area of 898 Sq.km. It is around 4 km (2.4 miles) southeast of Chandigarh and 259 km (162 miles) upper east of New Delhi, the Indian capital. It has mixed use land uses such as Residential, Commercial, Administrative etc. The city has the Chandi-Mandir Cantonment, the home office of the Western Command of the Indian Army.

Figure 3.1 Map Showing all the Districts of Haryana and the location of Panchkula which is Located at the North of Haryana

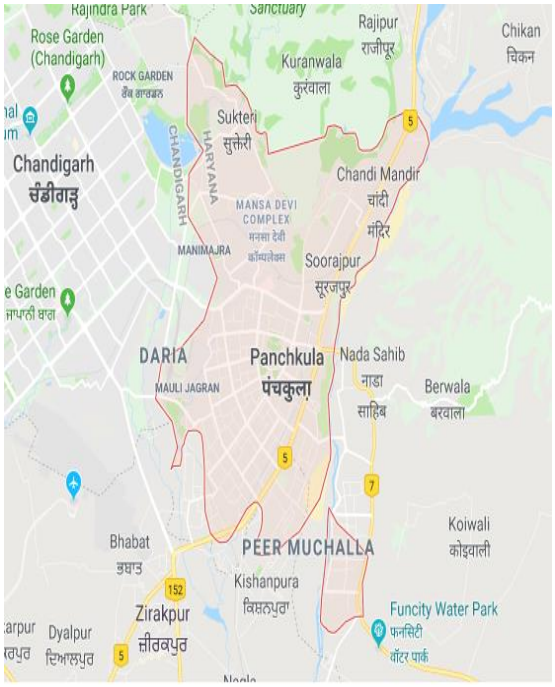

Figure 3.2 Map showing area covered by Panchkula and the important places like Chandi-Mandir Cantonment and Suketri

Panchkula is a city with very good Green Cover. It is located at the foot of The Hills of Himalaya's. Some of the tourist attractions of the city are like Pinjore Garden. The City is divided into 30 Sectors. The Sectors with Major Commercial, Residential, Industrial and

Administrative activity are Sector 1-21. The rest of the Sectors are considered in the Panchkula extension area which is not fully developed.

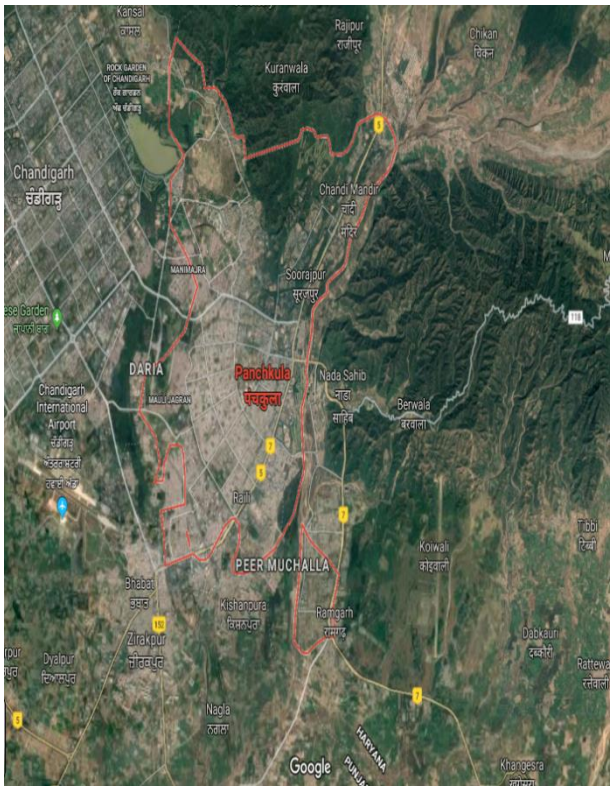

Figure 3.3 Satellite Map showing the Green Cover all around the City

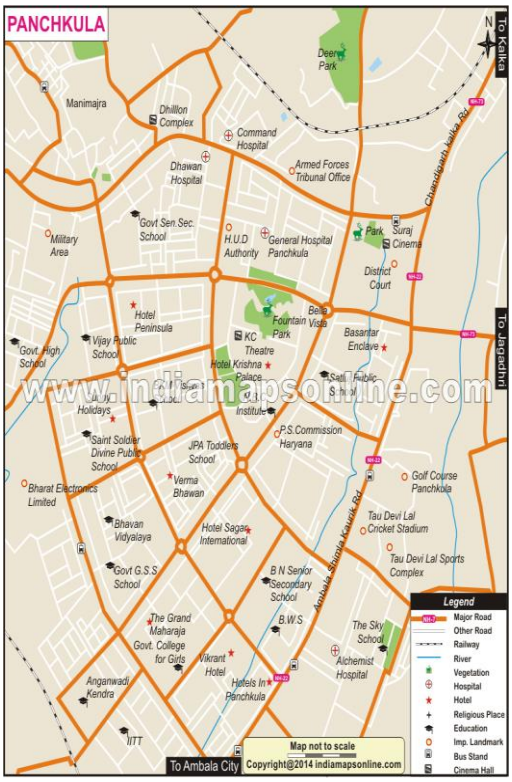

Figure 3.4 Map Showing Major Roads & Places of Panchkula

The main roads of the city are taken for the study purpose. The required information of the study was gathered through Various Surveys conducted at the main locations in Panchkula, considering the locations with highly busy areas, medium busy areas and disserted areas criteria. For our study, we have attempted to select roads from different areas of the city based on activity levels. The various study locations selected and the reasons for their selection are summarized in the Table 3.1 given below.

Table 3.1 List of all the Selected Locations & Reason for their Selection

Sr. No.	CORRIDOR NAME	CORRIDOR LOCATION	REASON FOR SELECTION
1.	Indian Express Roundabout	Roundabout Connecting Maheshpur Rd & Nada Sahib Road	• Administrative & Institutional type land use • Medium Pedestrian Density • High Vehicle Density • Congestion because of vehicles in peak hours
2.	Tank Chowk	Tank Chowk	• Major Intersection connecting Cantonment area of Panchkula & Shimla Highway • Medium Pedestrian Density • High Vehicle Density
3.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector 6	• Institutional type land use • High Pedestrian Density • High Vehicle Density in Peak hours
4.	Sector-6 Market Road	Road opposite Sector-6 Market	• Commercial, Residential & Recreational type land use • High Pedestrian Density in peak hours • Medium Vehicle Density
5.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout towards Bella Vista Roundabout	• Administrative & Recreational type land use • High Pedestrian Density • High Vehicle Density

6.	Bella Vista Roundabout to Bus Stand Roundabout	Bella Vista Roundabout to Bus Stand Roundabout	• Administrative type land use • Major location is the 5-Star Bella Vista Hotel & Head office of CBSE Board
7.	Mahespur Road	Bus Stand & Sector-10 dividing Road	• Terminal & Commercial type land use • High Pedestrian Density • High Vehicle Density
8.	Sector-7 Market Road	Road opposite Sector-7 Market	• Commercial & Institutional type land use • High Pedestrian Density • High Vehicle Density • Congestion because of vehicles in peak hours
9.	Housing Board Chowk	Housing Board Chowk	• Terminal & Commercial type land use • High Pedestrian Density • High Vehicle Density • Congestion because of vehicles in peak hours
10.	Chandigarh-Panchkula Road	Road opposite MDC Market	• Commercial & Recreational type land use • Low Pedestrian Density • Medium Vehicle Density
11.	Mahespur Road	Sector-9 & Sector-5 dividing Road	• Commercial & Recreational type land use • Low Pedestrian Density • Medium Vehicle Density

12.	Sector-9 Market Road	Road opposite Sector 9 Market & Prachin Shiv Mandir	• Commercial & Residential type land use • Major benchmark is the Prachin Shiv Mandir • Medium Pedestrian Density • High Vehicle Density • Congestion because of vehicles in peak hours
13.	Sector-9 Road	Sector-9 & Sector-16 dividing Road to Arya Samaj Mandir	• Residential type land use • Low Pedestrian Density • Low Vehicle Density
14.	BEL Factory Road	Sector-9 & Sector-10 dividing Road to Govt. Ayurveda Dispensary	• Residential type land use • Low Pedestrian Density • High Vehicle Density
15.	Old Panchkula	Old Panchkula Trisection	• Terminal type land use • Major Intersection of Panchkula as it connects to the Shimla Highway • Medium Pedestrian Density • High Vehicle Density
16.	Majri Chowk	Majri Chowk	• Terminal type land use • Major Intersection connecting to Morni hills and Nada Sahib
17.	District Court Panchkula	District Court Panchkula	• Administrative type land use • Medium Pedestrian Density • Medium Vehicle Density
18.	Rally Chowk to 11/15 Chowk	Rally Chowk to 11/15 Chowk	• Residential type land use • Low Pedestrian Density

			• Medium Vehicle Density
19.	Sector-15	Road Covering Hallmark Public School, Bhavan Vidyalya School & Market Area	• Commercial & Institutional type land use • High Pedestrian Density • High Vehicle Density • Congestion because of vehicles in peak hours
20.	Budanpur Road	Labour Chowk to Agrasen Chowk	• Commercial and Residential type land use • Low Pedestrian Density • Low Vehicle Density
21.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	• Residential type land use • Low Pedestrian Density • Medium Vehicle Density
22.	Pashuram Chowk to BEL Factory Intersection	Pashuram Chowk to BEL Factory Intersection	• Industrial area type land use • Major Benchmark Bharat Electronics Limited (BEL) • Medium Pedestrian Density • High Vehicle Density
23.	Industrial Area Road	Road opposite Nexa, Renault till Haryana Border	• Industrial Area type land use • Medium Pedestrian density • High Vehicle Density
24.	Sector-20 Market Road	Road opposite Sector-20 Market	• Commercial, Institutional & Residential type land use • High Pedestrian Density • High Vehicle Density

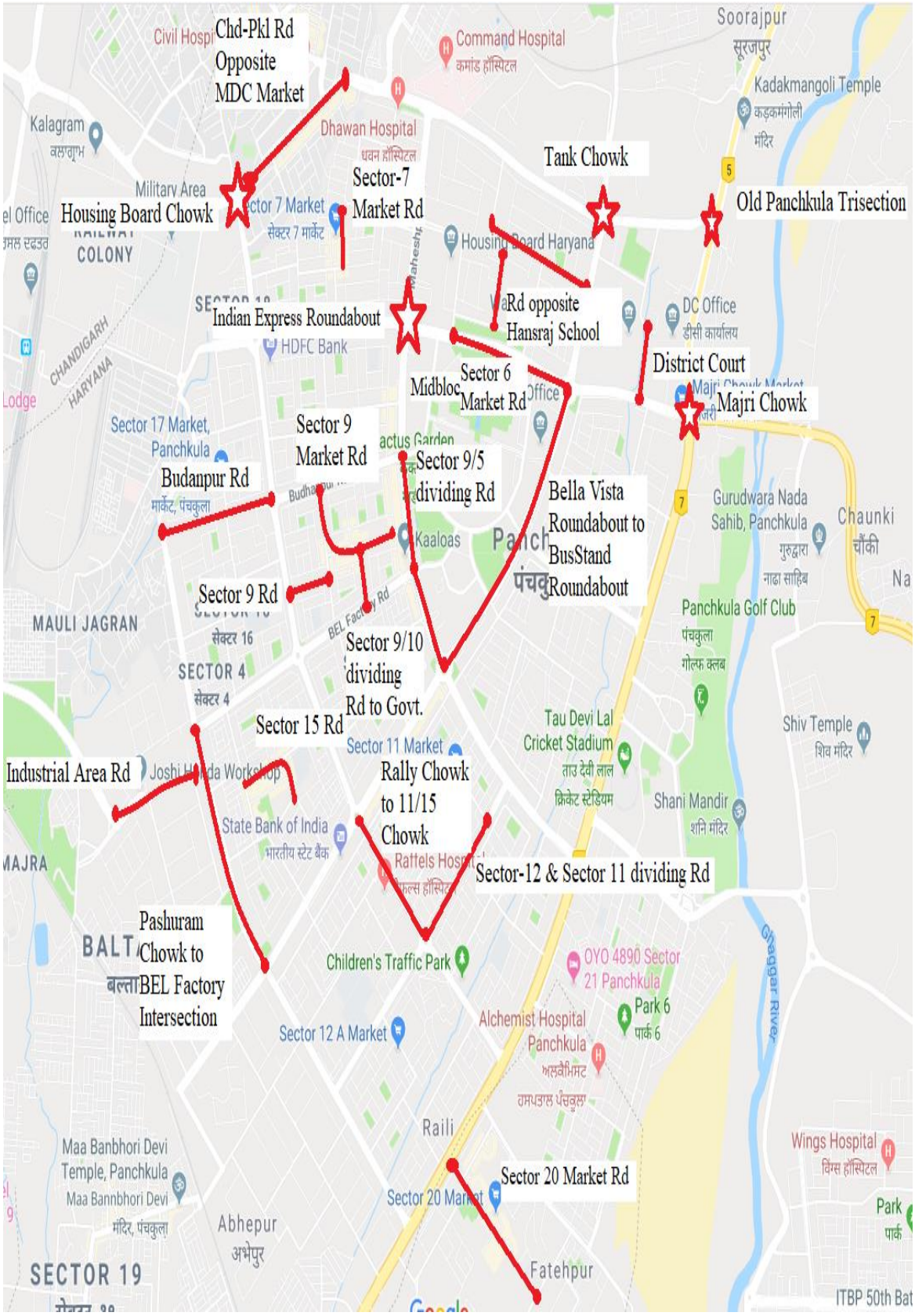

Figure 3.5 Map Showing all the twenty-four Selected Locations

3.2 STUDY METHODOLOGY

Quantitative and qualitative data was collected from the twenty-four selected location. For the collection of this data first of all the attributes need to be finalised which were to be considered. Thereafter the finalization of the attributes the design of the data collection formats was done, Data collection was done by conducting an Inventory Survey, Volume Survey and Pedestrian Perception Survey in Panchkula, Haryana. From the surveys the existing scenario was analysed and the attributes such as pedestrian flow rate, count on the subject sidewalk on both directions were obtained. Sidewalks attribute measurements helped to evaluate quantitative Pedestrian LOS by HCM 2010, INDO-HCM 2017 and the PLOS Scores were obtained from the Pedestrian Perception. Comparison of the Results and Interpretation were made to identify the issues faced by the pedestrians & Recommendations are made w.r.t the results.

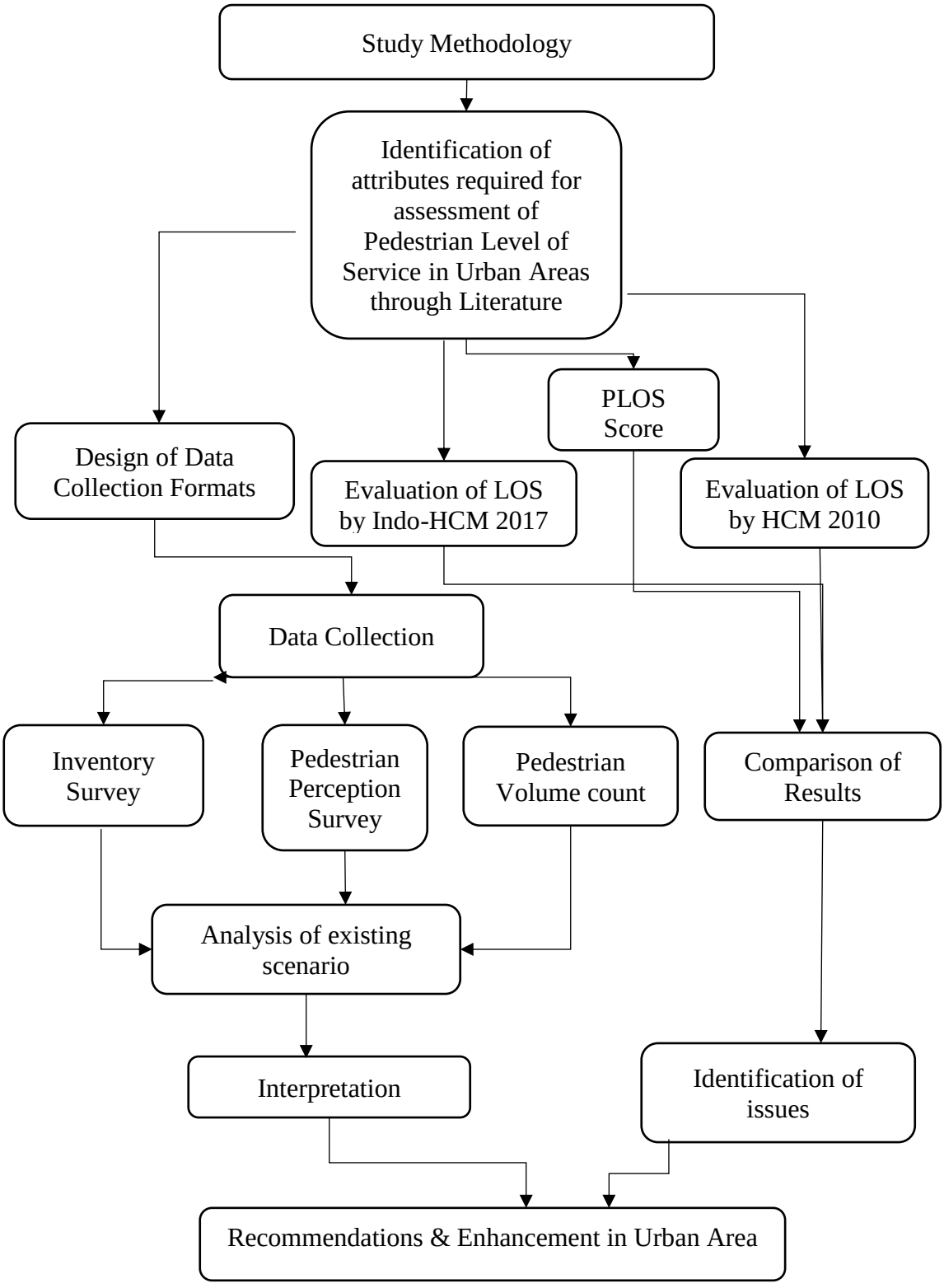

Figure 3.6 A Flowchart to explain the methodology

3.3 DATA COLLECTION

The first step of determining the applicable extent and standard of pedestrian amenities is to evaluate the demand for facilities. The Pedestrian needs are to be analysed like age distribution, frequency to trips in a day, Profession of respondents, trip purpose, distance of walk trips, etc. The Analysis involve three types of surveys or the data collection technique which were the Pilot Survey, Pedestrian Volume Survey and the Pedestrian Perception. The Pilot Survey Involves the Current scenario examination of the selected locations, the Pedestrian Volume Survey is the manual counting of the pedestrian in the peak hours at selected locations which has high pedestrian traffic, & the Pedestrian Perception survey involves the perception of pedestrian towards the available facilities and scope of improvement in the current scenario. There are different methods, such as video survey and manual count, which can be used to estimate the pedestrian flow rate to obtain the level of demand. The following describes the manual data collection process for the twenty-four selected street segments in Panchkula. Manual counting is easy to conduct and flexible.

Manual count of pedestrian flow along Seven selected road section in both directions is done by using a tally marking sheet. As it wasn't possible at all to cover all the locations for the pedestrian volume survey, so only Seven locations were finalized at which the manual volume count survey was conducted. Before starting the manual counts the following conditions need to be satisfied.

The manual count of pedestrian flow needed to occur during the peak time of the day in order to represent the actual demand. Panchkula is a popular place, but to represent the real demand, the activity took place at morning peak hours i.e. 7.30am – 9.30am and evening peak at 5.30pm – 7.30pm based on the City traffic engineer's suggestion. The count for each segment continued for two hours. The hourly pedestrian flow rate on the subject sidewalk was calculated using a ratio of the fifteen-minute frame from the manual count of pedestrian flow rate.

Other components that needed to be considered are: day of the week, month of the year. The occurrence of special events, early closing, and school holidays were avoided per HCM suggestion.

The survey locations also needed to be thoughtfully chosen in order to depict the overall existing demand. The selection of pedestrian segments to be considered for the study area was carefully chosen to include a variety of facilities.

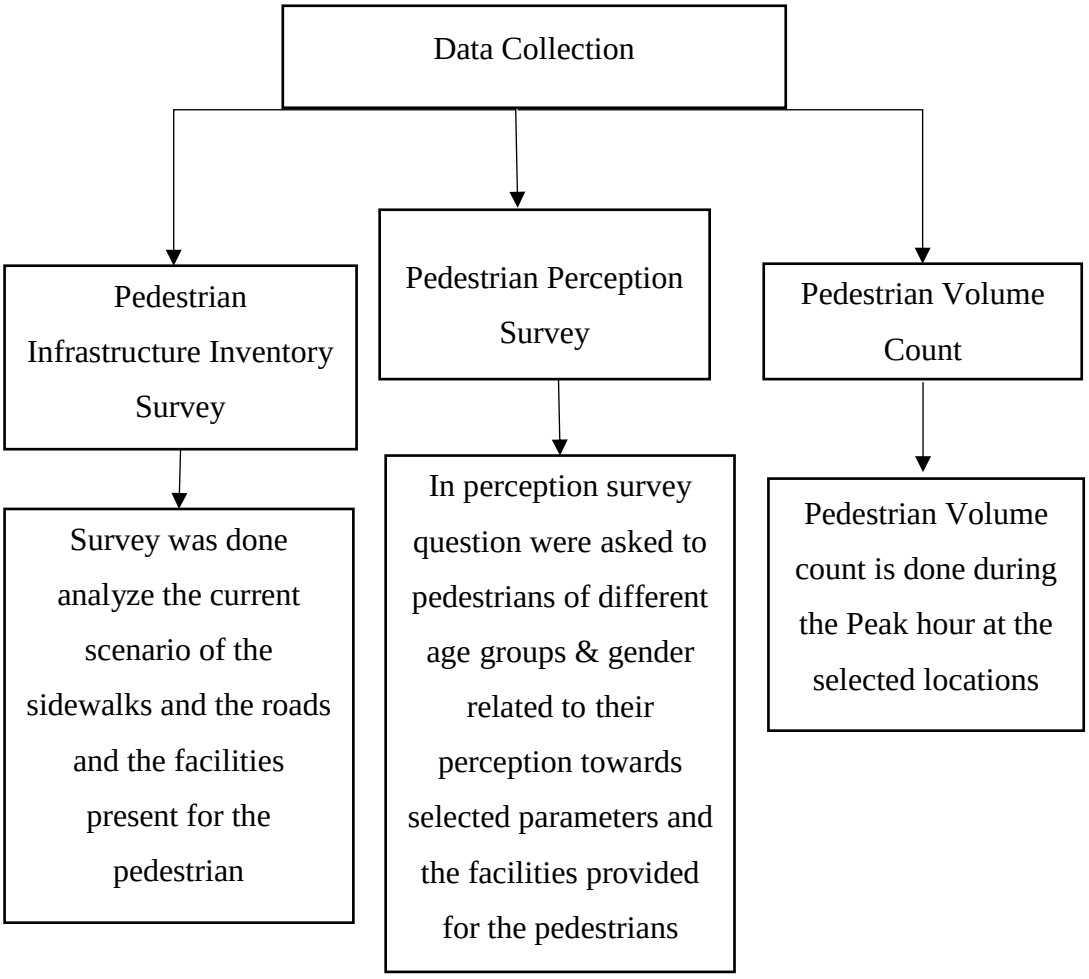

Figure 3.7 Methodologies of Data Collection Flowchart

3.3.1 SAMPLE SIZE DETERMINATION

For data collection we targeted a sample size of 385, the targeted data is calculated by using the sample size calculation for large population.

The sample size is calculating as:

Since Delhi has a population of 561,293 and

Taking a margin of error (e) as 5% and standard deviation (p) 50% and 95% confidence level (z-score for 95% confidence level is 1.96) we calculate the sample size by the formula

Sample size= $[z^2 * p (1-p)] / e^2$

Calculation:

Sample size= $[(1.96)^2 * 0.5(1-0.5)] / (0.05)^2$

On calculating we get

Sample size= 383.89

As per the sample size determination, 384 respondents could justify the data sample. Further, we have collected 440 responses from Pedestrians across 24 locations in Panchkula City.

CHAPTER 4

RESULTS OF CURRENT SCENARIO

4.1 PEDESTRIAN PERCEPTIONS RESULTS

A questionnaire was developed to determine sidewalk performance. The questionnaire consisted of thirty-one items in different sections to understand the quality of the facility based on pedestrian's experience (see questionnaire in Annexure II). The questions have been designed to assess pedestrians' perceptions in areas of Sidewalk Surface, Sidewalk width, obstructions, encroachment, safety, comfort, walk environment, etc. The first section of the questionnaire focuses on characteristics of trips, such as the trip purpose, frequency, etc. The second part evaluates the pedestrians' experience about safety and comfort on the subject sidewalks by asking questions about street lightings, amount of shade, landscape, street furniture etc. The third section of the questionnaire evaluates the existing condition and accessibility of the facility that pedestrians were experiencing at that moment. It also evaluated and rate their overall experience of walking in Panchkula.

This questionnaire has been designed to assess pedestrians' comfort level as most of the qualitative PLOS studies used questionnaires and direct observations to get estimates on pedestrians' perception of the sidewalks condition. Therefore, twenty-four sidewalk segments have been selected for this pilot survey. It's important to note that this informal pedestrian questionnaire is a main factor of this study. The questionnaire started with a brief and friendly conversation about the key role that this survey and its result would play for this project. Then, adult pedestrians randomly were asked to take the survey to convey their experience about that specific sidewalk they were walking at the moment and their overall experience walking in Panchkula. At least, 10 people per segment answered the questionnaire.

As mentioned previously, the questionnaire survey was used to collect the qualitative data. The interview was conducted over the course of 6 hours from 12:00 to 6:00 p.m. a day. Four Hundred and Forty respondents in total from both genders and different age groups filled out the survey. Out of which 185(42%) women and 255(58%) men

responded. The following results were obtained and analysed after the total data collection which are given below:

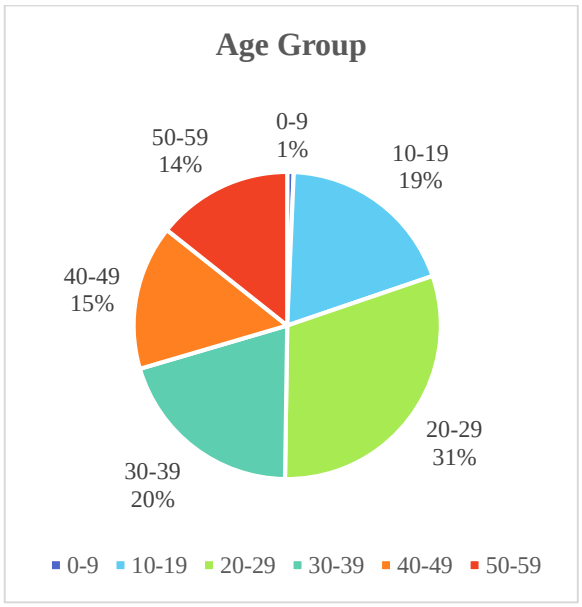

Figure 4.1 Age Group Distribution

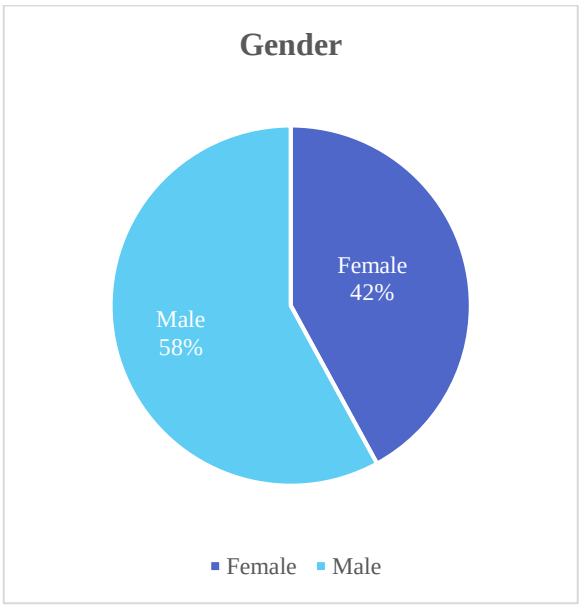

Figure 4.2 Gender Distribution

From figure 4.1 it can be observed that maximum no. of respondents was of 20-29 age group and from figure 4.2 about 42 percent were females and 58 percent were males.

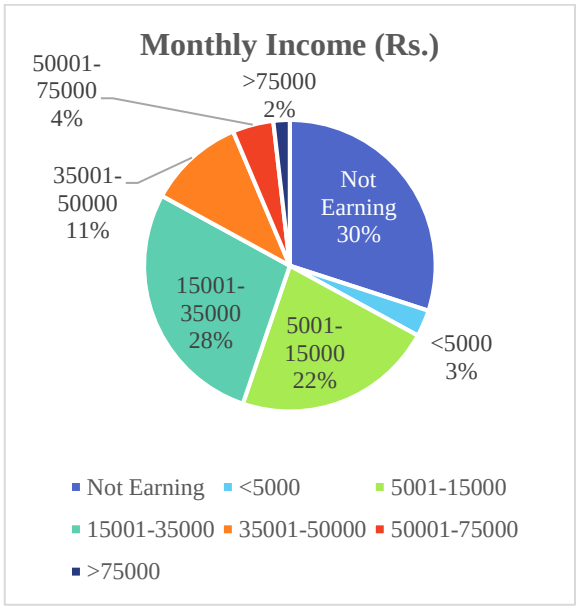

Figure 4.3 Monthly Income of Respondents

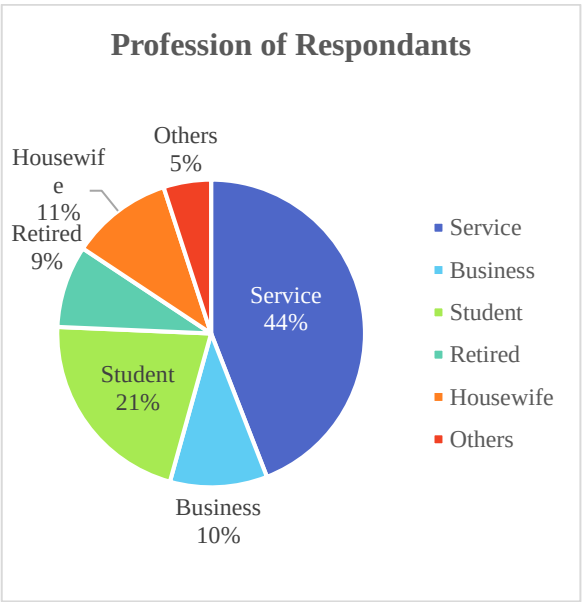

Figure 4.4 Profession of Respondents

The average monthly income of the respondents was 15001-35000 but the major share was 30 percent which included students and housewives which were not earning (from figure 4.3). About 30 percent of the pedestrians reported to be working (from figure 4.4).

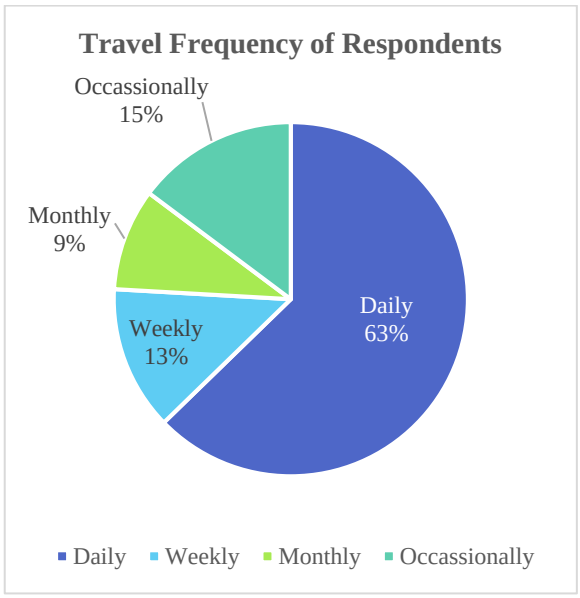

Figure 4.5 Travel Frequency of Respondents

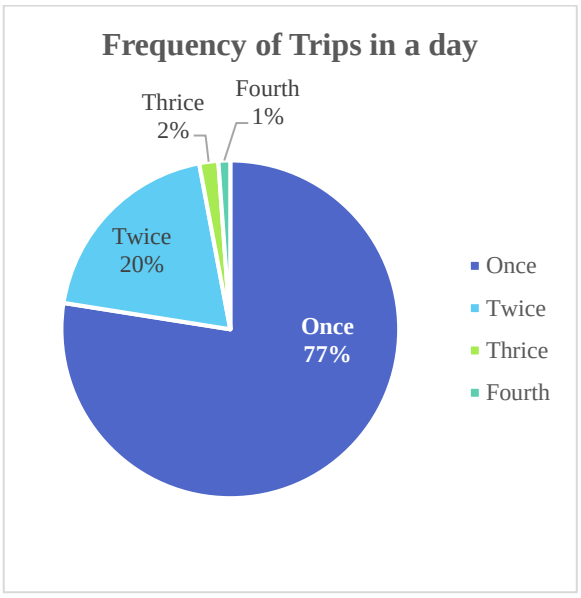

Figure 4.6 Frequency of Trips in a Day

At the subjected locations the majority of pedestrians came daily i.e. around 63 percent people came daily and around 77 percent had a frequency of once in a day i.e. they choose the selected route once a round trip day which can be observed from figure 4.5 and figure 4.6

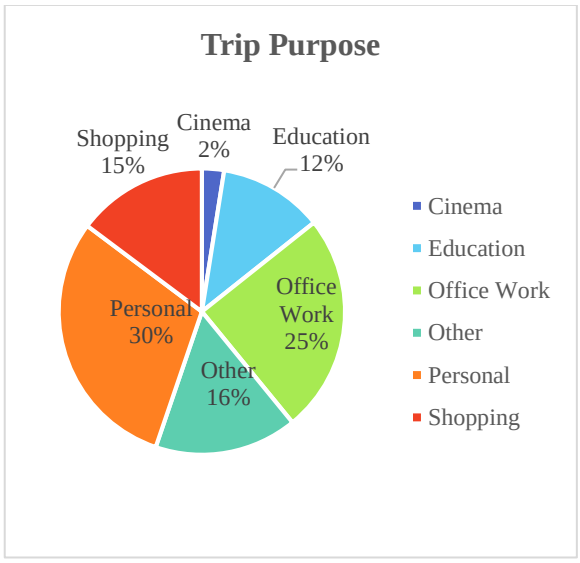

Figure 4.7 Trip Purpose

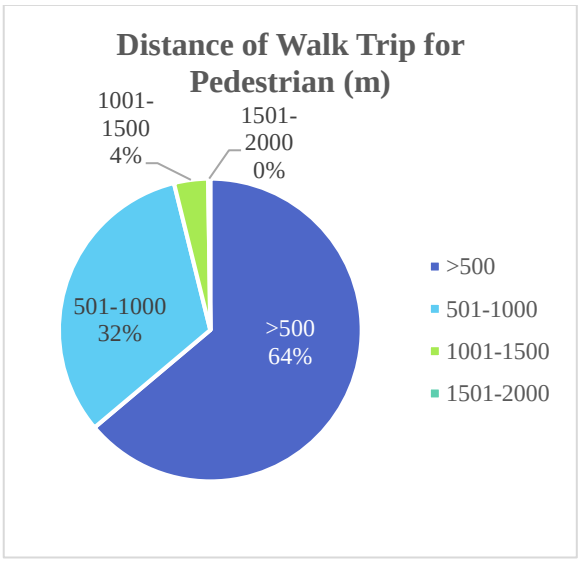

Figure 4.8 Distance of Walk Trip

Around 25 percent of the pedestrians visited for office work and 30 percent for any of their personal work. Maximum (64 percent) people prefer to walk for a distance of less than 500 meter and none of them prefer to walk for a distance more than 1500-2000 meter (from figure 4.7 and figure 4.8).

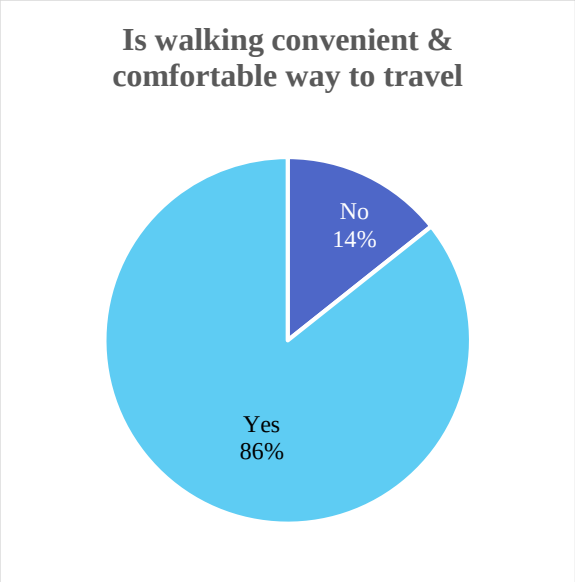

Figure 4.9 Pedestrians Perception on Walking a Convenient Mode

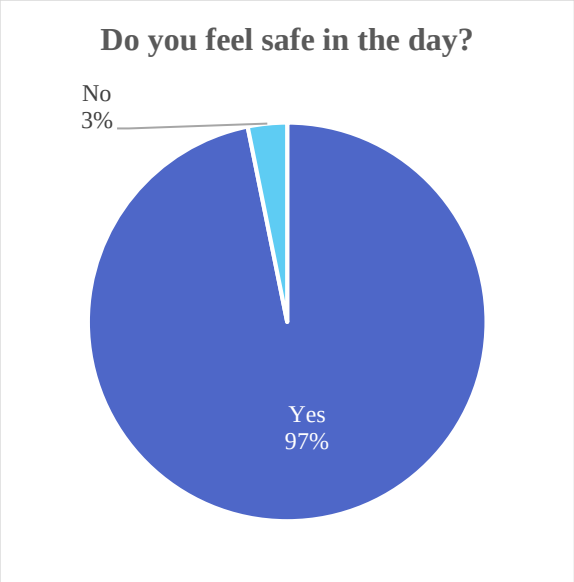

Figure 4.10 Pedestrians Perception on Feeling Safe at Day time

Around 86 percent of the pedestrians think that walking is a convenient mode of travel and 14 percent of the respondents think it's not convenient as they prefer to use motorized mode (see figure 4.9). About 97 percent of the pedestrians feel safe in the day time (see figure 4.10)

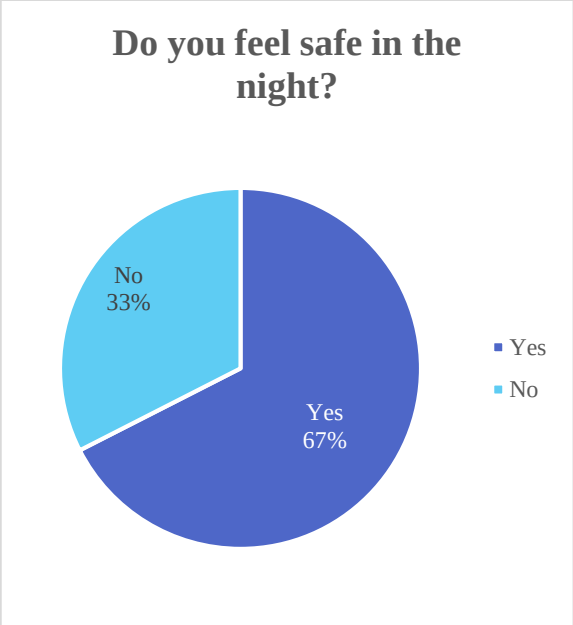

Figure 4.11 Pedestrian Perception on Feeling Safe at Night

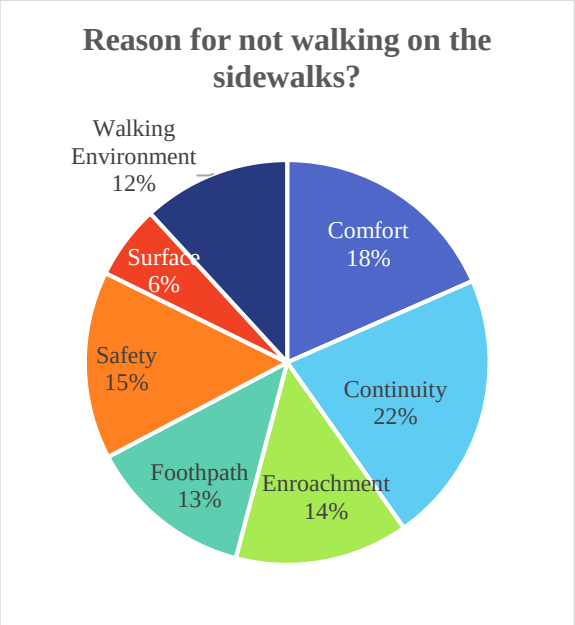

Figure 4.12 Reason for not Walking on the Sidewalks

When asked about the Safety of the pedestrians at the night time 67 percent responded that they feel safe at night, but some of the females (33 percent) responded that they do not feel safe in night (figure 4.11).

Figure 4.13 Pedestrians Perception on Feeling risky while Walking

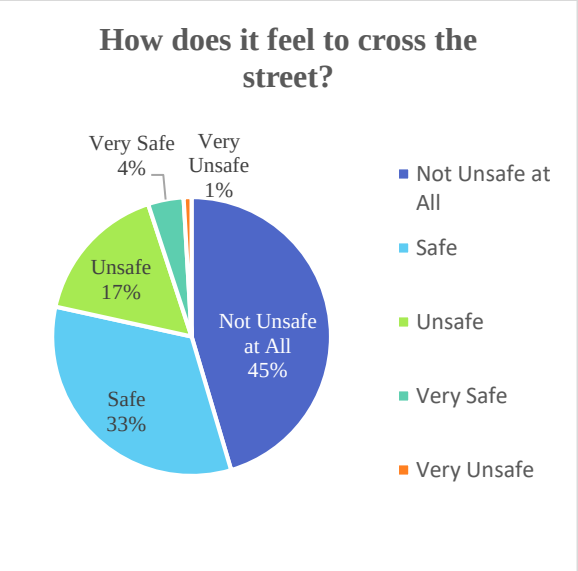

Figure 4.14 Pedestrian Perception on Feeling on Crossing the Road

Around 48 percent of people do not feel risky when walking and 2 percent of the pedestrians feel very risky when walking (figure 4.13). Whereas 78 percent of pedestrians almost feel safe while crossing the street. (see figure 4.14).

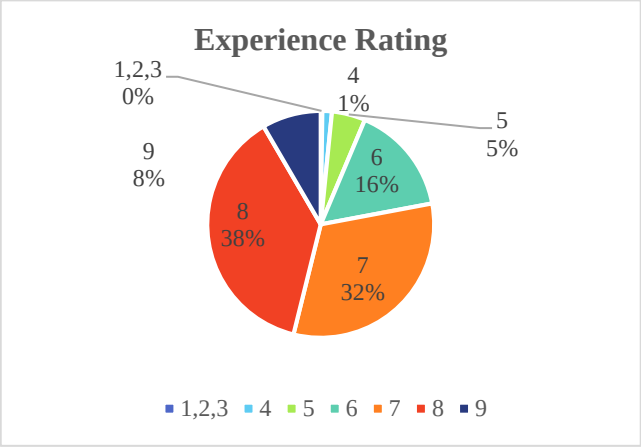

Figure 4.15 Experience Rating

Regarding the facilities and amenities provided for the pedestrians less than 5 rating was given by 6 percent of the pedestrians and only 8 percent gave 9 rating at selected locations

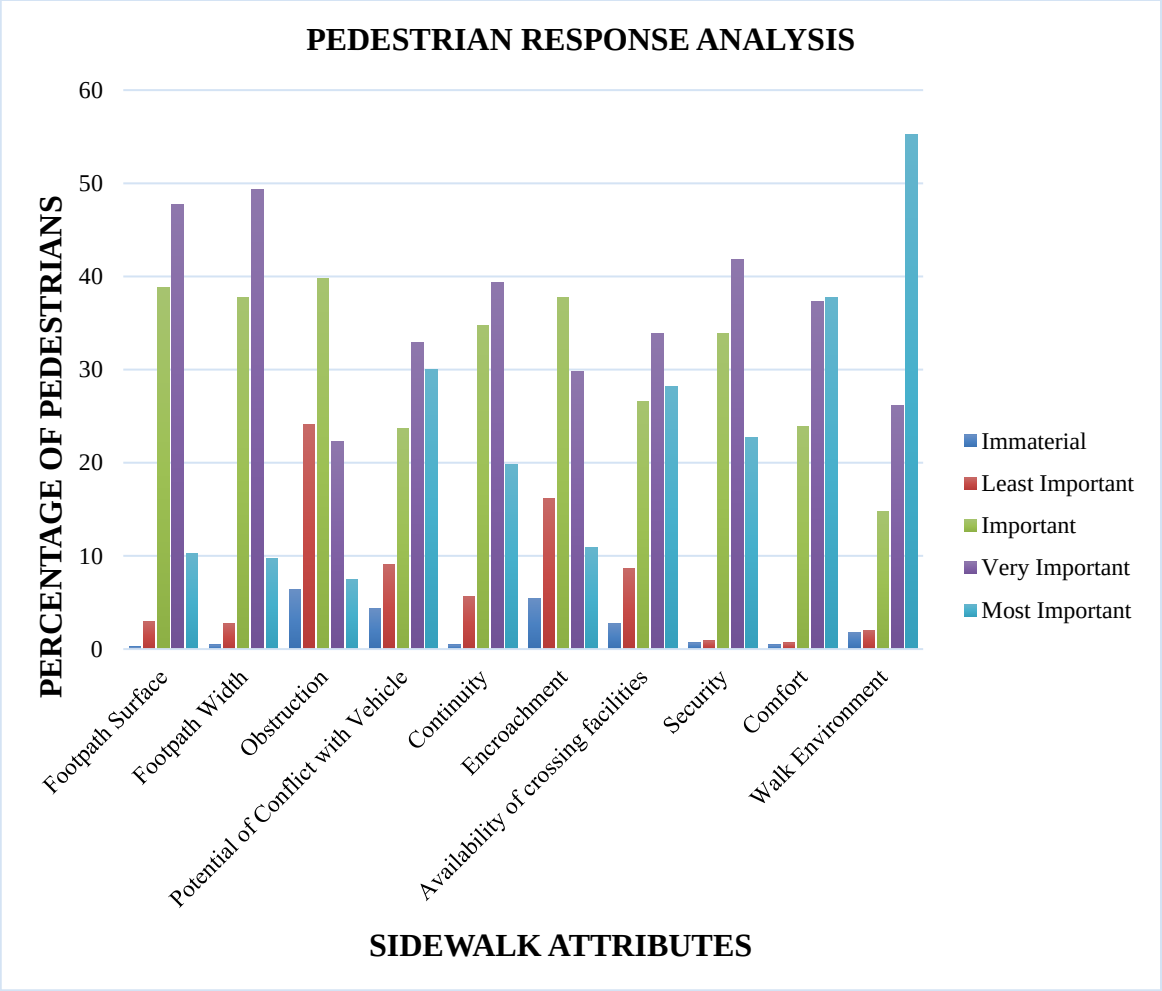

Figure 4.16 Response Rating of Pedestrians for Importance of Various Sidewalk Attributes

Service quality evaluation of sidewalks is based on characteristics of sidewalks and its walking environment. The response rates of pedestrians on the level of importance for various attributes are illustrated in Figure 4.16. Obstruction factor has got very least importance among all other factors, that is about 6.4% people rated it as 1, which signifies that factor 'obstruction' is immaterial for them. Footpath Width has been given very important as 49.3% pedestrians find it the most essential factor while walking. The Walking Environment has got highest importance rating of 5 (55.2%). 'Walking Environment' is the factor which pedestrians consider most important for walking on sidewalks.

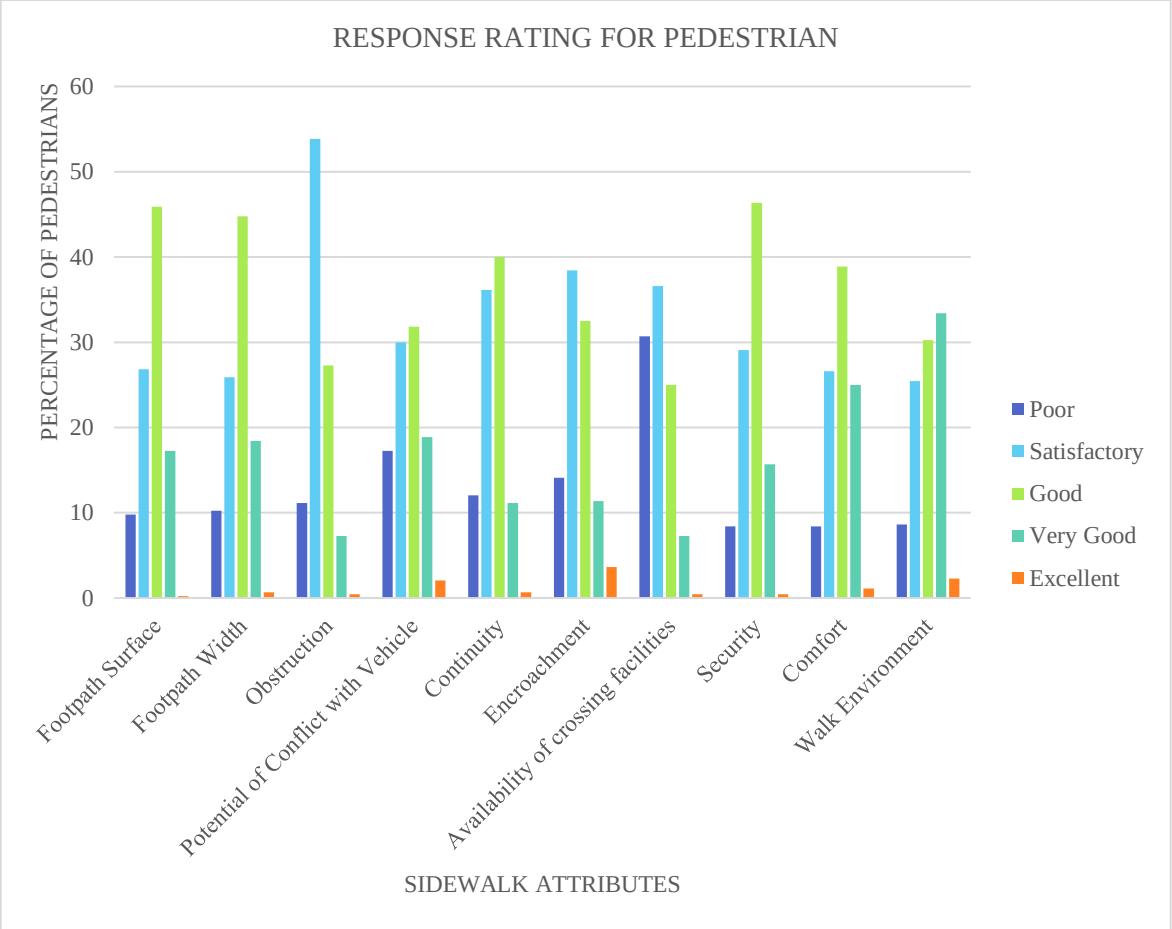

Figure 4.17 Response Rating of Pedestrians for Satisfaction on Various Sidewalk Attributes

Figure 4.17 illustrates the response rating for the level of satisfaction. Majority of pedestrians rated the attributes as satisfactory. Therefore, Security & Comfort factor has got very least satisfaction rating among all the other factors. It has been noted that satisfaction ratings are comparatively low for those factors that got the highest importance. For example, factors like 'security' and 'comfort' have got a maximum poor rating, which indicates the absence of security features like lighting, police patrolling etc. along sidewalks. So, in order to improve the Quality of Service of sidewalks, satisfaction rating of the most important parameters has to be improved which can be possible only by implementing suitable improvement strategies for that characteristic of sidewalk. There is a possibility that socio-demographic factors like age, gender, income, etc. could influence the perceptions of pedestrians. Future researchers can be conducted to explore potential perception variances resulting from such socio-demographic differences.

4.2 INVENTORY RESULTS

Table 4.1 Pedestrian Elements Observed in The Pedestrian Area

STUDY AREA	SIDEWALK	CROSSWALK	DISABILITY INFRASTRUCTURE		PUFFIN CROSSING	TRAFFIC CALMING MEASURES	ARE THERE ANY GUARD POST PROVIDED TO DISCOURAGE THE PARKING OF VEHICLES ON SIDEWALK	IS THERE A SEPARATE BICYCLE PATH PRESENT	IS THERE ENOUGH SHELTER PROVIDED FROM SUN & RAIN?
			TACTILE PAVEMENT	WHEELCHAIR RAMP					
Indian Express Roundabout	Yes	No	No	No	No	No	No	No	Yes
Tank Chowk	No	No	No	No	No	No	No	No	No
Road in front of Hansraj Public	Yes	No	No	No	No	No	No	No	No

School, Sector-6									
Sector-6 Market Road	No	No	No	No	No	No	No	No	No
Nada Sahib Road	Yes	Yes	No	No	No	No	No	No	Yes
Bella Vista Roundabout to Bus Stand Roundabout	Yes	Yes	No	No	No	No	No	No	Yes
Bus Stand & Sector-10 dividing Road	Yes	No	No	No	No	No	No	No	Yes
Sector-7 Market Road	Yes	No	No	No	No	No	No	No	No
Housing Board Chowk	Yes	No	No	No	No	No	No	No	No

Chandigarh-Panchkula Road	Yes	Yes	No	No	No	No	No	No	Yes
Sector-9 & Sector-5 dividing Road	Yes	No	No	No	No	No	No	No	Yes
Road opposite Sector 9 Market & Prachin Shiv Mandir	No	No	No	No	No	No	No	No	No
Sector-9 & Sector-16 dividing Road to Arya Samaj Mandir	No	No	No	No	No	No	No	No	Yes
Sector-9 & Sector-10 dividing Road to Govt.	Yes	No	No	No	No	No	No	No	No

Ayurveda Dispensary									
Old Panchkula Trisection	Yes	No	No	No	No	No	No	No	No
Majri Chowk	Yes	No	No	No	No	No	No	No	Yes
District Court Panchkula	Yes	No	No	No	No	No	No	No	Yes
Rally Chowk to 11/15 Chowk	Yes	Yes	No	No	No	No	No	No	Yes
Road Covering Hallmark Public School, Bhavan Vidyalya School & Market Area	Yes	No	No	No	No	No	No	No	No

Labour Chowk to Agrasen Chowk	Yes	No	No	No	No	No	No	No	No
Road Dividing Sector-12 & Sector-11	Yes	No	No	No	No	No	No	No	Yes
Pashuram Chowk to BEL Factory Intersection Industrial Area Road	Yes	No	No	No	No	No	No	No	No
Sector-20 Market Road	Yes	Yes	No	No	No	No	Yes	No	Yes

4.3 VOLUME RESULTS

1. Road in front of Hansraj Public School

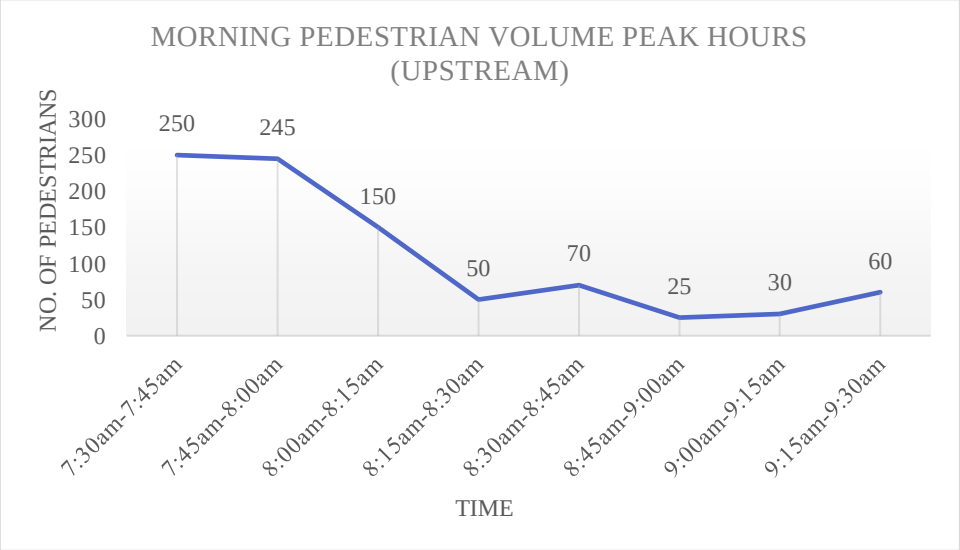

Figure 4.18 Morning Pedestrian Volume Peak Hours (Upstream) at Location 1

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 7.30am-7.45am as due to school area peak timings where some parents also use the sidewalk and the street segment for dropping off their children.

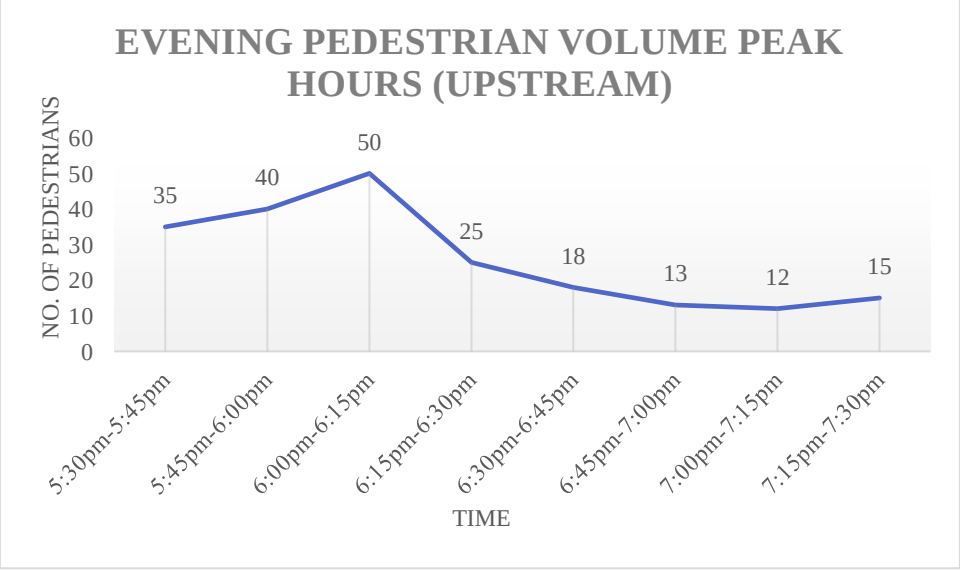

Figure 4.19 Evening Pedestrian Volume Peak Hours (Upstream) at Location 1

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.00pm-6.15pm as due to recreational and residential area as pedestrian come for walk at the park located opposite to School area.

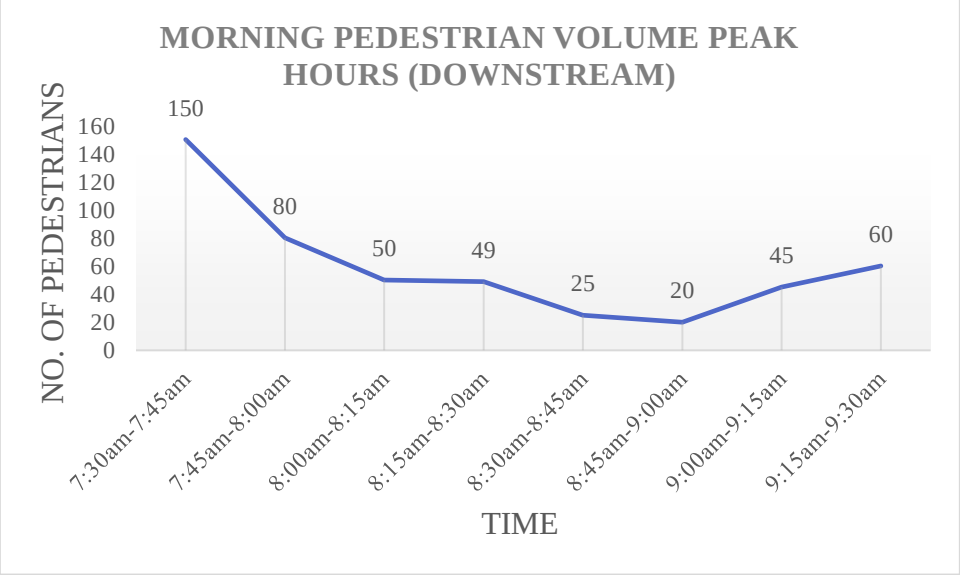

Figure 4.20 Morning Pedestrian Volume Peak Hours (Downstream) at Location 1

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 7.30am-7.45am as due to school area peak timings where some parents also use the sidewalk and the street segment for dropping off their children.

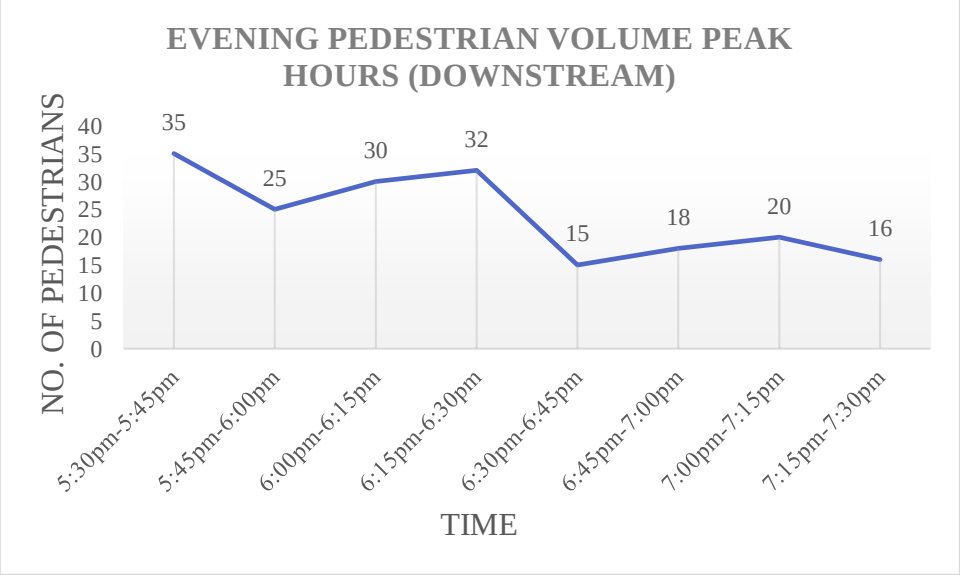

Figure 4.21 Evening Pedestrian Volume Peak Hour (Downstream) at Location 1

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.00pm-6.15pm as due to recreational and residential area as pedestrian come for walk at the park located opposite to School area.

2. Sector-7 Market Road

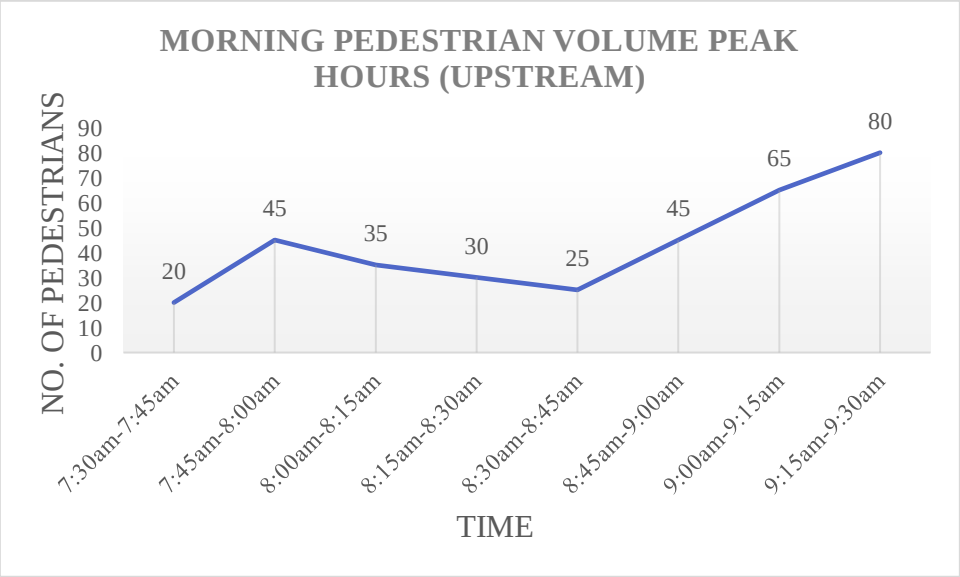

Figure 4.22 Morning Pedestrian Volume Peak Hours (Upstream) at Location 2

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am as due to commercial area peak timings where people come for opening of their shops and some came for work purpose

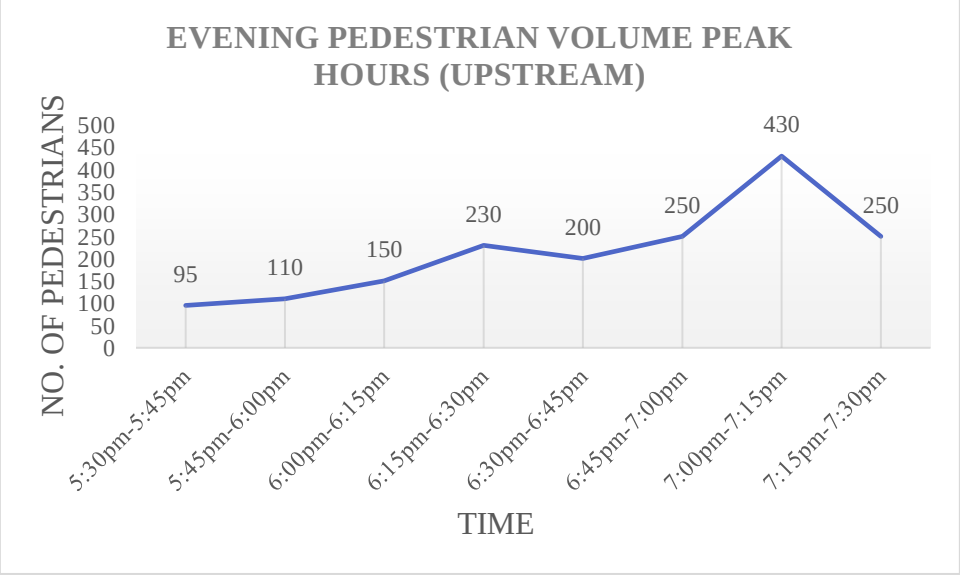

Figure 4.23 Evening Pedestrian Volume Peak Hours (Upstream) at Location 2

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 7.00pm-7.15pm which was very high because of people came for shopping and eating at food joints purposes

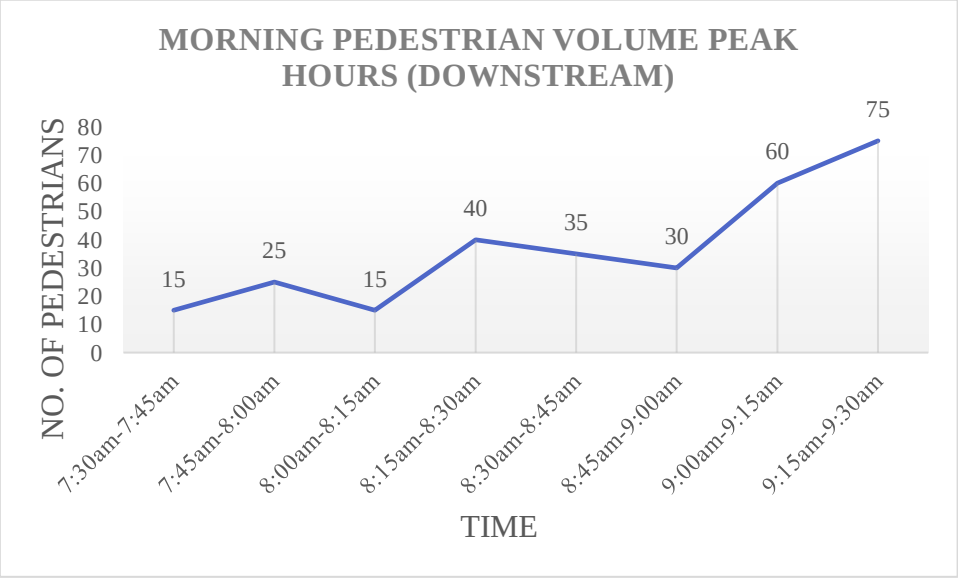

Figure 4.24 Morning Pedestrian Volume Peak Hours (Downstream) at Location 2

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am as due to commercial area peak timings where people come for opening of their shops and some came for work purpose

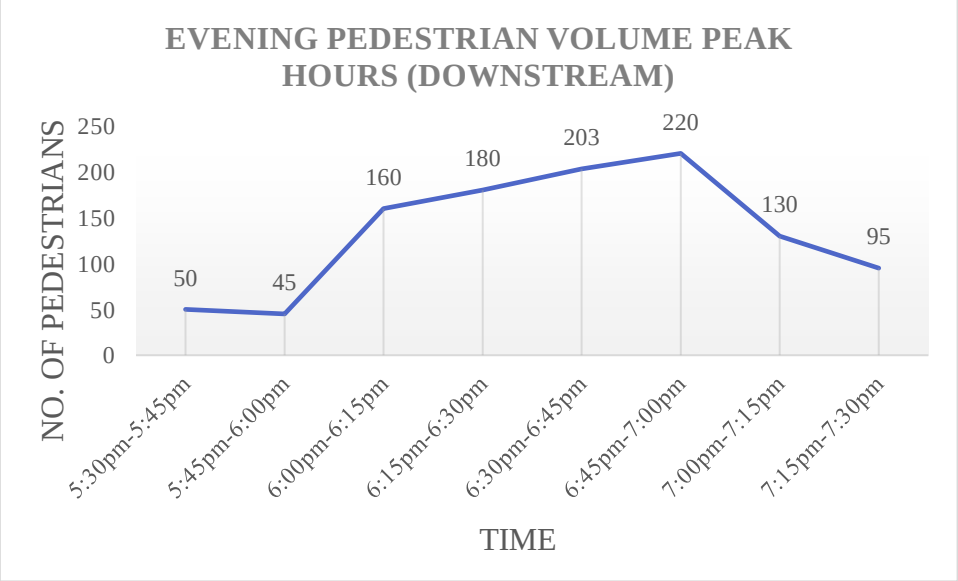

Figure 4.25 Evening Pedestrian Volume Peak Hour (Downstream) at Location 2

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.45pm-7.00pm which was very high because of people came for shopping and eating at food joints purposes

3. Chandigarh-Panchkula Road

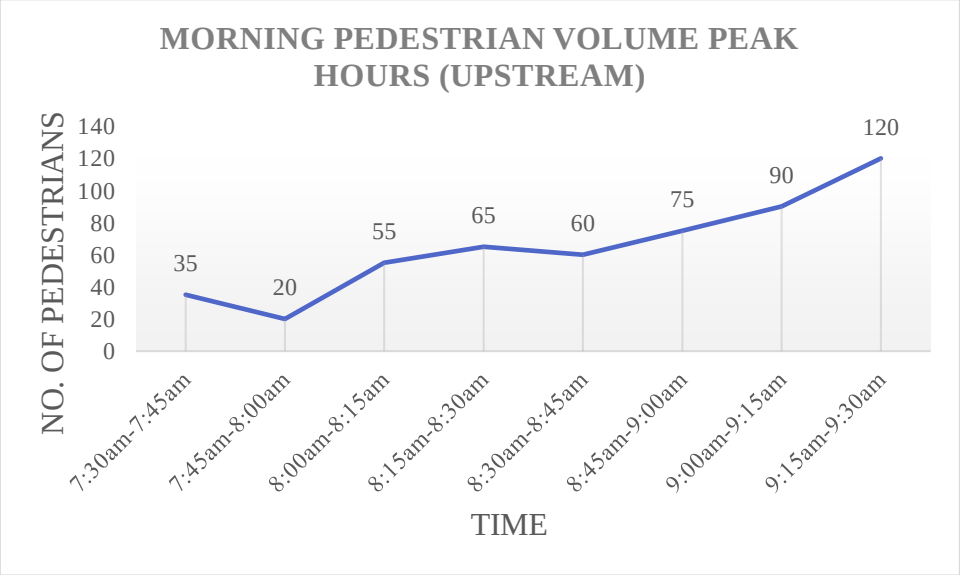

Figure 4.26 Morning Pedestrian Volume Peak Hours (Upstream) at Location 3

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am which was due to commercial area peak timings where people come for opening of their shops and some came for work purpose.

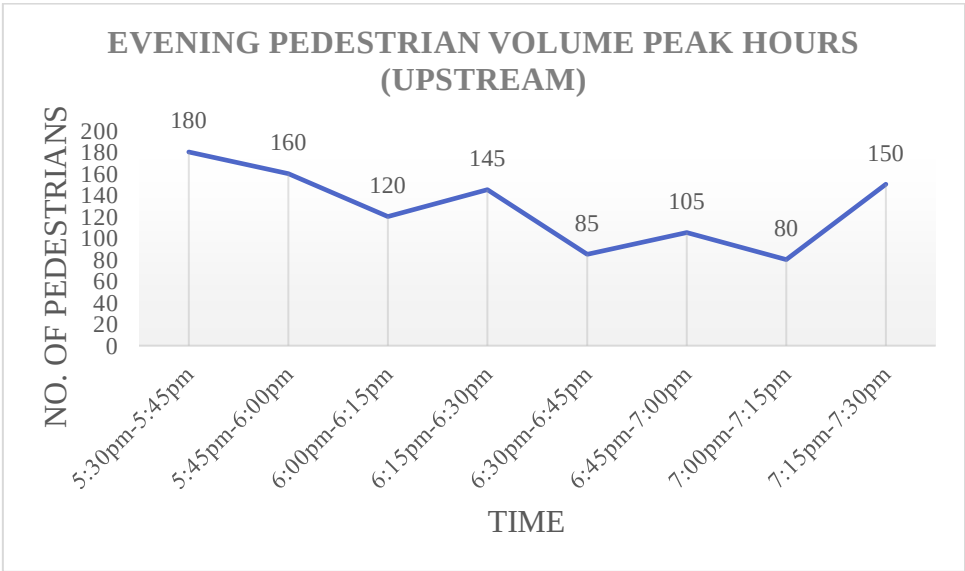

Figure 4.27 Evening Pedestrian Volume Peak Hours (Upstream) at Location 3

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm which was due to Commercial area people came for Shopping and also for watching movies, etc.

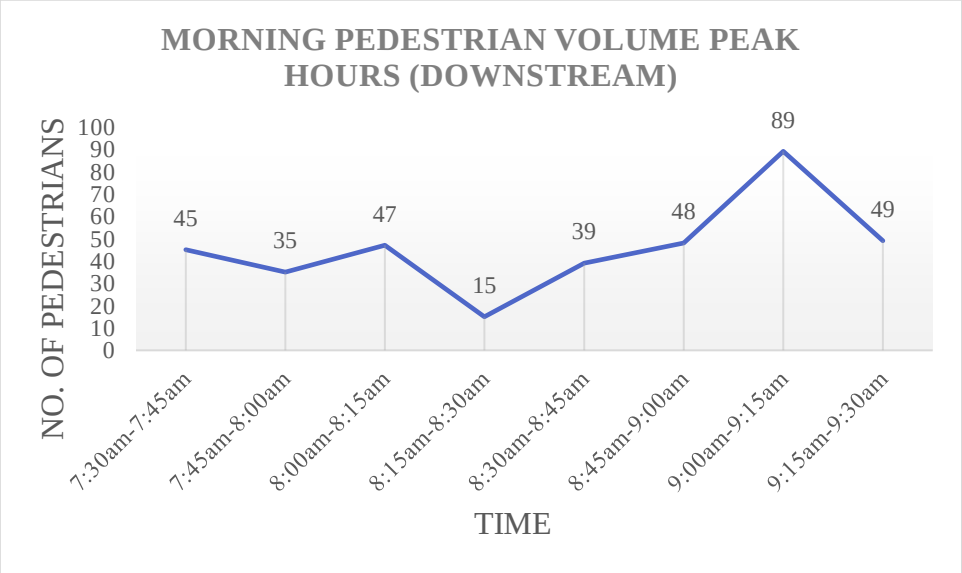

Figure 4.28 Morning Pedestrian Volume Peak Hours (Downstream) at Location 3

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.00am-9.15am which was due to commercial area peak timings where people come for opening of their shops and some came for work purpose.

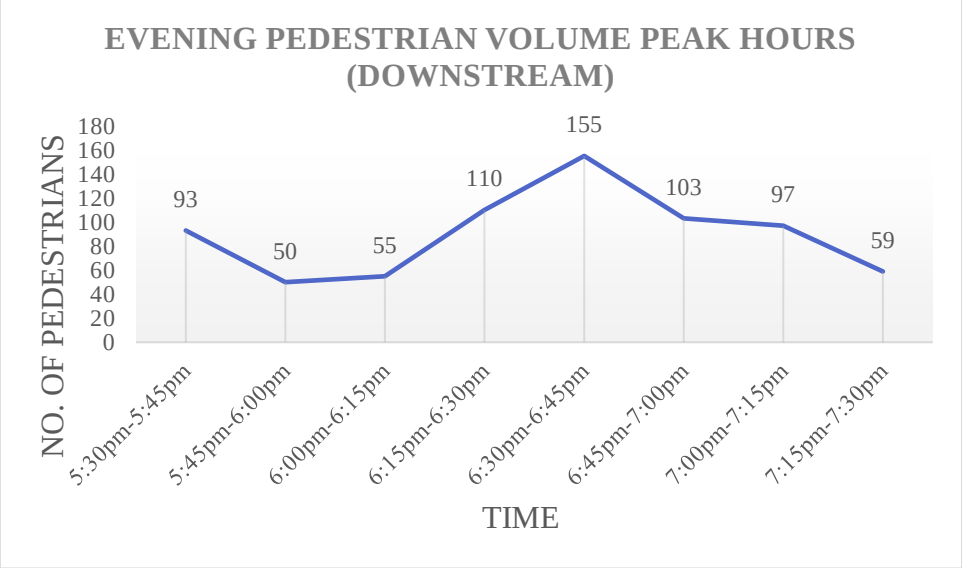

Figure 4.29 Evening Pedestrian Volume Peak Hour (Downstream) at Location 3

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.30pm-6.45pm which was due to Commercial area people came for Shopping and also for watching movies, etc.

4. Budanpur Road

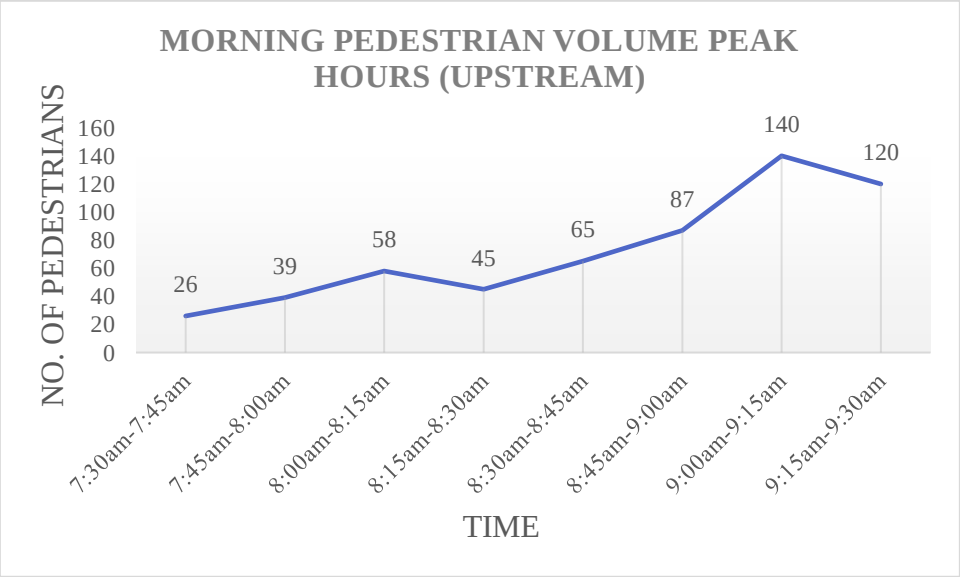

Figure 4.30 Morning Pedestrian Volume Peak Hours (Upstream) at Location 4

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.00am-9.15am which was due to Commercial area and Residential area the peak hour is at a obvious reason which is people leaving for their work purposes.

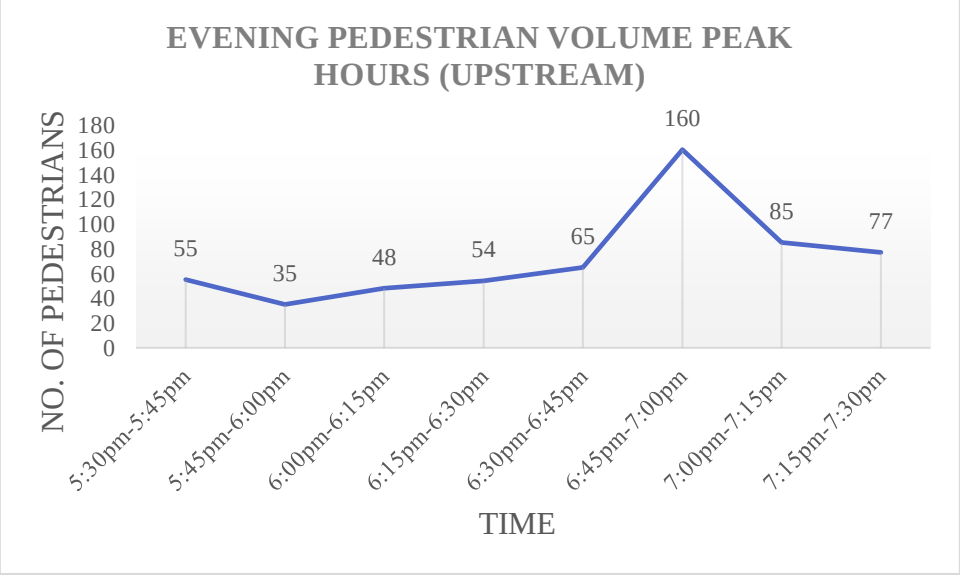

Figure 4.31 Evening Pedestrian Volume Peak Hours (Upstream) at Location 4

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.45pm-7.00pm which was due to Commercial area and Residential area the peak hour is at a obvious reason which is people coming back home from their work purposes.

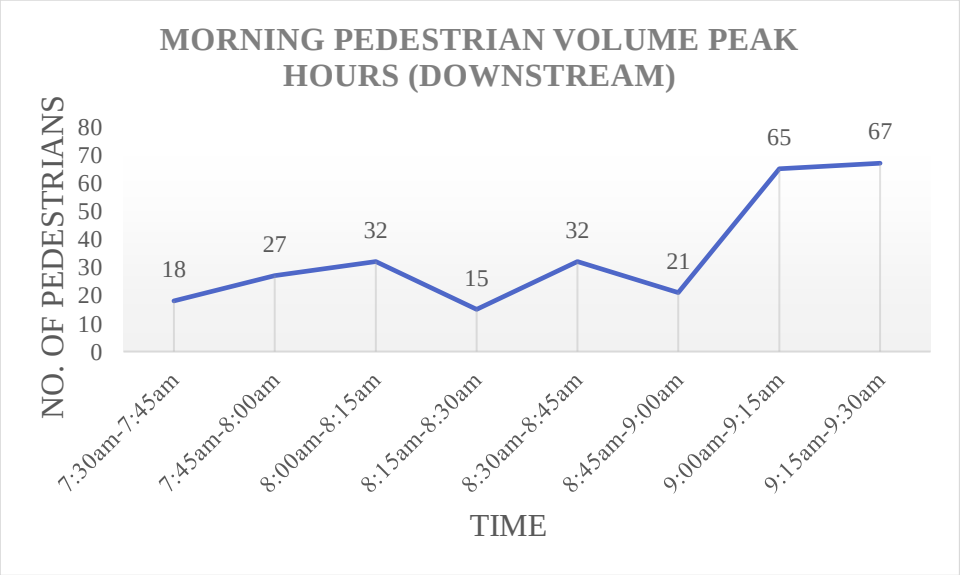

Figure 4.32 Morning Pedestrian Volume Peak Hours (Downstream) at Location 4

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am which was due to Commercial area and Residential area the peak hour is at a obvious reason which is people leaving for their work purposes.

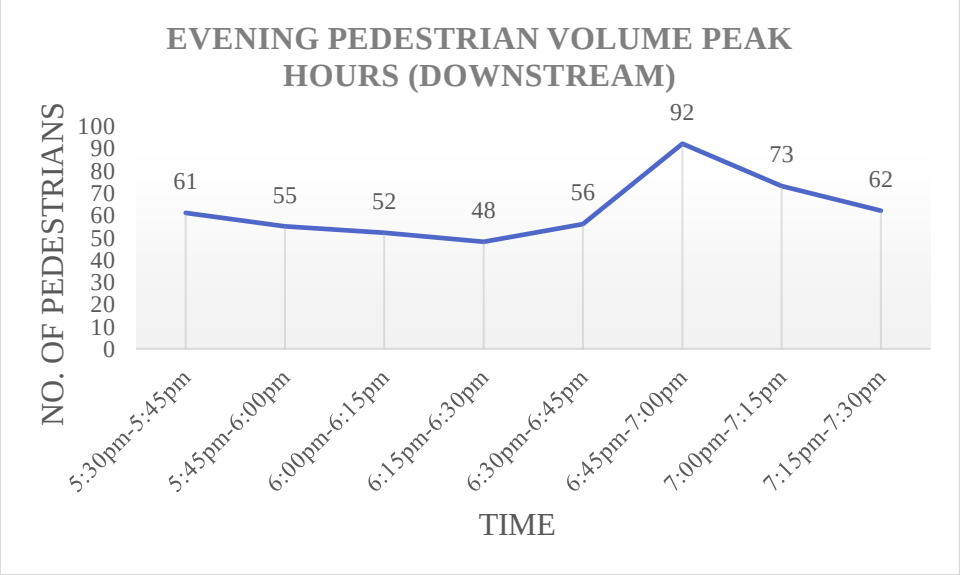

Figure 4.33 Evening Pedestrian Volume Peak Hour (Downstream) at Location 4

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.45pm-7.00pm which was due to Commercial area and Residential area the peak hour is at a obvious reason which is people coming back home from their work purposes.

5. Road Dividing Sector-12 & Sector-11

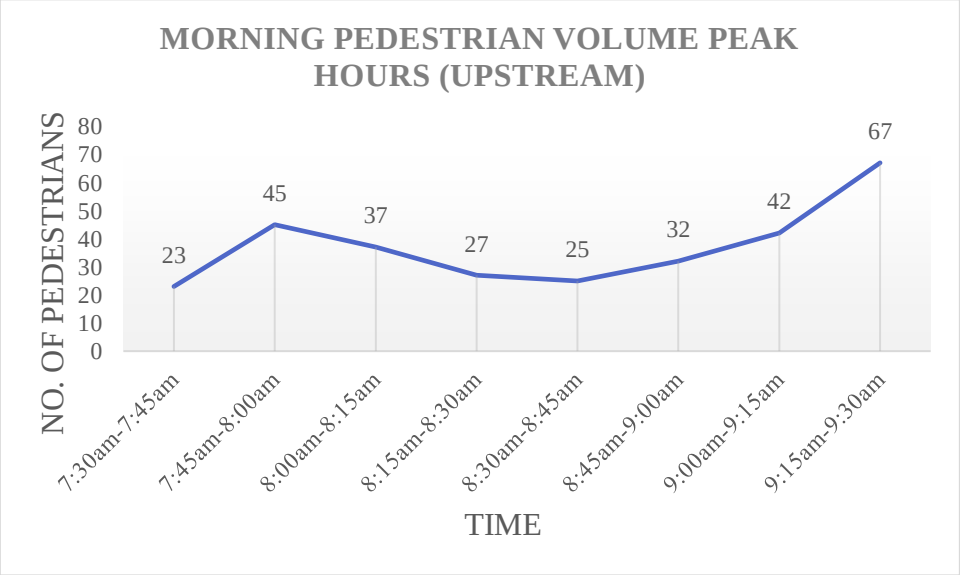

Figure 4.34 Morning Pedestrian Volume Peak Hours (Upstream) at Location 5

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area does not have much pedestrian count as it is used by pedestrians which travel for work purpose or any of the personal purposes.

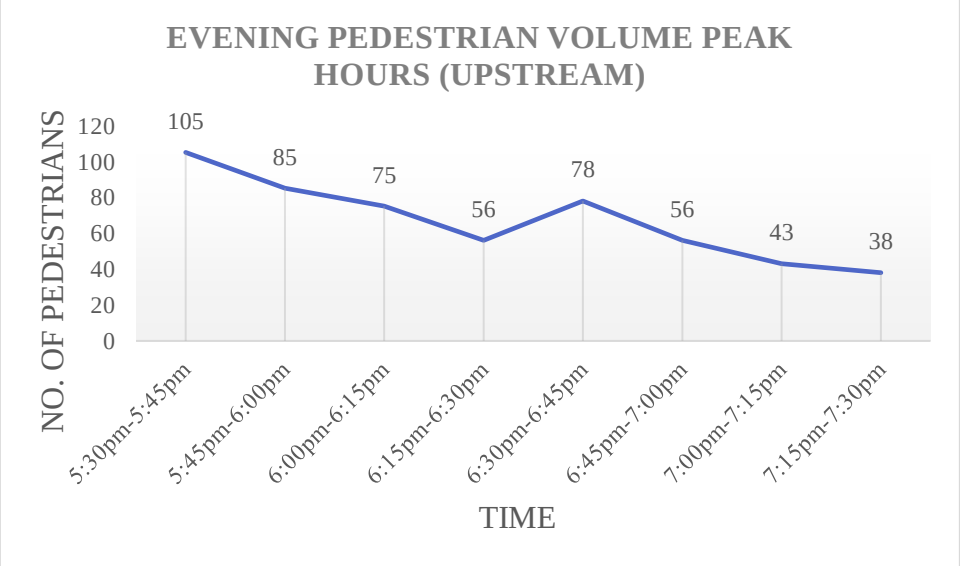

Figure 4.35 Evening Pedestrian Volume Peak Hours (Upstream) at Location 5

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm. The people who left for work purposes in the morning were observed coming back.

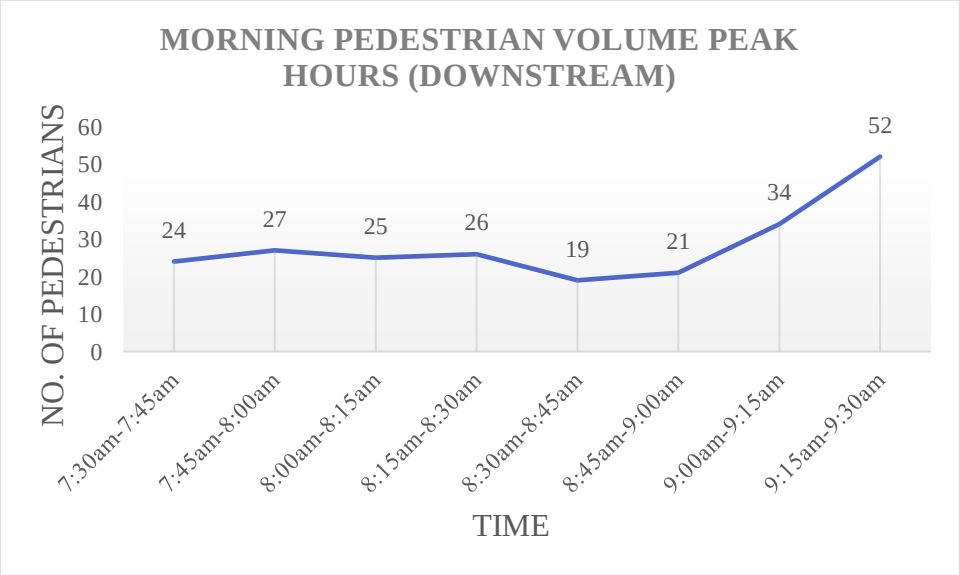

Figure 4.36 Morning Pedestrian Volume Peak Hours (Downstream) at Location 5

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area does not have much pedestrian count as it is used by pedestrians which travel for work purpose or any of the personal purposes.

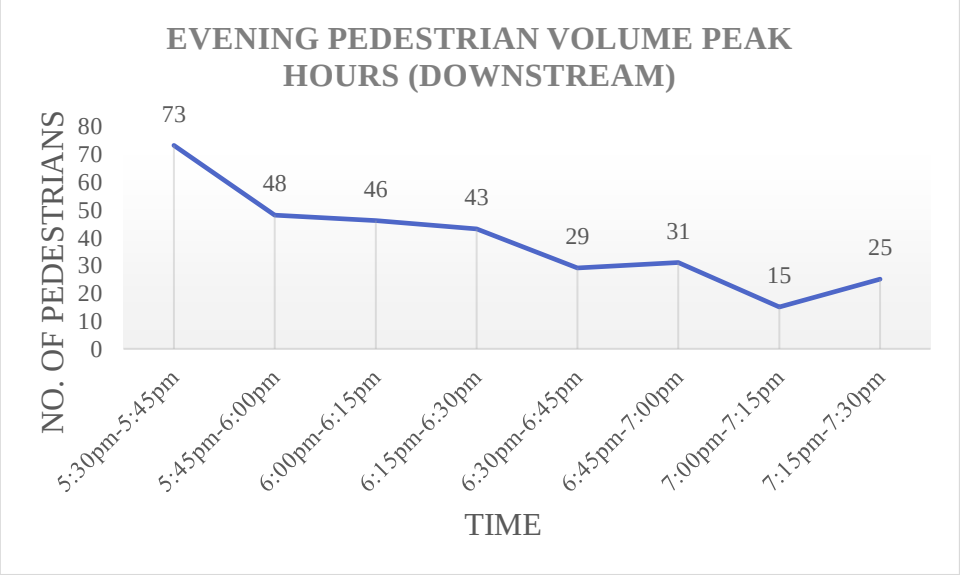

Figure 4.37 Evening Pedestrian Volume Peak Hour (Downstream) at Location 5

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm. The people who left for work purposes in the morning were observed coming back.

6. Nada Sahib Road

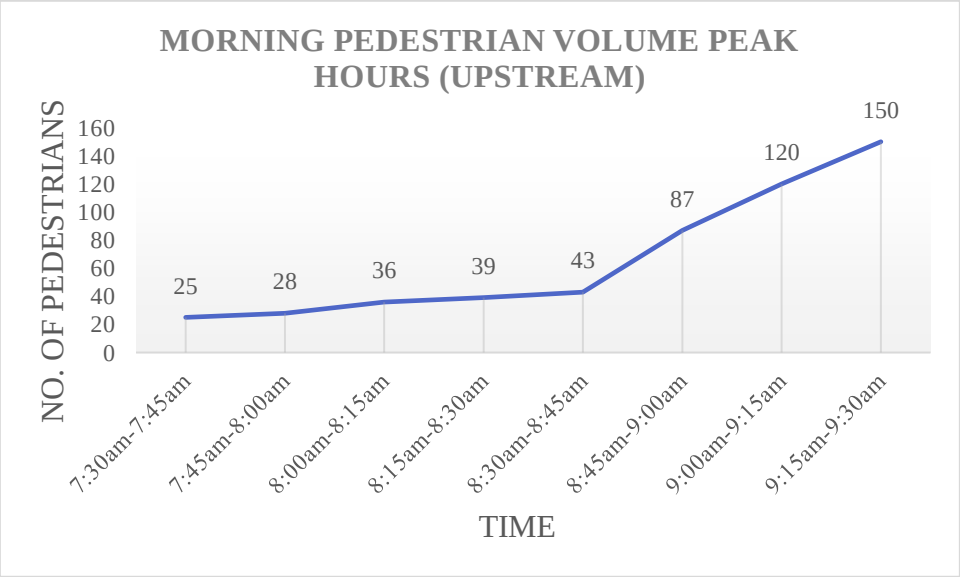

Figure 4.38 Morning Pedestrian Volume Peak Hours (Upstream) at Location 6

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area is an administrative type area which had pedestrian count during office hours only.

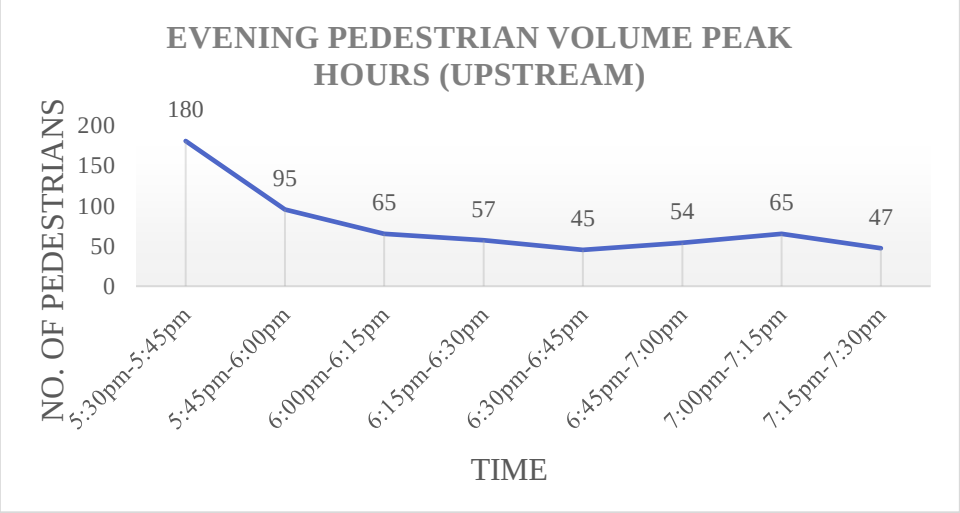

Figure 4.39 Evening Pedestrian Volume Peak Hours (Upstream) at Location 6

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm. This area is an administrative type area which had pedestrian count during office hours only.

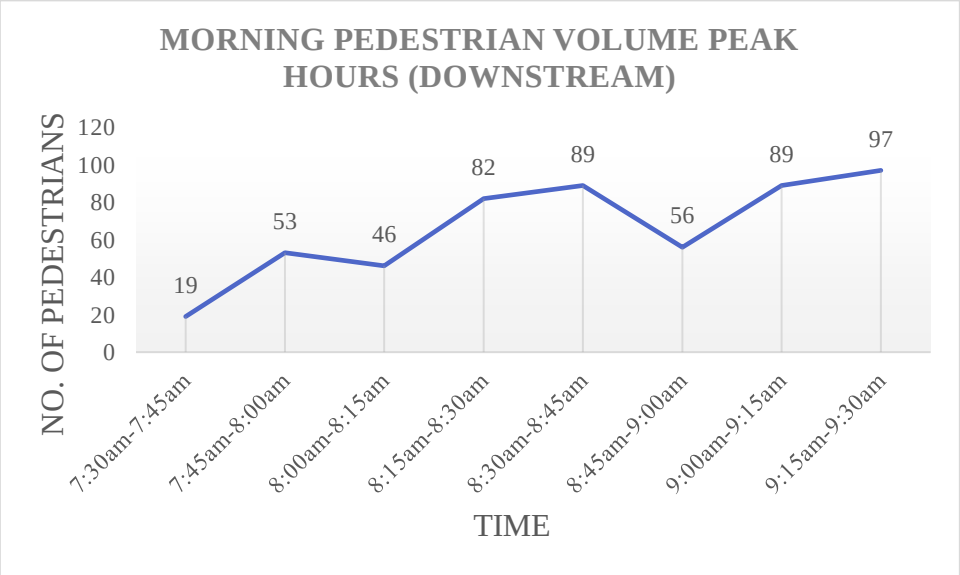

Figure 4.40 Morning Pedestrian Volume Peak Hours (Downstream) at Location 6

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area is an administrative type area which had variable pedestrian count at some time slots because of recreational area opposite to administrative area whereas in the morning people came for walk purposes also.

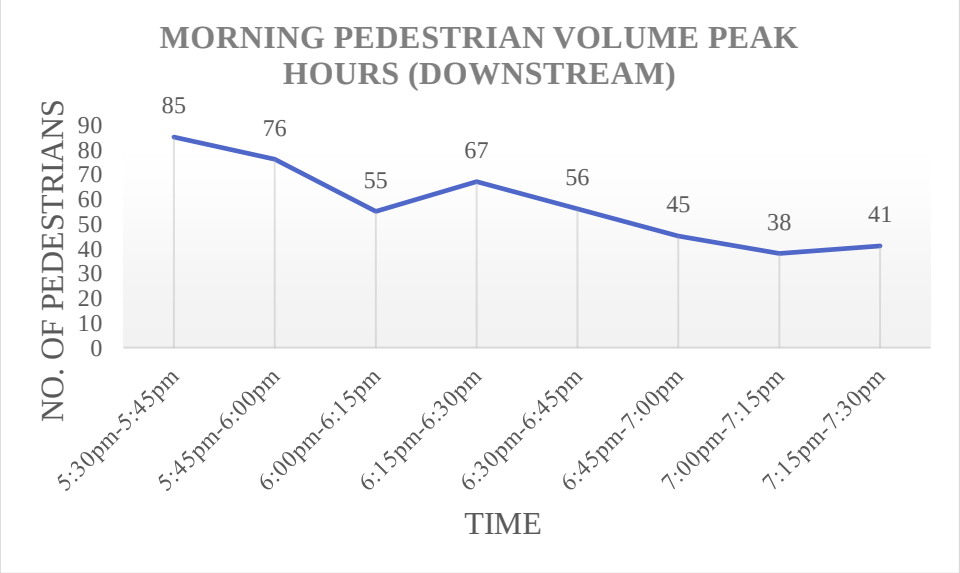

Figure 4.41 Evening Pedestrian Volume Peak Hour (Downstream) at Location 6

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm. This area is an administrative type area which had pedestrian count during office hours only.

7. Mahespur Rd

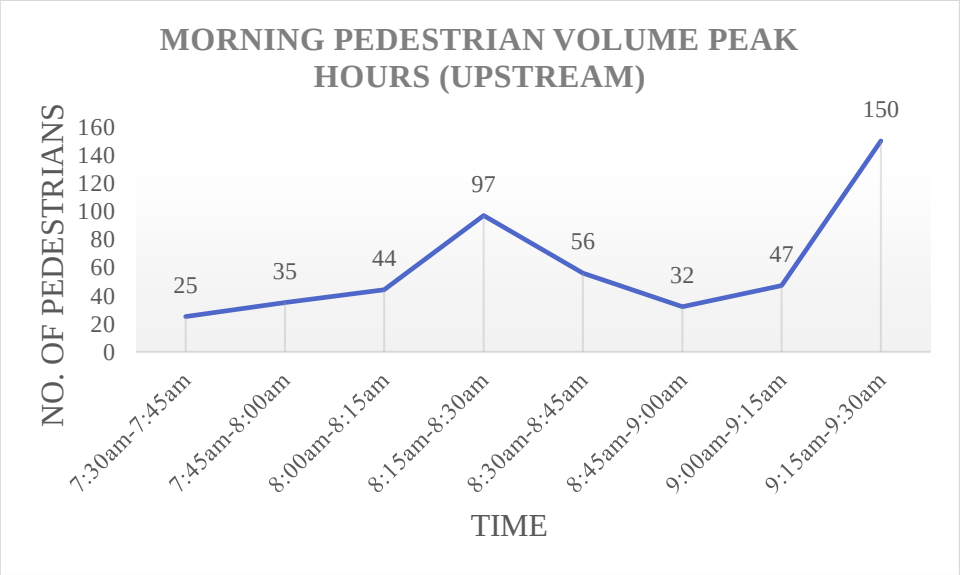

Figure 4.42 Morning Pedestrian Volume Peak Hours (Upstream) at Location 7

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area is a Bus terminal area which had pedestrian count at office hours and at institutional hours.

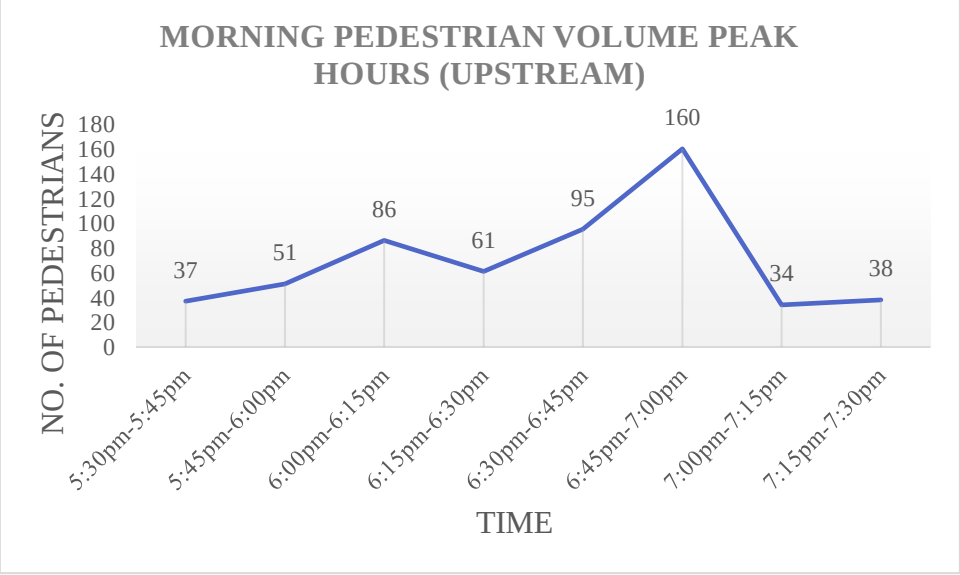

Figure 4.43 Evening Pedestrian Volume Peak Hours (Upstream) at Location 7

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 6.45pm-7.00pm. The people who left for work purposes in the morning were observed coming back.

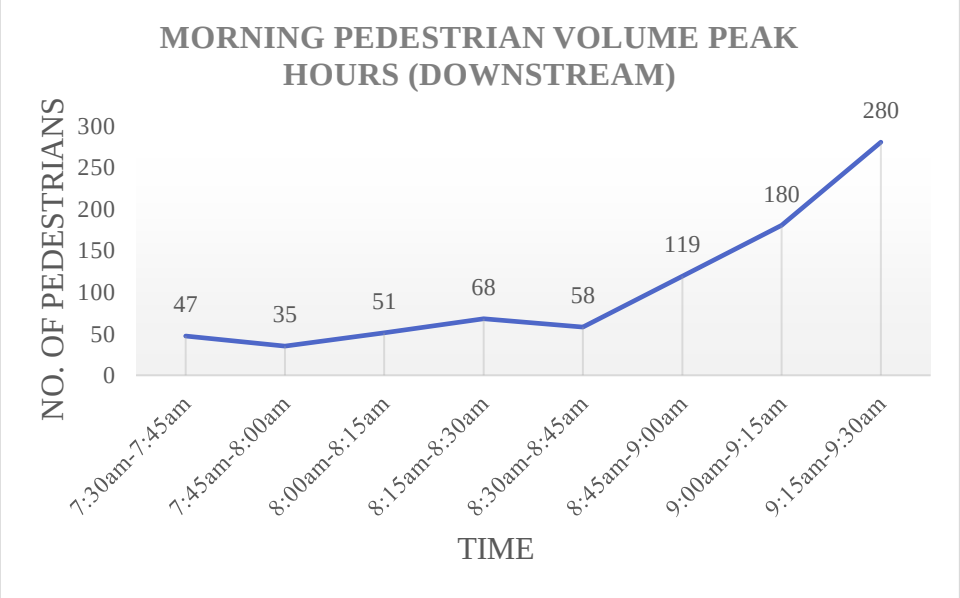

Figure 4.44 Morning Pedestrian Volume Peak Hours (Downstream) at Location 7

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 9.15am-9.30am. This area is a Bus terminal area which had pedestrian count at office hours and at institutional hours.

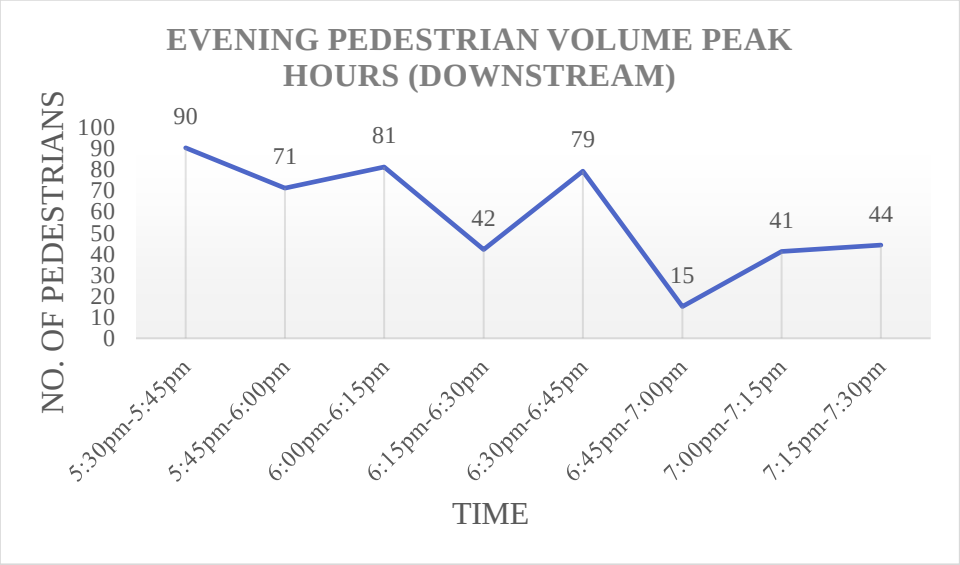

Figure 4.45 Evening Pedestrian Volume Peak Hour (Downstream) at Location 7

As it can be observed in the figure Max 15-min Pedestrian Peak flow rate is found at time 5.30pm-5.45pm. The people who left for work purposes in the morning were observed coming back.

Table 4.2 Summary of all the Selected Location and Their Max 15-min Peak Pedestrian Count

Sr. No.	CORRIDOR NAME	CORRIDOR LOCATIONS	MAX 15-MIN PEAK PEDESTRIAN COUNT (UPSTREAM)	MAX 15-MIN PEAK PEDESTRIAN COUNT (DOWNSTREAM)
1.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector-6	250	150
2.	Sector-7 Market Rd	Road opposite Sector-7 Market	430	220
3.	Chandigarh-Panchkula Road	Road opposite MDC Market	180	220
4.	Budanpur Road	Labour Chowk to Agrasen Chowk	160	92
5.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	105	73
6.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout towards	180	97

		Bella Vista Roundabout		
7.	Mahespur Road	Bus Stand & Sector-10 dividing Road	160	280

As it can be seen from Table 4.2 the Maximum Peak Count was observed at Sector-7 Market Road of 430 people in 15-min. Whereas, the Minimum Peak Count was observed for the Road Dividing Secotr-12 & Sector-11 at 73 Pedestrians in 15-min

CHAPTER 5

5.1 LEVEL OF SERVICE CONCEPT (LOS)

The concept of "Level-of-service (LOS)" is merely an abstraction of quality of the considered phenomenon at the study time and location. If it is traffic, we are considering, LOS shows the state of traffic in a qualitative way. There may be some difference in the LOS techniques among different regions, but LOS is generally represented by levels of A through F, where A shows high levels of comfort and/or available capacity while F stand for congestion and/or several delays in the system. While a LOS A is the most favorable condition from a user perspective, it is not the best case from a system manager perspective, who should focus on better utilization of the existing capacity with acceptable negative outcomes for the users, such as in LOS C.

For different traffic flows (vehicular, pedestrian, bicycle, transit, etc.) different definitions of LOS are needed, based on the characteristics and factors affecting such flows. Furthermore, for a given mode, such as pedestrian or vehicular, LOS concept can be defined based on different measures, such as capacity usage, delay, fluidity of the flow, etc. As this study focus on understanding and evaluating PLOS, here, we are going to focus on this concept and relevant ones needed in the assessment of PLOS, only.

5.1.1 Level of Service A

Average area occupancy per pedestrian is equal to 35 sq. ft. which gives pedestrians the opportunity of choosing their own speed freely to avoid slower pedestrian traffic and skip to cross conflicts with others (Figure 5.1). The pedestrian volume would be about 7 pedestrians per minute per foot of the walkways' width. The example of this type of design would be plazas or public buildings with no severe peaking space limitations.

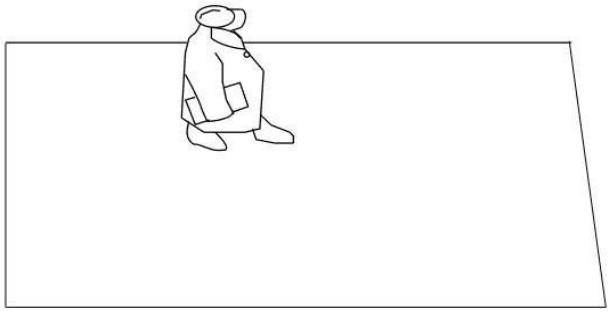

Figure 5.1 Pedestrian LOS A According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.1.2 Level of Service B

The average area occupancy is in the range of 25 – 35 sq. ft. per person and pedestrians would be able to choose normal walking speed to avoid other pedestrians (Figure 5.2). Minor conflicts can occur when opposite direction or pedestrian crossing movement happens to be there, and will cause a lower pedestrian speed. The pedestrian volume would be around 7- 10 pedestrians per minute per foot of walkways' width. An example of this type of design would be transportation terminals and buildings where normally no severe peaks occur.

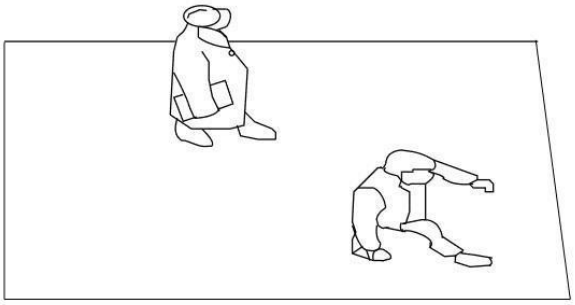

Figure 5.2 Pedestrian LOS B According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.1.3 Level of Service C

The average area occupancy is in the range of 15 – 25 sq. ft per pedestrian. At this level, pedestrians have less freedom to walk in a speed that allows to easily bypass other pedestrians. At this level of service, to avoid interruption, pedestrians will experience

frequent adjustment of speed when pedestrian cross movements and reverse flow occur. The design volumes would be around 10 – 15 pedestrians per minute per foot of walkways' width. Pedestrians walking at this level of service should expect to experience considerable amount of frictions and contacts. Example of this type of design would be public buildings, transportation terminals with severe peaking and space restrictions (see Figure 5.3).

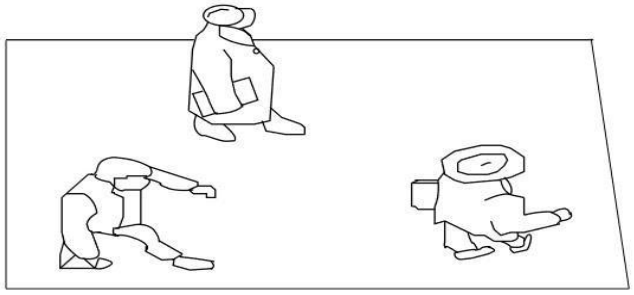

Figure 5.3 Pedestrian LOS C According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.1.4 Level of Service D

The average area occupancy is around 10–15 sq. ft. per pedestrian and most likely the majority of pedestrians wouldn't be able to have a normal walking speed. It would be difficult for pedestrians to avoid having conflicts with slower pedestrians. Probability of multiple conflicts will increase when pedestrians get involved in reverse flow and crossing movements. The walkways with this level of service would have the flow rate would be 15 – 20 pedestrians per minute per foot of walkways' width. The most crowded public areas would only represent areas with this level of service (Figure 5.4).

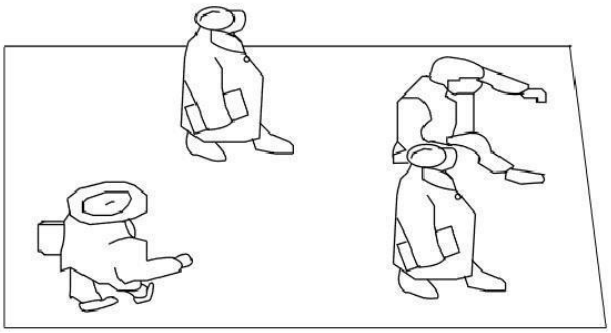

Figure 5.4 Pedestrian LOS D According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.1.5 Level of Service E

The average area occupancy for this level is 5 – 10 sq. ft. per pedestrian. Almost all pedestrians' normal walking speed would be restricted and required to alter their walking speed repeatedly. When the average area occupancy gets close to the bottom of the range, shuffling would become the only option to move forward. Pedestrians would struggle to attempt reverse flow and cross flow movements. The flow rate of 20 – 25 per minute per foot width of walkway is considered to be the fullest possible capacity of the walkway with recurrent deterrence and interruptions. The example of this design would be the rail transit facilities or stadiums where the short-term crowd of passengers exists (Figure 5.5).

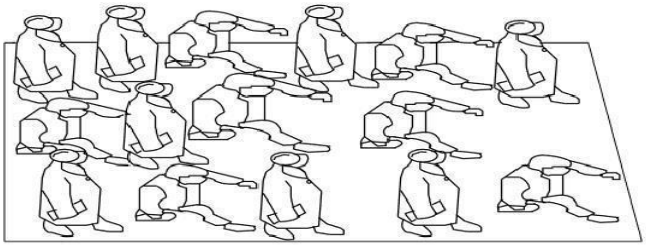

Figure 5.5 Pedestrian LOS E According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.1.6 Level of Service F

Average area occupancy of 5 sq. ft. or lower per person represents level of service F. At this level of service, all pedestrians' walking speed is tremendously limited and shuffling is the only way to move forward. Reverse or crossing movements, and avoiding contact with other pedestrians would be impossible. Making forward progress would be dependent on the movements of pedestrians in front. Clearly, the pedestrian areas lower than range 5 sq. ft. represent queuing rather than traffic flow situation and this level of service would be an unsuccessful design for walkways (Fruin, 1971).

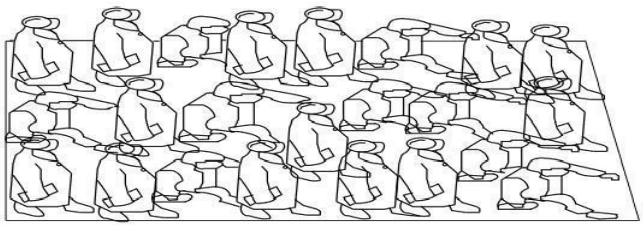

Figure 5.6 Pedestrian LOS F According to HCM

Source: Bloomberg, M. R., & Burden, A. M. (2006, April)

5.2 EVALUATION OF THE LOS BY HCM 2010

According to the HCM, pedestrian perspective off-street facility performance needs to be separately calculated for each side of the urban sidewalk facilities. Hence, for this study, wherever a facility LOS was needed for both sides of a street, the performance evaluation has been done independently for each side. The following figure shows the steps that were taken to determine LOS of facilities.

To evaluate urban sidewalk performance for pedestrians, a variety of measurements need to be done. Each measure portrays a different feature of the pedestrian trip along the facility. For instance, LOS score is one measure that specifies the classical pedestrian's perception of the overall facility travel experience. The second measure is the average speed of pedestrians traveling along the facility. The third measure, which is based on the concept of "circulation area," depicts the average available sidewalk area for each pedestrian walking on the facility. The larger the sidewalk area is, the more desirable it will be for pedestrians. The following table (table 5.7) from the HCM provides a qualitative illustration of pedestrian space that can be employed for sidewalk evaluation performance from a flow-area perspective.

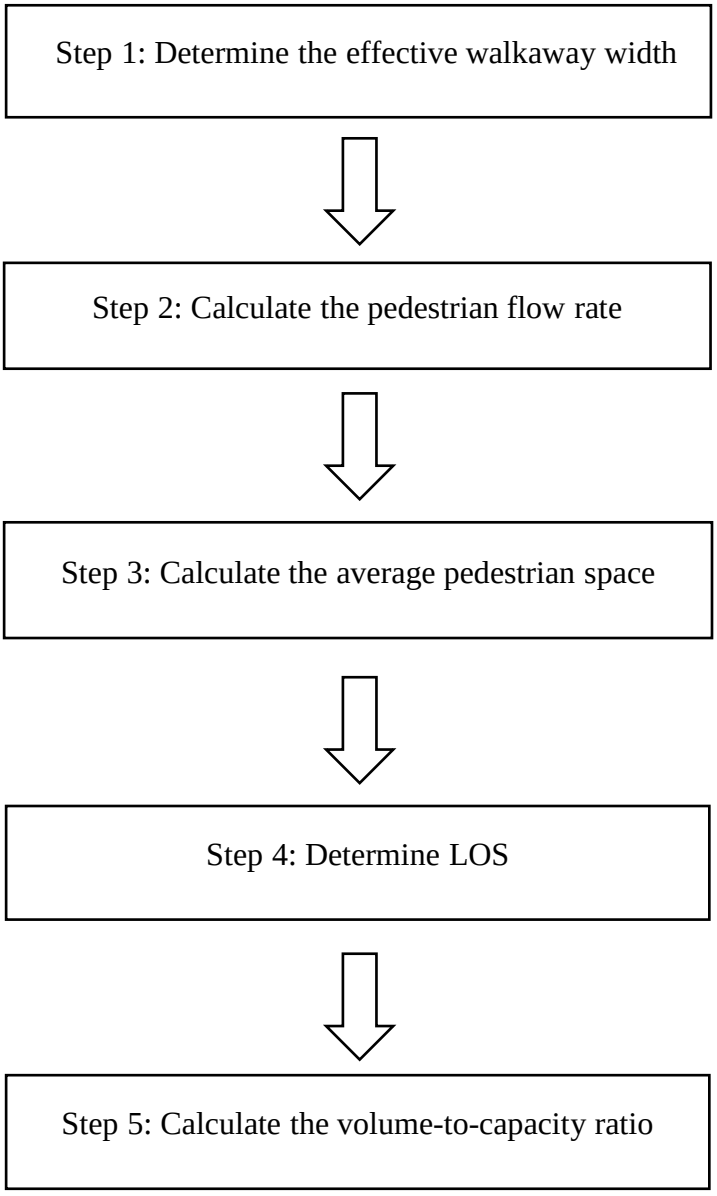

Figure 5.7 Flowchart explaining the Step-by Step Procedure to evaluate LOS by HCM 2010

Table 5.1 Average flow LOS criteria for sidewalks.

LOS	AVG. SPACE (ft^2/p)	FLOW RATE (p/min/ft)[a]	AVG. SPEED (ft/s)	v/c Ratio[b]	Comments
A	>60	≤5	>4.25	≤0.21	Ability to move in desired path, no need to alter movements
B	>40-60	>5-7	>4.17-4.25	>0.21-0.31	Occasional need to adjust path to avoid conflicts
C	>24-40	>7-10	>4.00-4.17	>.031-0.44	Frequent need to adjust path to avoid conflicts
D	>15-24	>10-15	>3.75-4.00	>.044-0.65	Speed and ability to pass slower pedestrians restricted
E	>8-15	>15-23	>2.50-3.75	>0.65-1.00	Speed restricted, very limited ability to pass slower pedestrians
F	≤8	Variable	≤2.50	Variable	Speeds severely restricted, frequent contact with other users

Note: [a]Pedestrians per minute per foot of walkaway width. (Source: HCM 2010)

[b]v/c ratio = flow rate/23. LOS is based on average space per pedestrian.

The capacity of pedestrian facilities is based on research conducted on constrained facilities (e.g., bridges and underground passageways), where there is no opportunity for pedestrians to walk outside the designated area. Off-street pedestrian facilities, in contrast, typically have no barriers keeping pedestrians to the designated path. As a result, these facilities reach effective failure (i.e.,

pedestrian spill over) at densities less than their capacity. For this reason, in combination with considerations of general pedestrian comfort, off-street walkways are desirably designed to achieve LOS C or better, based on pedestrian space, rather than for capacity conditions. The methodologies are generally appropriate regardless of the type of surface used for the pedestrian facility. The Step by Step Procedure to evaluate the LOS of sidewalk is given below:

Step 1: Determine Effective Walkway Width

Walkways and Cross-Flow Areas Effective walkway width is the portion of a walkway that can be used effectively by pedestrians. Various types of obstructions and linear features, discussed below, reduce the walkway area that can be effectively used by pedestrians. The effective walkway width at a given point along the walkway is computed as follows:

$$W_E=W_T-W_O$$

where

W_E = effective walkway width (ft),

W_T= total walkway width at a given point along walkway (ft), and

W_O = sum of fixed-object effective widths and linear-feature shy distances at a given point along walkway (ft).

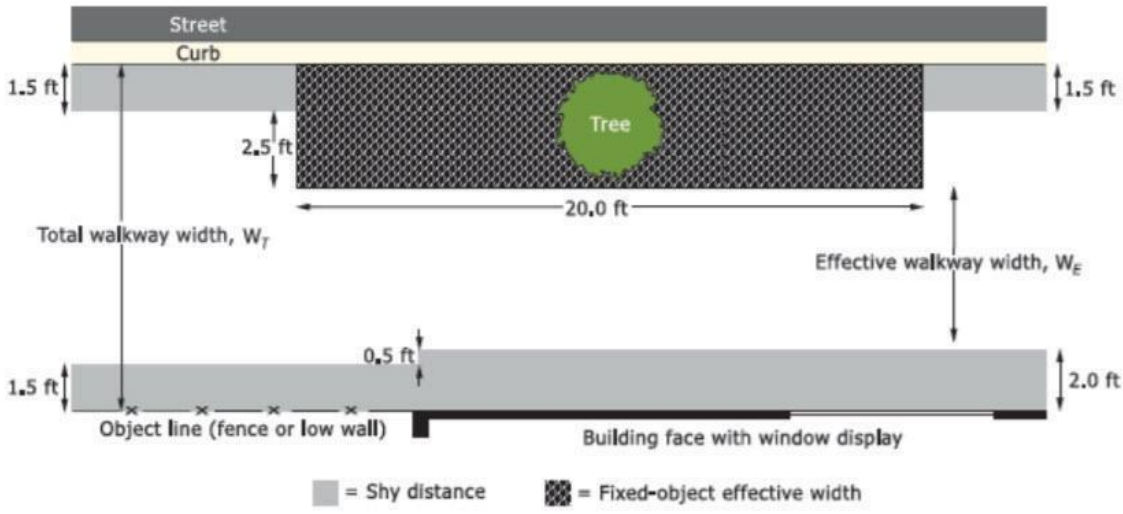

Figure 5.8 Figure Showing Effective Width of Sidewalk

illustrates a portion of a sidewalk or walkway. The general concepts shown are applicable both to sidewalks along urban streets and to exclusive off-street paths not located adjacent to a street. Linear features such as the street curb, the low wall, and the building face each have associated shy distances. The shy distance is the buffer that pedestrians give themselves to avoid accidentally stepping off the curb, brushing against a building face, or getting too close to other pedestrians standing under awnings or window shopping. Fixed

objects, such as the tree, have effective widths associated with them. The fixed object effective width includes the object's physical width, any functionally unusable space (e.g., the space between a parking meter and the curb or the space in front of a bench occupied by people's legs and belongings), and the buffer given the object by pedestrian

Step 2: Calculate Pedestrian Flow Rate

Walkways and Cross-Flow Areas

Hourly pedestrian demands is used as an input to the analysis. Consistent with the general analysis procedures used throughout the HCM, hourly demand is usually converted into peak 15-minflows, so that LOS is based on the busiest 15 consecutive minutes during an hour:

$$v_{15} = \frac{v_h}{4 \times PHF}$$

where

v_{15} = pedestrian flow rate during peak 15min(p/h),

v_h = pedestrian demand during analysis hour (p/h), and

PHF = peak hour factor.

However, if peak-15-min pedestrian volumes are available, the highest 15- Min volume can be used directly without the application of a peak hour factor. Next, the peak 15-minflow is converted into a unit flow rate (pedestrians per minute per foot of effective pathwidth):

$$v_p = \frac{v_{15}}{15 \times W_E}$$

where v_p is pedestrian flow per unit width (p/ft/min) and all other variables are as previously defined.

Step 3: Calculate Average Pedestrian Space

The service measure for walkways is pedestrian space, the inverse of density. Pedestrian space can be directly observed in the field by measuring a sample area of the facility and determining the maximum number of pedestrians at a given time in that area. The pedestrian unit flow rate is related to pedestrian space and speed:

$$A_{\mathbf{p}} = \frac{S_{\mathbf{p}}}{v_{\mathbf{p}}}$$

where

A_p= pedestrian space (ft^2/p),

S_p = pedestrian speed (ft/min), and

v_p =pedestrian flow per unit width (p/ft/min).

Step 4: Determine LOS

Walkways with Random Pedestrian Flow

Where pedestrian flow on the path is not influenced by platooning (see next subsection), Exhibit 23-1 should be used to determine pedestrian LOS. Research (9-11) has shown that pedestrian speeds on ramps with grades up to 5% are not significantly different from speeds on level walkways but that speeds decrease at higher grades. Therefore, the walkway LOS values are also

applicable to ramps with grades of 5% or less. Ramps with steeper grades are discussed later in this chapter in the Special Cases section. The walkway LOS values can also be adapted to pedestrian plazas and pedestrian zones (exclusive pedestrian streets), as discussed in the Special Cases section.

Step 5: Calculate Volume-to-Capacity Ratio

The volume-to-capacity (pic) ratio can be computed by using the following values of capacity for various exclusive pedestrian facilities:

• Walkways with random flow: 23 p/min/ft,

• Walkways with platoon flow (average over 5 min): 18 p/min/ft,

• Cross-flow areas: 17 p/min/ft (sum of both flows),

Table 5.2 Results of seven selected locations

Sr. No	CORRIDOR NAME	CORRIDOR LOCATIONS	FLOW RATE (p/min/ft)[a]	AVG. SPACE (ft^2/p)	v/c Ratio[b]	LOS	COMMENTS
1.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector-6	4.19 (A)	57.168 (B)	0.18(A)	**A/B**	Occasional need to adjust path to avoid conflicts
2.	Sector-7 Market Road	Road opposite Sector-7 Market	6.02(B)	39.85(C)	0.26(B)	**B/C**	Frequent need to adjust path to avoid conflicts
3.	Chandigarh-Panchkula Road	Road opposite MDC Market	5.63(B)	42.6(C)	0.24(B)	**B/C**	Occasional need to adjust path to avoid conflicts
4.	Budanpur Road	Labour Chowk to Agrasen Chowk	4.16(A)	57.69(B)	0.18(A)	**A/B**	Occasional need to adjust path to avoid conflicts
5.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	2.33(A)	102.85(A)	0.10(A)	**A**	Ability to move in desired path, no need to alter movements
6.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout	6.09(B)	39.4(C)	0.26(B)	**B/C**	Frequent need to adjust path to avoid conflicts
7.	Mahespur Road	Bus Stand & Sector-10 dividing Rd	4.12(A)	58.24(B)	0.18(A)	**A/B**	Occasional need to adjust path to avoid conflicts

As can be seen from these results, the LOS values are coming different from different methods. Therefore, more specific Parameters and more evolved methods could be tried out in future research. Also, in next chapter, the Pedestrian LOS has been found out with the INDO-HCM (2017) document which is an adaptation of HCM for Indian Environment.

CHAPTER 6

EVALUATION OF LOS BY INDO-HCM 2017

PLOS has been established for Footpaths using the methodology flow chart presented in Figure 6.1 Six steps should be followed to identify PLOS of Footpath. In the first step, Footpath should be identified considering surrounding land use. Then in the second step, width of the available Footpath should be measured and after that effective width should be calculated. Effective width calculation is already discussed in the previous section. In the next step, pedestrian flow (ped/min) should be observed from the selected site and peak flow value should be converted into flow rate (ped/min/m) to estimate maximum or peak flow rate. In the final step, using the peak flow rate value, PLOS can be identified for any Footpaths given earlier in Table 6.1

Table 6.1 PLOS determination in relation to various land uses

LOS	Commercial	Institutional	Terminal	Recreational	Residential
A	≤13	≤13	≤15	≤12	≤16
B	>13-19	>13-19	>15-26	>12-20	>16-23
C	>19-30	>19-27	>26-32	>20-32	>23-34
D	>30-47	>27-36	>32-68	>32-54	>34-47
E	>41-49	>36-42	>68-78	>54-91	>47-59
F	Variable	Variable	Variable	Variable	Variable

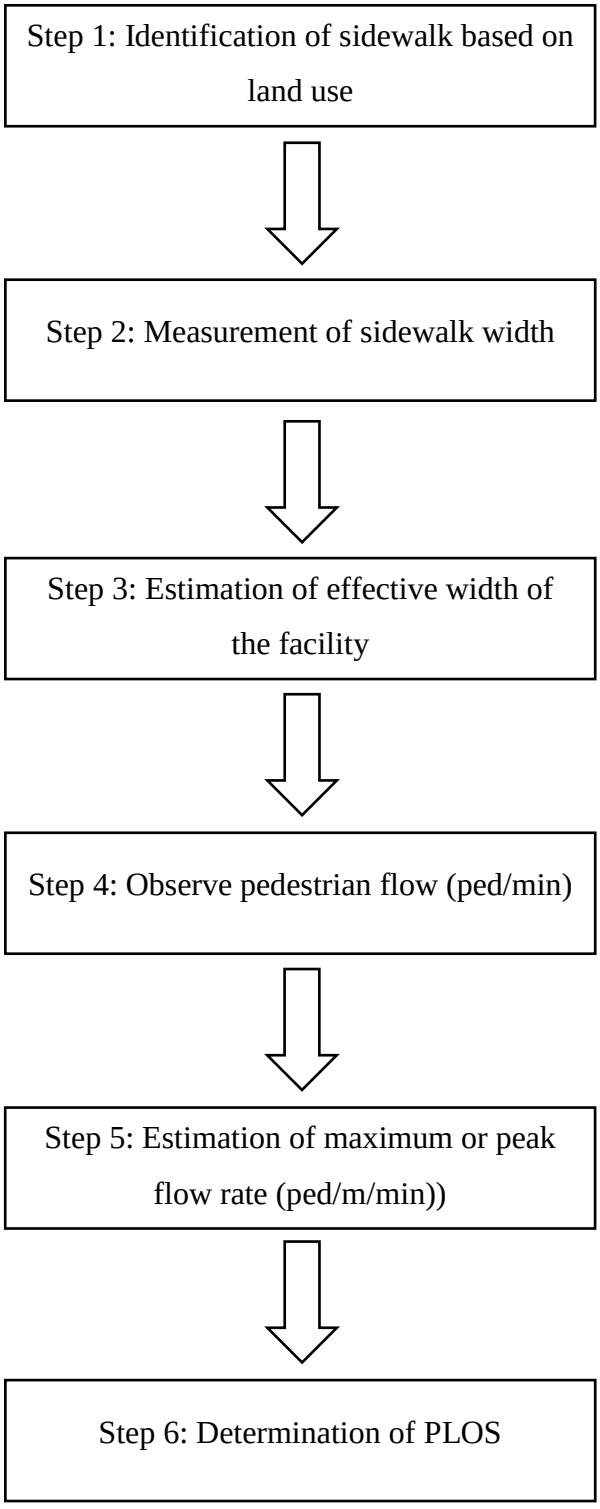

Figure 6.1 Flowchart Explaining Step by Step Procedure to evaluate LOS

Step 1: Identification of sidewalk based on land use

For determining LOS first of all the land use is to be determined i.e. whether the land use is of Commercial type, Institutional type, Terminal type, Recreational type or Residential type.

Step 2: Measurement of Sidewalk Width

The sidewalk width is to be measured on site for which inventory or Pilot Survey is to be conducted at the selected locations.

Step 3: Estimation of Effective width of the facility

The effective width is measured by excluding the obstruction from the width of the sidewalk, the obstruction covering the largest area is to be used including the shy distance.

Step 4: Observe Pedestrian Flow

For the Pedestrian Flow volume survey or manual counting of the pedestrian is to be conducted on the selected location through which pedestrian walking on sidewalk per minute can be obtained.

Step 5: Estimation of maximum or peak flow rate

The peak flow rate can be obtained from volume survey of pedestrian. A 15-min maximum peak values is to be used for the estimation of maximum flow rate.

Step 6: Determination of PLOS

The PLOS can be determined after comparing all the above factors by using table 6.1

Table 6.2 Results LOS on the basis of various land uses

Sr. No.	CORRIDOR NAME	CORRIDOR LOCATION	LAND USE	PEAK FLOW (ped/min/m)	LOS
1.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector-6	Institutional	13.77	**B**
2.	Sector-7 Market Road	Road opposite Sector-7 Market	Commercial	19.77	**C**
3.	Chandigarh-Panchkula Road	Road opposite MDC Market	Commercial	18.46	**B**
4.	Budanpur Road	Labour Chowk to Agrasen Chowk	Recreational	13.67	**B**
5.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	Residential	7.65	**A**
6.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout	Commercial	20	**C**
7.	Mahespur Road	Bus Stand & Sector-10 dividing Road	Terminal	13.52	**A**

The LOS values for the locations mentioned in table 6.2 indicate the following:

1. Road in front of Hansraj Public School, Sector-6 The **LOS B** is attained from INDO-HCM 2017 for this road having effective width of 1.21m and 15-min Maximum Pedestrian count 250 has medium congestion & Smooth Flow.

2. Sector-7 Market Road The **LOS C** is attained from INDO-HCM 2017 for this road having effective width of 1.5m and 15-min Maximum Pedestrian count 430 has high congestion/Encroachments & The Pedestrian flow is not so smooth.

3. Chandigarh-Panchkula Road The **LOS B** is attained from INDO-HCM 2017 for this road having effective width of 0.65m and 15-min Maximum Pedestrian count 220 has medium congestion & Smooth Flow.

4. Budanpur Road The **LOS B** is attained from INDO-HCM 2017 for this road having effective width of 0.78m and 15-min Maximum Pedestrian count 160 has medium congestion & Smooth Flow.

5. Road Dividing Sector-12 & Sector-11 The **LOS A** is attained from INDO-HCM 2017 for this road having effective width of 0.915m and 15-min Maximum Pedestrian count 105 has Very Less Congestion & Free Flow Condition.

6. Nada Sahib Road The **LOS C** is attained from INDO-HCM 2017 for this road having effective width of 0.6m and 15-min Maximum Pedestrian count 180 has high congestion/Encroachments & The Pedestrian flow is not so smooth.

7. Mahespur Road The **LOS A** is attained from INDO-HCM 2017 for this road having effective width of 1.38m and 15-min Maximum Pedestrian count 280 has Very Less Congestion & Free Flow Condition.

CHAPTER 7

QUALITATIVE ASSESSMENT OF PEDESTRIAN FACILITY BY PLOS METHOD

Qualitative assessment for the evaluation of pedestrian facility encompasses the quality assessment of the characteristics of the Footpaths. This method uses the perception of the pedestrians and attempts to quantify the comfort level of pedestrians while encountering certain roadway characteristics. Quality of Service *(QOS)* indicates the environmental qualities of pedestrian space and serves as a guide for the development of standards for pedestrian facilities. Pedestrian spaces should be designed considering human convenience and should be suitable to the needs of pedestrians.

Walkability Index is used for evaluating pedestrian infrastructure performance considering the following factors:

- Physical and user characteristics/parameter
- Importance weight and satisfaction rating of individual parameter

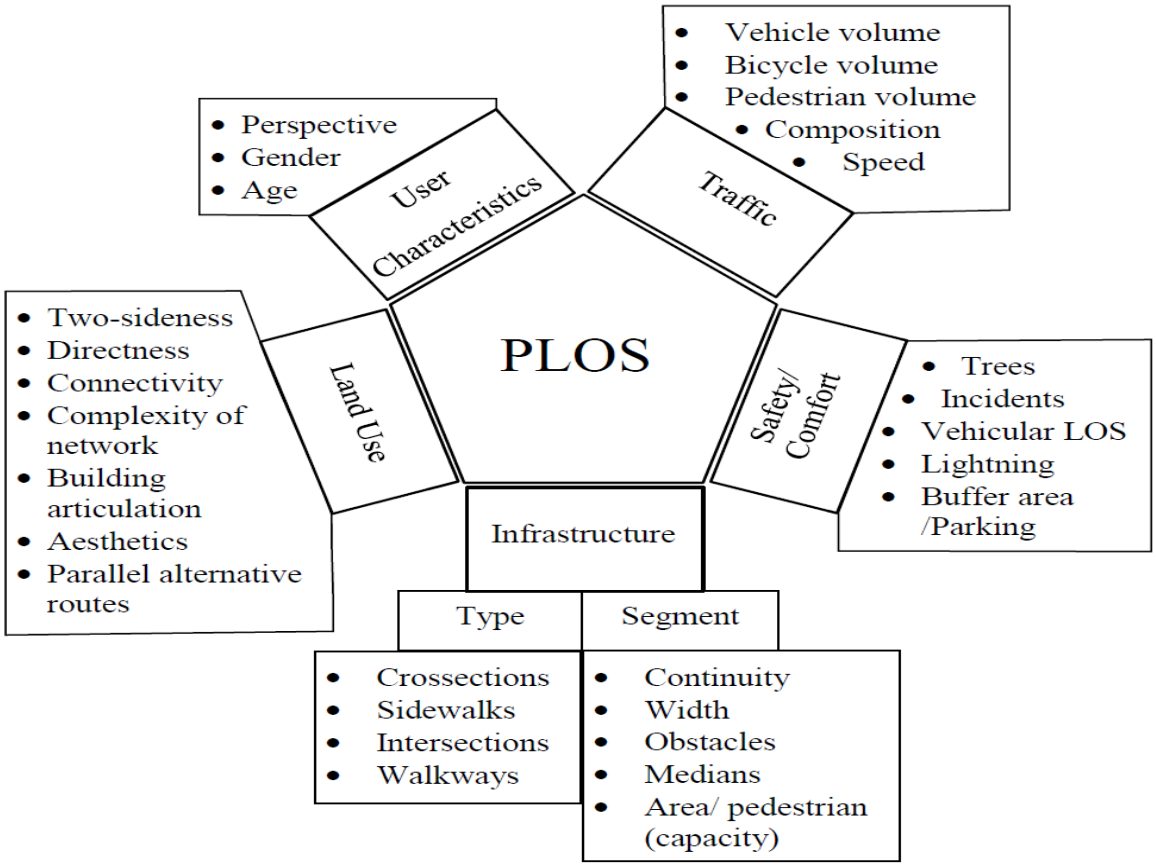

Figure 7.1 Dimensions of Pedestrian Level of Service

The dimensions of PLOS are bifurcated to User Characteristics, Traffic, Land Use, Safety, Comfort, Infrastructure, etc. which is further divided into more categories as in figure 2.1 To determine the Walkability Index, the perception of the pedestrians on the quality of Footpaths available and needs of the pedestrians has been captured through a detailed questionnaire surveys conducted at Panchkula by interviewing about 440 respondents to build the Walkability Index. Thus, the Walkability Index is calculated using

Equation:

Walkability Index: PLOS = $\sum_{i=1}^{10} A_i \times B_i$

Where,

A_i: importance weight for physical and user characteristics

B_i: satisfaction rating for physical and user characteristics

The relative importance weight of each sidewalk characteristic (A) gives the effect of each sidewalk factor for the PLOS. The relative weight of each sidewalk is given by following equation:

$$A_i=\frac{\sum_{j=1}^{J=5} I_j \times n_j}{N}$$

Here, A is relative weight of each sidewalk factor, i is number of parameters, I is importance rating, j is the rating from 1 to 5, n is the number of pedestrians choosing 'j' rating, N is the total number of pedestrians.

PLOS score is obtained when the satisfaction rating of existing conditions of sidewalk characteristics is calculated. Satisfaction score is also calculated by multiplying the corresponding five-point scale rating to the number of pedestrians who has been given that rating. In this study, excellent rating gets five points, very good gets four points, good gets three points, satisfactory gets two points while the poor gets one point. The satisfaction assessment score for each factor is given using the following equation:

$$B_i=\frac{\sum_{j=1}^{J=5} S_j \times n_j}{N}$$

Where B is the satisfaction score obtained for each sidewalk, is number of parameters, S is the satisfaction score, j is the rating from 1 to 5, n is the number of the pedestrians choosing 'j' rating and N is the total number of pedestrians.

PLOS score classifications; their interpretations and required level of improvements are presented in Table 7.1. The point system involves rating from A to F. PLOS A indicates that excellent street facilities and sidewalks are excellent condition, B indicates that street facilities and sidewalks are in very good condition, PLOS C indicates that street facilities and sidewalks are in good condition, PLOS D indicates that street facilities and sidewalks are with average quality, but slight issues in safety and comfort , PLOS E indicates poor condition of the street network and pedestrian infrastructures with severe issues on safety and comfort. Finally, PLOS F indicates sidewalks are at worst condition and not at all appropriate for walking.

Physical characteristics and user characteristics are listed in the mean weights for importance and for satisfaction rating for physical features and user characteristics computed are given below. Quality of Service *(QOS)* evolved in this manual is based totally

on the INDO-HCM 2017. The importance rating and satisfaction rating (1 to 5) for Footpath attributes are collected by questionnaire survey where importance (1=immaterial, 2=least importance, 3=important, 4=very important and 5=most important) and satisfaction (1=poor, 2=satisfactory, 3=good, 4=very good, 5=excellent) with respect to ten Footpath attributes. The factors affecting the quality of service for pedestrians have been classified as physical characteristics (footpath surface, footpath width, obstruction, potential for vehicular conflict, continuity) and the user factors (encroachment, availability of crossing facilities, security, walk environment, comfort) of Footpaths are evaluated based on the description given in Proforma (refer Annexure II).

Table 7.1 PLOS scores and Level of Improvement needed

PLOS Scores	PLOS Rating	Condition	Description	Level of improvement
>125	A	Excellent	Highest quality sidewalk facilities	No improvement needed
≥100 - <125	B	Very Good	High quality of sidewalk facilities and light issues of pedestrian comfort	Very limited improvement needed
≥75 - <100	C	Good	Basic quality of sidewalk facilities with considerable issues on pedestrian safety and comfort.	Limited improvement needed

≥49 - <75	D	Average	Average facilities for pedestrians with slight issues of safety and comfort.	Some improvement needed
≥25 - <50	E	Poor	Low quality facilities for pedestrians with severe issues of safety and comfort.	Many improvements are needed
<25	F	Worst	Worst pedestrian facilities where factors influencing PLOS are below acceptable standards.	So many improvements are needed

(Source: Bivina *et.al*, 2018)

Table 7.2 Results on the basis of the walkability index

Sr. No.	Corridor Name	Corridor Location	Walkability Index	Level of improvement	PLOS Rating
1.	Indian Express Roundabout	Roundabout Connecting Maheshpur Rd & Nada Sahib Road	76.0075	Limited improvement needed	**C**
2.	Tank Chowk	Tank Chowk	63.81	Limited improvement needed	**C**
3.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector 6	125.06	No improvement needed	**A**
4.	Sector-6 Market Road	Road opposite Sector-6 Market	71.5	Limited improvement needed	**C**
5.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout towards Bella Vista Roundabout	89.2	Limited improvement needed	**C**
6.	Bella Vista Roundabout	Bella Vista Roundabout to	85.60688	Limited improvement needed	**C**

	to Bus Stand Roundabout	Bus Stand Roundabout			
7.	Mahespur Road	Bus Stand & Sector-10 dividing Road	92.2625	Limited improvement needed	**C**
8.	Sector-7 Market Road	Road opposite Sector-7 Market	109.1825	Very limited improvement needed	**B**
9.	Housing Board Chowk	Housing Board Chowk	73.205	Limited improvement needed	**C**
10.	Chandigarh-Panchkula Road	Road opposite MDC Market	115.91	Very limited improvement needed	**B**
11.	Mahespur Road	Sector-9 & Sector-5 dividing Road	103.6025	Limited improvement needed	**C**
12.	Sector-9 Market Road	Road opposite Sector 9 Market & Prachin Shiv Mandir	110.02	Very limited improvement needed	**B**
13.	Sector-9 Road	Sector-9 & Sector-16 dividing Road to Arya Samaj Mandir	64.7	Some improvement needed	**D**
14.	BEL Factory Road	Sector-9 & Sector-10 dividing Road to Govt.	102.33	Limited improvement needed	**C**

		Ayurveda Dispensary			
15.	Old Panchkula	Old Panchkula Trisection	85.5375	Limited improvement needed	**C**
16.	Majri Chowk	Majri Chowk	77.2725	Limited improvement needed	**C**
17.	District Court Panchkula	District Court Panchkula	106.8175	Very limited improvement needed	**B**
18.	Rally Chowk to 11/15 Chowk	Rally Chowk to 11/15 Chowk	112.9325	Very limited improvement needed	**B**
19.	Sector-15	Road Covering Hallmark Public School, Bhavan Vidyalya School & Market Area	108.265	Very limited improvement needed	**B**
20.	Budanpur Road	Labour Chowk to Agrasen Chowk	89.9	Limited improvement needed	**C**
21.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	107.485	Very limited improvement needed	**B**
22.	Pashuram Chowk to	Pashuram Chowk to BEL	125.22	No improvement needed	**A**

	BEL Factory Intersection	Factory Intersection			
23.	Industrial Area Road	Rd opposite Nexa, Renault till Haryana Border	91.12	Limited improvement needed	**C**
24.	Sector-20 Market Road	Road opposite Sector-20 Market	121.36	Very limited improvement needed	**B**

Major Issues identified were:

- **Indian Express Roundabout** Due to increasing vehicle volume, pedestrians face problems at crossing of Roundabout and also as it is located near to all government offices, traffic jams were observed at peak hours and it was very difficult for a pedestrian to cross the road.
- **Tank Chowk** It is the main interchange point for pedestrians going towards Pinjore or Shimla Highway. The main Problem is that the essential need of the pedestrian i.e. the Sidewalk are not are not present.
- **Road in front of Hansraj Public School, Sector-6** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Sector-6 Market Road** The Location is a commercial market area with a prominent no. of pedestrians. The main Problem is that the essential need of the pedestrian i.e. the Sidewalk are not are not present.
- **Nada Sahib Road** Due to increasing vehicle volume, pedestrians face problems at Intersections and also as it is located near to all government offices, traffic jams were observed at peak hours and it was very difficult for a pedestrian to cross the road.
- **Bella Vista Roundabout to Bus Stand Roundabout** It is located at the centre of city having all the administrative offices along its way. But the major problem is

that the essential need of the pedestrian i.e. the Sidewalk is not present on one side (i.e. Upstream) due to which Vehicles are Parked on that area.

- **Mahespur Road (Bus Stand & Sector-10 dividing Road)** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. But still Pedestrians are walking on Road because people park their vehicles on Sidewalk.
- **Sector-7 Market Road** Overall the location has essential the amenities needed for pedestrian's i.e. a very good width of footpath, because of encroachments like street vendors pedestrians need to change their path causing inconvenience.
- **Housing Board Chowk** It is the main interchange point for pedestrians going towards Chandigarh or Shimla Highway. The main Problem is that the essential need of the pedestrian i.e. the Sidewalk is not present on one side and the one which is present is unpaved.
- **Chandigarh-Panchkula Road** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Mahespur Road (Sector-9 & Sector-5 dividing Road)** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath & also guard rails are provided to restrict the parking of vehicles on sidewalks etc. But the problem persists in the footpath surface which is in deteriorated condition.
- **Sector-9 Market Road** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. & also recently a vendor space has also been provided.
- **Sector-9 Road** The Area is a Residential area so no footpaths are present for the pedestrians, obviously they have to walk on Road which is high risk to life.
- **BEL Factory Road** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. but the location has an unsignalized intersection, which further increases the delay time of pedestrians while crossing.

- **Old Panchkula** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. But no crosswalks are provided for the crossing of pedestrians.
- **Majri Chowk** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. But because of the increasing vehicle volume its difficult for pedestrian to cross the Road.
- **District Court Panchkula** Overall the location has the essential amenities needed for pedestrian's shade from sun, a good width of footpath, etc. But no Sitting Area is Present for Pedestrians.
- **Rally Chowk to 11/15 Chowk** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Sector-15** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Budanpur Road** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc. But the footpath Surface is in Deteriorated condition.
- **Road Dividing Sector-12 & Sector-11** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Pashuram Chowk to BEL Factory Intersection** Overall the location has all the amenities needed for pedestrian's shade from sun, sitting area for pedestrians a good width of footpath, etc.
- **Industrial Area Road** It is the major industrial area road. The main Problem is that the essential need of the pedestrian i.e. the Sidewalk is not present at one side which directly affects the comfort of Pedestrians & also no Crosswalks are provided for the crossing of pedestrians.
- **Sector-20 Market Road** It is the main interchange point for pedestrians going towards Pinjore or Shimla Highway. The main Problem is that the essential need of the pedestrian i.e. the Sidewalk are not are not present.

CHAPTER 8

8.1 COMPARISON OF RESULTS OF LOS VALUES

Table 8.1 Comparisons of LOS on the bases of HCM, INDO-HCM and Walkability Scores

Sr. No.	CORRIDOR NAME	CORRIDOR LOCATIONS	HCM LOS	INDO-HCM LOS	PLOS RATING BASED ON PLOS SCORE	COMMENTS
1.	Road in front of Hansraj Public School, Sector-6	Road in front of Hansraj Public School, Sector-6	A/B	B	A	The corridor location has a good PLOS as all the results are almost similar and fall into the same category
2.	Sector-7 Market Road	Road opposite Sector-7 Market	B/C	C	B	The results fall into B and C category which means that there is sometimes occasional and sometime frequent need to adjust their path to avoid conflicts
3.	Chandigarh-Panchkula Road	Road opposite MDC Market	B/C	B	B	The results fall into B and C category which means that there is sometimes

						occasional and sometime frequent need to adjust their path to avoid conflicts
4.	Budanpur Road	Labour Chowk to Agrasen Chowk	A/B	B	C	The results are very much contradictory, the reason could be high variotions in pedestrian volume peak hours
5.	Road Dividing Sector-12 & Sector-11	Road Dividing Sector-12 & Sector-11	A	A	B	The corridor location has a good PLOS as all the results are almost similar and fall into the same category
6.	Nada Sahib Road	Midblock Location 300m away from Indian Express Roundabout towards Bella Vista Roundabout	B/C	C	C	The results fall into B and C category which means that there is sometimes occasional and sometime frequent need to adjust their path to avoid conflicts
7.	Mahespur Road	Bus Stand & Sector-10 dividing Road	A/B	A	C	The corridor location has a good PLOS as all the results are almost

						similar and fall into the same category

- **Road in Front of Hansraj Public School, Sector-6** As it can be seen from Table 8.1 that the results from HCM 2010 & INDO-HCM 2017 are almost the same that are obtained from Pedestrians Perception.
- **Sector-7 Market Road** As it can be seen from Table 8.1 that the results from HCM 2010, INDO-HCM 2017 & PLOS Rating fall into LOS B and LOS C which can be related like depending upon the pedestrian volume results vary.
- **Chandigarh- Panchkula Road** As it can be seen from Table 8.1 that the results from HCM 2010, INDO-HCM 2017 & PLOS Rating are almost similar.
- **Budanpur Road** As it can be seen from Table 8.1 that the results from HCM 2010 & INDO-HCM 2017 totally contradict with the results obtained from PLOS Rating which could be because sometimes things vary at ground reality.
- **Road Dividing Sector-12 & Sector-11** As it can be seen from Table 8.1 that the results from HCM 2010 & INDO-HCM 2017 are exactly the same but the results obtained from PLOS Rating contradict to some extent.
- **Nada Sahib Road** As it can be seen from Table 8.1 that the results from HCM 2010, INDO-HCM 2017 & PLOS Rating are almost similar and fall into the same category.
- **Mahespur Road** As it can be seen from Table 8.1 that the results from HCM 2010 & INDO-HCM 2017 are almost similar but they totally contradict with the results obtained from PLOS Rating which could be because pedestrians are not satisfied with the facilities provided.

8.2 REDESIGN OF SIDEWALK

As per the results evaluated by HCM 2010 & INDO-HCM 2017, LOS of some sections need to be improved, for this improvement we need to redesign the sidewalk for the future needs and providing a better walking space for the pedestrians. As it was not possible to redesign all the segments so the segment with the most pedestrian count and the problem area as per the pedestrian perception is selected. The location selected for the redesign is Sector 7 Market Road because this location has a commercial & Institutional type land use and it was also observed that also out of all the volume surveys conducted it has the maximum pedestrian count. The Reason for Selection of this location for Re-design as it was one of the Poorly Performing Corridors in our evaluation. The procedure used for redesign is adapted from INDO-HCM 2017. The detailed changes are given below:

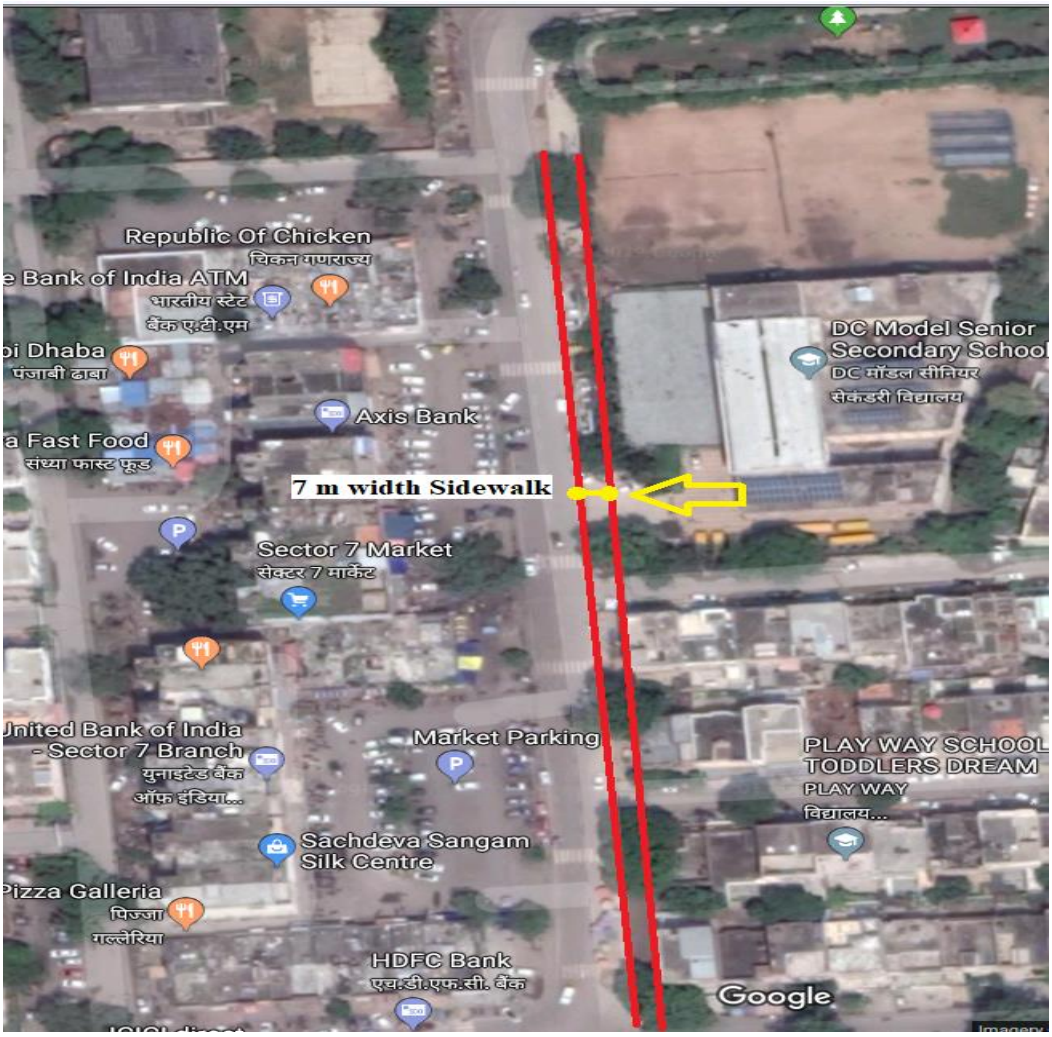

Figure 8.1 Satellite Map of Sector-7 Market Road Highlighting the Sidewalk

Pre- Redesign Dimensions

Width of Sidewalk = 7m

Width of Encroachment = 5.5m

Effective Width of Sidewalk = 1.5m

Max 15-min Peak Flow Rate = 430

Population Projection for 2031

Current Population of Panchkula (2011, Census) = 5,61,293

Projected Population of Panchkula by 2021 (Estimated by Linear Population Projection) = 6,73,552

Projected Population of Panchkula by 2031 (Estimated by Linear Population Projection) = 8,08,263

Projected Max 15-min Peak Flow rate by 2031 (Estimated with respect to Projected Population) = 516

So, for the redesign according to IRC 103-2012 the minimum adaptable width for these types of commercial areas is 4m.

Basically, the effective width of footpath for the redesign should be taken as 4m.

Determination of Peak Flow Value:

$$Q_p = \frac{516}{15 \times 4}$$

$$Q_p = 8.6 \text{ ped/min/m}$$

Determination of Level of Service:

Referring to LOS Table 6.1 As per INDO-HCM 2017

LOS corresponding to Q_p = 8.6 ped/min/m is **'A'** which was previously obtained 'C'

Suggestions for the improvement of LOS of Sidewalk

- For increasing the footpath width there would be a need to remove the encroachment of Vendor shops.
- A Proper Vendors Space could be allotted for the existing vendors and they shall be fined if they cover space more than that.
- It was observed that in peak hours vehicles are parked on the sidewalks which interrupt the path of pedestrian and force them to change their direction again and again causing inconvenience.
- More parking space can be allotted for the parking of vehicles based on their demand in either off street location or Multi-Level Parking can also be considered in future.

Table 8.2 Redesign of Sector 7 Market Road Sidewalk

PARAMETERS	BASE SCENARIO	RE-DESIGN
Width of Sidewalk	7m	7m
Effective width of Sidewalk	1.5m	4m
Lane Width	12.5m	12.5m
Encroachments on Sidewalk	Vendor Shops	Allotted Particular Space
LOS	C (2011)	A (2031)

CHAPTER 9

RECOMMENDATIONS

Pedestrian Safety is a Concern for Urban Transportation Planners in Developing Countries like India as little Provisions is there for Pedestrian Base Infrastructure Planning in Indian Urban Development Plans.

There are Several key Infrastructural facilities which are Necessity to provide a smooth & Safe Walking Experience which should be incorporated in urban areas. The Pedestrian Safety is a highly Compromised Parameter in several Indian Urban areas. At the Research, Academia & Government Level, several guidelines and recommendations have been in time and again issued to Urban Municipal Corporation in order to make sure these facilities & Infrastructure are provided in order to make Pedestrians walking a comfortable & Convenient Experience. Following are some Recommendations from Global Best Practices that can be implemented.

1. Right of way: As the term specifies a proper right way should be designed for the pedestrians which could give them a separate path so that they could feel more secure while walking. Implementation of Guard Rails could also help them to feel safe and also restrict the parking of vehicles on the sidewalk.

2. Vehicle Volume: PLOS has a very important and significant relation with the vehicle volume. At any intersection or roundabout wherever there is interaction between the pedestrians and vehicles there is always a conflict between pedestrian and vehicular movement. The conflicts change the pedestrian's perception in regard to safety comfort and security.

3. Vehicle Speed: The intersection which is unsignalized pedestrians find it very difficult to cross the road for that they need to find a gap in the movement of vehicles. But as the speed of vehicle normally increases at crosswalk which put pedestrians to a greater risk of

accidents. Hence the speed of vehicle at crosswalks should be organised in such a way that it would not affect the movement of pedestrians, as it would directly affect the PLOS.

Figure 9.1 Showing Speed Limit for Vehicles

4. Carriageway Width: The carriageway width directly affects the LOS as increase in the carriageway width makes it a longer distance for the pedestrians to cross, which would be riskier as pedestrians will encounter with a greater number of vehicles i.e. more risks of accidents. Hence the carriageway width should be designed carefully in respect to the pedestrians crossing at the crosswalk at intersections and roundabouts.

Figure 9.2 Showing Wider Carriageway Width

5. Pedestrian Refuge: It is a very important part of design as it affects the LOS in a positive way. Pedestrian Refuge also acts like a median. It not only proves a safe crossing but also facilitates a two-step crossing. The pedestrians need to look for vehicle in one direction at a time, which effects on the comfort and security of the pedestrians.

Figure 9.3 Showing Pedestrian Refuge

6. Crosswalk Marking Condition: The crosswalk marking condition highly affects the pedestrians, as soon as pedestrian approaches towards the zebra crossing, they have a right of way over the vehicular traffic. Also, a well-marked crosswalk attracts the pedestrians, otherwise crossing at random location could risk the life of pedestrians as well as others. Sometimes due to any reason the crosswalk is not visible properly or a faded which give the motorised of non-stopping at the particular mark and affects the crossing of pedestrians at the crosswalks. It also directly affects the PLOS**.**

Figure 9.4 Showing Faded Marking Conditions

Figure 9.5 Showing Ideal Crosswalk Marking Condition

7. Crosswalk Surface Condition: The surface condition of the crosswalk includes a levelled, smooth and slip resistant surface which is not in a deteriorated condition and more comfortable is preferred by pedestrians. Hence, it affects the LOS in a very influential way, good surface condition crosswalk is normally preferred by pedestrians than poor & non-uniform surface condition.

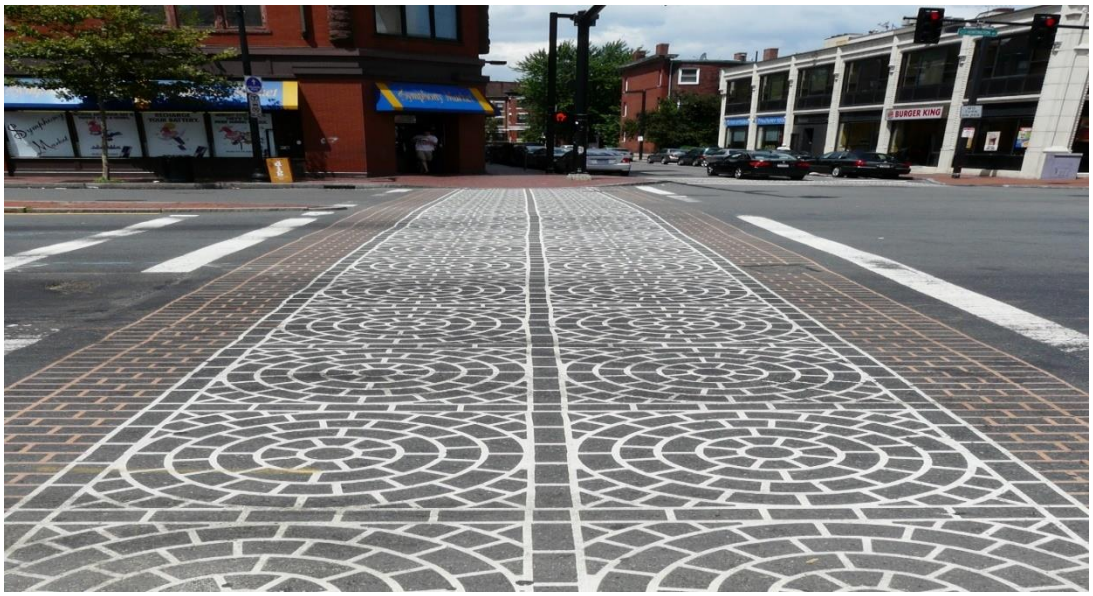

Figure 9.6 Showing Texture of Crosswalk Surface

Figure 9.7 Showing Rainbow Shade Crosswalk Surface

8. Lighting Condition at Crosswalk: Crosswalk area with a good lightening condition gives motorist a proper visibility during night time in regard to crossing pedestrians. Thus, a well-lit crosswalk area enhances safety of pedestrians and affects the PLOS.

Figure 9.8 Showing ideal lightning condition at crosswalk

9. Climate Based Solution: The walking environment should have attractions which should influence the pedestrians to walk on it. Attraction like green cover, shade of tress, advertisements, etc. have a good effect on pedestrians. Shade of trees allow the pedestrians to walk in the day time also. Landscape strip can also pe provided which attracts the pedestrian towards the sidewalk.

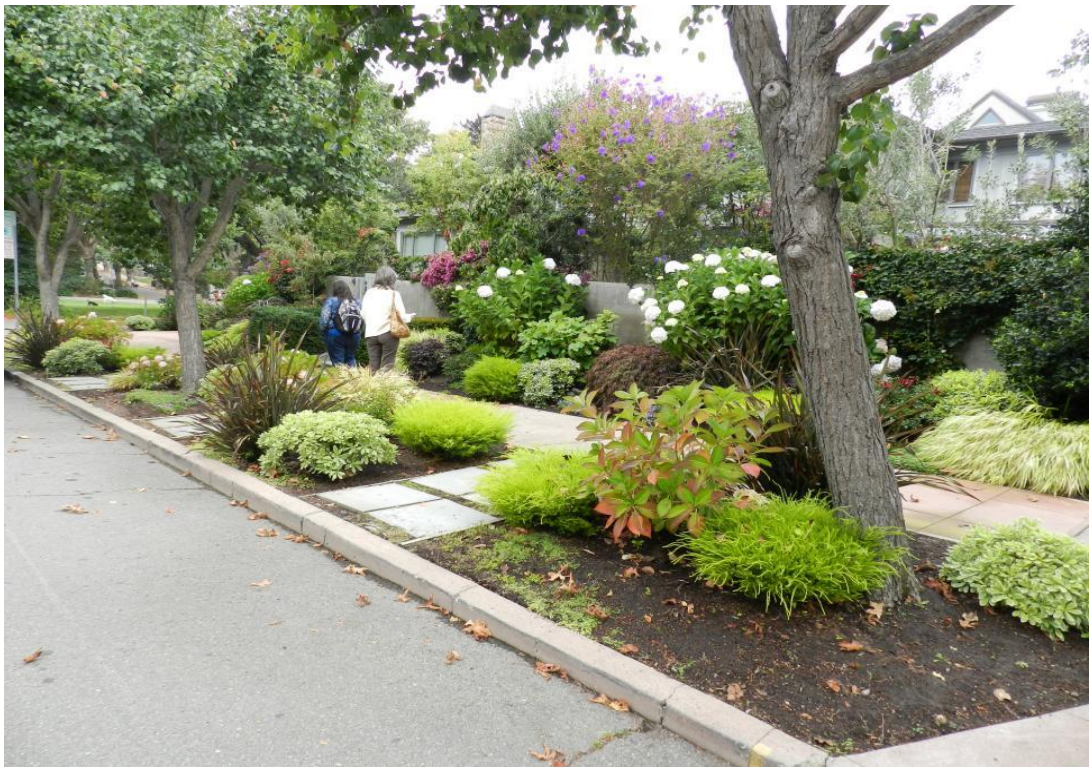

Figure 9.9 Showing walking environment adjacent to sidewalks

Abundance of trees & Green cover will encourage Pedestrian to use sidewalk in a Tropically hot country like India

Figure 9.10 Showing the landscaping near the residential area

Figure 9.11 Showing How to Make the Pedestrian Walking Area More Attractive

10. Roadway Geometry: The roadway geometry directly affects the Pedestrian LOS. It should be designed in such a way that the pedestrian does not have to cross a single lane in two parts the width of the carriageway should not be too longer that pedestrians can't cross it in one go. It should also have zebra crossing and all the markings needed for the pedestrian safety that ensures pedestrians a great comfort and security from the motorized.

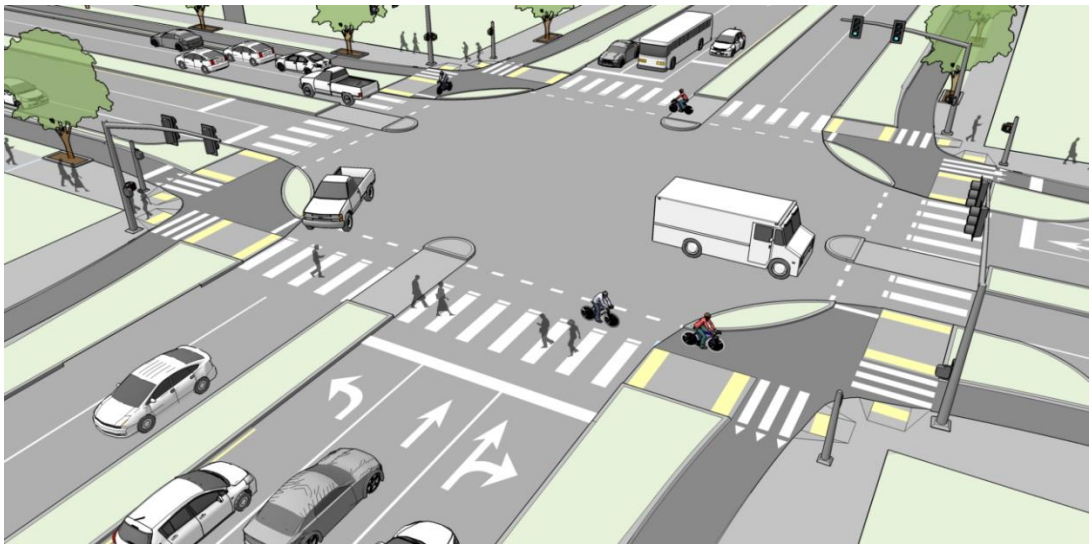

Figure 9.12 Showing the roadway Geometry and pedestrians crossing

11. Pedestrian Behavior: The behavior is a very contradictory thing, pedestrian is full-fledged mode of non- motorized transportation, if not proper crosswalks or sidewalks with all the facilities and amenities are provided to the pedestrians, they are free to walk in random directions and cross the street at random locations. So, providing essential facilities to the pedestrians is a must to avoid road accidents and put their life and other in danger.

12. Turning Traffic (Left & Right): The turning movement of traffic is to be decided with respect to the pedestrians. As on an intersection whether it would be signalized or a non-signalized intersection the turning of the traffic should be designed keeping in mind the pattern of the crossing of the pedestrians at the crosswalk.

12. Signal type: The signal type should be organized not only for the motorized but also for the non-motorized. For the safety and security of pedestrian's signal should be designed for the pedestrians which give them a priority over the motorized. Instead puffin signal facilities should also be designed for the pedestrians. This could reduce they delay at the crosswalk faced by the pedestrians and would affect the LOS in a positive way.

13. Signal phasing & Timing features: Signal Phasing can be automated to sense the Pedestrian Platoon over an area bed through sensors & allow Pedestrians to Phase through.

Figure 9.13 Showing Pedestrians crossing by Signal

14. Interrupted Pedestrians facilities: Due to encroachments & other unorganized mushroom growth of street vendors, the pedestrian sidewalks result in reduced effective width. These Encroachments should be regulated or removed as per the city Pedestrian Policy

Figure 9.14 Showing Encroachments on Sidewalks

Figure 9.15 Showing Vendor Shops on Sidewalks

CHAPTER 10

10.1 CONCLUSION

The basic aim of the current research is to evaluate the current scenario of walkability in the selected urban area of Panchkula City. Various Survey Methods like Inventory Survey, Volume Count, Pedestrian Perception Questionnaire Survey were carried out in order to study the Pedestrian Walkability Scenario in The Panchkula Region

Further, Detailed Literature Review & Detailed Study of Global Manual HCM - 2010(USA) & INDO-HCM (2017) was done to understand the methodology for detailed evaluation of LOS metrices for the region

The Main Conclusion that can be drawn from this research work are

- Around 51% people who prefer to walk are in the 20-40 Age Group.
- The Income group of majorities of Pedestrians was 5000-35000/- Rupees.
- 63% of Pedestrian travel through walk mode once on a Daily basis.
- 64% of People who walk in Panchkula area are walking Less than 500 meters.
- The Major reasons reported by Pedestrians to not to walk were Discontinuous Surfaces, Safety issues, Lack of footpath facility, Encroachments & not a great Walking Environment.
- Maximum Pedestrian Volume was 430 Pedestrians Per 15 minutes at Sector-7 Market.
- Least Pedestrian Count was 73 Pedestrian per 15-minute at Dividing Road of Sector-12 & Sector-11.
- The LOS Values from HCM was obtained A for Road Dividing Sector-12 & Sector-11.
- The Contradictory LOS Values from HCM was obtained A/B for Road in front of Hansraj Public School, Sector-6, Budanpur Road and Mahespur Road.
- The Contradictory LOS Values from HCM was obtained B/C for Sector-7 Market Road, Chandigarh-Panchkula Road and Nada Sahib Road.
- As per INDO-HCM LOS A was obtained from Dividing Road of Sector-12 and Sector-11 and Mahespur Road.

- As per INDO-HCM LOS B was obtained from Road in front of Hansraj Public School, Sector-6, Chandigarh-Panchkula Road and Budanpur Road.
- As per INDO-HCM LOS B was obtained from Sector-7 Market Road and Nada Sahib Road.
- The LOS Values for Location Road in front of Hansraj Public School, Sector-6 and Pashuram Chowk to BEL Factory Intersection was obtained LOS A on the Basis of Pedestrians Perception.
- The LOS Values for Location Sector-7 Market Road, Chandigarh-Panchkula Road, Sector-9 Market Road, District Court Panchkula, Rally Chowk to 11/15 Chowk, Sector-15 Road, Dividing Road of Sector-12 and Sector-11 and Sector-20 Market Road was obtained LOS B on the Basis of Pedestrians Perception.
- The LOS Values for Location Indian Express Roundabout, Tank Chowk, Sector-6 Market Road, Nada Sahib Road, Bella Vista Roundabout to Bus Stand Roundabout, Mahespur Road, Housing Board Chowk, Mahespur Road, BEL Factory Road, Old Panchkula Trisection, Majri Chowk, Budanpur Road and Industrial Area Road was obtained LOS C on the Basis of Pedestrian Perception.
- The Sidewalk for Sector-7 Market Road was redesigned from LOS C to LOS A.
- Reason proposed for the enhancement of LOS were removal of Vendor Shops (Encroachments), providing a proper vendor space to the existing vendors and providing guard rails to stop parking of vehicles on sidewalks.

10.2 SCOPE FOR FUTURE WORK

- To Evaluate Pedestrian LOS for Various tiers of Urban Cities in India. Example Metro Cities, Tier II Cities.
- To Explore other methods of Pedestrian LOS Evaluation for Indian Cities.
- Simulation Procedures can be explored to evaluate the effects changes in Parameters of the Geometry & Infrastructure installation.
- Pedestrian Los Parameters can be subdivided in further detail & can be made more comprehensively to accommodate microscopically affecting calibrations.

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Manuals/ Guidelines/ Project Reports

- Census 2011 Report Panchkula
- Centre For Disease Control Walking Data
- Highway Capacity Manual (HCM) 2010
- Indian Highway Capacity Manual (INDO-HCM 2017)
- The Shimla Road Users and Pedestrians (Public Safety and Convenience) Act, 2007
- WHO 2013 Report on Road Safety
- WHO Report on Pedestrians Accidents

ANNEXURE-I

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY, PATIALA

CIVIL ENGINEERING DEPARTMENT

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY (Deemed to be University)

M.TECH THESIS -: Pedestrian Level of Service for the Urban Areas

This study is taken up to evaluate the level of service criteria for the city of Panchkula. It is hereby assumed that the data collected would be utilized for academic purpose only.

Part A: - **Inventory Data Survey** Date: - _____

Time: - _____

INVENTORY DATA SURVEY - DETAILED SURVEY PROFORMA

GENERAL	CORRIDOR NAME: CORRIDOR LOCATION: CORRIDOR LENGTH: CORRIDOR WIDTH: CARRIAGEWAY TYPE: Divided Undivided Divided with Service Lane NUMBER OF LANES IN THE CARRIAGEWAY: 2 4 6 8
MEDIAN	IS THERE ANY MEDIAN PRESENT IN THE AREA? Yes No IF YES, WHETHER THE MEDIAN HAS PLANTATION? Yes No IF YES, WHETHER THE PLANTATION HAS GAPS FOR PEDESTRIAN CROSSING? Yes No POINTS ON THE MEDIAN FROM WHERE PEDESTRIAN CAN CROSS _____m FROM THE STARTING POINT
SIDEWALK	ARE THERE ANY SIDEWALK PRESENT IN THE AREA? Yes No IF YES, WIDTH ON UPSTREAM IS: IF YES, WIDTH ON DOWNSTREAM IS: SIDEWALK SURFACE TYPE IS: CONCRETE PAVED BITUMEN SURFACE PAVERBLOCK MASTIC UNPAVED IS THERE ANY ENCHROACHMENT PRESENT? Yes No IF YES, THEN OF WHAT DENSITY? LOWDENSITY MEDIUM DENSITY HIGH DENSITY ENCHROACHMENT WIDTH: POLE:

	TREE: VENDOR/SHOP:
	LETTER BOX: EFFECTIVE WIDTH: IS THERE ANY TACTILE PAVEMENT FOR PEDESTRIAN PRESENT? Yes No WHETHER SITTING AREA IS PRESENT FOR PEDESTRIAN? Yes No WHETHER DRINKING WATER PRESENT? Yes No WHETHER ADEQUATE SHADE IS AVAILABLE IN WALKING CORRIDOR FOR PEDESTRIAN VERY GOOD SHADE PRESENT AT SOME PLACES NOT VERY DENSE NOT PRESENT AT ALL IS THERE ANY DISABILITY INFRASTRUCTURE PRESENT? Yes No ARE THERE ANY GUARD RAILS PROVIDED ON THE SIDEWALKS? Yes No ARE THERE ANY WHEELCHAIR RAMP PROVIDED FOR THE DISABLED? Yes No ARE THERE ANY GUARD POST PROVIDED TO DISCOURAGE THE PARKING OF VEHICLES ON SIDEWALKS? Yes No
ROAD SAFETY	IS THE CORRIDOR IS HAVING AN INTERSECTION? Yes No IF YES, THEN WHAT TYPE OF INTERSECTION? SIGNALISED NON-SIGNALISED IS THERE ANY ZEBRA CROSSING AVAILABLE? Yes No IS THERE PEDESTRIAN PLATOON AVAILABLE? Yes No IS THERE POTENTIAL FOR VEHICLE & PEDESTRIAN CONFLICT? HIGH MEDIUM LOW IS THERE A SEPARATE BICYCLE PATH PRESENT? Yes No IF YES, THEN WHAT IS THE WIDTH? UPSTREAM: DOWNSTREAM: IS THERE ANY TRAFFIC CLAIMING MEASURE PRESENT? IF YES, THEN WHICH ONE?

ANNEXURE-II

THAPAR INSTITUTE OF ENGINEERING & TECHNOLOGY, PATIALA

CIVIL ENGINEERING DEPARTMENT

M.TECH THESIS -: Pedestrian Level of Service for the Urban Areas

This study is taken up to evaluate the level of service criteria for the city of Panchkula. It is hereby assumed that the data collected would be utilized for academic purpose only.

Part C: - Pedestrian Perception Survey

Date: - _____

Time: -_____

PEDESTRIAN PERCEPTION SURVEY - DETAILED SURVEY PROFORMA

CORRIDOR NAME: -

CORRIDOR LOCATION: -

Age Group	0-9	10-19	20-29	30-39	40-49	50-59
Gender	**MALE**		**FEMALE**			
Monthly Income (Rs.)	<5000	5001-15000	15001-35000	35001-50000	50001-75000	>75000
Profession of Respondents	Student	Service	Housewife	Business	Retired	Others
Frequency of Respondents	Daily	Weekly	Monthly	Occasionally		
Frequency of Trips in a day	Once	Twice	Thrice	Fourth		
Trip Purpose	Education	Office Work	Shopping	Cinema	Personal	Other
Distance of Walk Trip for Pedestrian	>500	501-1000	1001-1500	1501-2000	>2000	
Is the height of side walk adequate?	High	Low	Adequate			
Are there proper lightening facilities available on pedestrian sidewalks?	Yes		No			
Is the walking area for pedestrian clean?	Yes		No			
Are there enough places to sit?	Yes		No			

Are there places to buy food & beverages nearby?	Yes		No			
Is there enough shelter provided from sun & rain?	Yes		No			
Is it a convenient & comfortable way to travel?	Yes		No			
Do you feel safe in the day?	Yes		No			
Do you feel safe in the night?	Yes		No			
Reason for not walking on the sidewalks?						
Walking Environment	Encroachment	Comfort	Continuity	Safety	Footpath	Surface
Pedestrian Response Analysis						
Footpath Surface	Immaterial	Least Important	Important	Very Important	Most Important	
Footpath Width	Immaterial	Least Important	Important	Very Important	Most Important	
Obstruction	Immaterial	Least Important	Important	Very Important	Most Important	
Potential of Conflict with Vehicle	Immaterial	Least Important	Important	Very Important	Most Important	
Continuity	Immaterial	Least Important	Important	Very Important	Most Important	
Encroachment	Immaterial	Least Important	Important	Very Important	Most Important	
Availability of crossing facilities	Immaterial	Least Important	Important	Very Important	Most Important	
Security	Immaterial	Least Important	Important	Very Important	Most Important	
Comfort	Immaterial	Least Important	Important	Very Important	Most Important	
Walk Environment	Immaterial	Least Important	Important	Very Important	Most Important	
Response Rating of Pedestrian for Satisfaction on Various Sidewalk Attributes						
Footpath Surface	Poor	Satisfactory	Good	Very good	Excellent	
Footpath Width	Poor	Satisfactory	Good	Very good	Excellent	
Obstruction	Poor	Satisfactory	Good	Very good	Excellent	
Potential of Conflict with Vehicle	Poor	Satisfactory	Good	Very good	Excellent	
Continuity	Poor	Satisfactory	Good	Very good	Excellent	
Encroachment	Poor	Satisfactory	Good	Very good	Excellent	
Availability of crossing facilities	Poor	Satisfactory	Good	Very good	Excellent	
Security	Poor	Satisfactory	Good	Very good	Excellent	
Comfort	Poor	Satisfactory	Good	Very good	Excellent	
Walk environment	Poor	Satisfactory	Good	Very good	Excellent	
How risky do you feel to walk?	Very Risky	Not so Risky	No Risky	Not Risky at All		
How does it feel to cross the street?	Very Unsafe	Unsafe	Not Unsafe at All	Safe	Very Safe	
Rate your experience out of 10 _____						
What prevents you from walking:						

ANNEXURE-III

PEDESTRIAN VOLUME SURVEY		
CORRIDOR LOCATION		CORRIDOR NAME
TIME		
	COUNT	

EVALUATING THE PEDESTRIAN LEVEL OF SERVICE FOR THE CITY OF PANCHKULA

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