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To cite this article: Harsimran Kaur *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **775** 012004

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# Qualitative Evaluation of Pedestrian Facilities using the PLOS Model

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**Abstract.** This paper evaluates the efficiency of existing pedestrian facilities in Ludhiana, Punjab (India) using the Pedestrian Level of Service (PLOS) model. Assessment of the PLOS is essential in analysing the factors that lead to pedestrian congestion in the city. The study focuses on the major junctions and the city's core and is limited to Ludhiana considering the population projection and the proposed Land use. The paper is an exploratory study that collects and analyses data from primary and secondary sources. Primary studies included on-site observations and surveys such as user evaluation survey and pedestrian volume count, interviews, and discussions with domain experts and residents on pedestrian facilities' problems. The approach is intended to assist Urban Planners and Transportation Engineers in making informed decisions when designing road cross-sections that satisfy pedestrians' basic need and assess and prioritise the needs of existing roadways for sidewalk retrofit development. Further, this study can be used as a benchmark for pedestrianizing the other congested streets and intersections.

## 1. Introduction

Rapid urbanisation and economic growth have led to considerable increases in urban transport crises in many Asian cities [1-3]. Asian cities have long been known for being pedestrian-friendly. However, pedestrian and public transportation services have received little coverage [4]. Walking is one of the most ancient and fundamental ways of transportation. Every day, as part of every journey, each of us does it. The quality of pedestrian facilities, roadway conditions, land use patterns, protection, safety, and comfort for walking are all factors to consider.

Moreover, walking has been a sustainable type of transportation with numerous social, environmental and economic benefits for pedestrian and walkable communities [5]. 'Social' improves health, universal mobility, and energised communities; 'environmental' decreases greenhouse effect, energy consumption and more efficient use of land; and 'economic' lower health cost, transport cost, and employee productivity [6].

Pedestrian planning guidelines exist on a small to large scale, from enhancing pedestrian access to a community bus stop to a regional or state-wide master plan. Any forward-thinking society should aim to enhance pedestrian safety and comfort, encouraging people to conduct business and experience the world around them on foot. Organisations that promote walking sow the seeds for improvement by raising consciousness about pedestrian problems and informing others about walking's advantages. A pedestrian plan supports walking as a viable mode of transportation for short trips and recognises its



significance. However, in the planning, architecture, and growth of our cities, it has received little to no consideration. Walking is a minor mode of transportation even from a linear planning perspective, and walkability deserves just a small amount of public support.

Pedestrianisation requires special attention in urban planning, design, and development to address all pedestrians' issues and needs. Therefore, this study attempts to evaluate the efficiency of existing pedestrian facilities using the Pedestrian Level of Service (PLOS) model, thus analysing the factors that lead to pedestrian congestion in the city. The study focuses on the major junctions and the city's core and is limited to Ludhiana considering the population projection and the proposed Land use.

## 2. Literature Review

Every journey starts and ends with a pedestrian journey to a bus stop, office, or crossing a parking lot to enter the vehicle. A pedestrian is described as "any person who is on foot or who is using a wheelchair, a power wheelchair, or a means of conveyance powered by human power other than a bicycle", according to Washington state law [7]. Some people walk by their own choice even if they have an alternative mode of transport. 'Pedestrians' are the people who are on foot or in a wheelchair. A bicycle person is not considered a pedestrian. However, a person pushing the bicycle is considered a pedestrian. Some people are 'Captive pedestrian' who cannot afford any transport mode or access to any transport. Pedestrians are divided into four categories: Commuters (travel from one location to another, such as from suburb to city); Shoppers (looks for ease of access, attractive shopping area, and routes); Disabled (requires clearly defined easy access and careful attention in design); and Children (requires clearly defined easy access and careful attention in design) (requires a high level of segregation from motorised vehicles).

Walking is a basic form of accessibility that can be used alone or in combination with other modes. Walking offers essential mobility, and most people depend on it to get to places like medical facilities, workplaces, and schools [8]. Consumer transportation costs are affected by walkability, and good walking conditions allow customers to save money on vehicle expenses. Low-density construction with much land paved for roads and parking has many economic, social, and environmental costs. However, it also saves money by reducing the amount of land needed for transportation. It also improves the livability of the community by ensuring protection, health, and local environmental quality. Walkability may also aid in achieving multiple equity goals, such as equitable allocation of public services to non-drivers and financial savings.

### 2.1. Factors affecting the demand pedestrian facilities

The nature of the local community, car ownership, local land use activities, quality of provision, safety and security (freedom from conflict with a motor vehicle, as a minimal threat from personal attack and the risk of tripping from the uneven surface), all affect the demand for pedestrian facilities. Quick trips are better made by walking. As a result, the distance between origin and destination is a significant determinant of demand, particularly among the young and elderly.

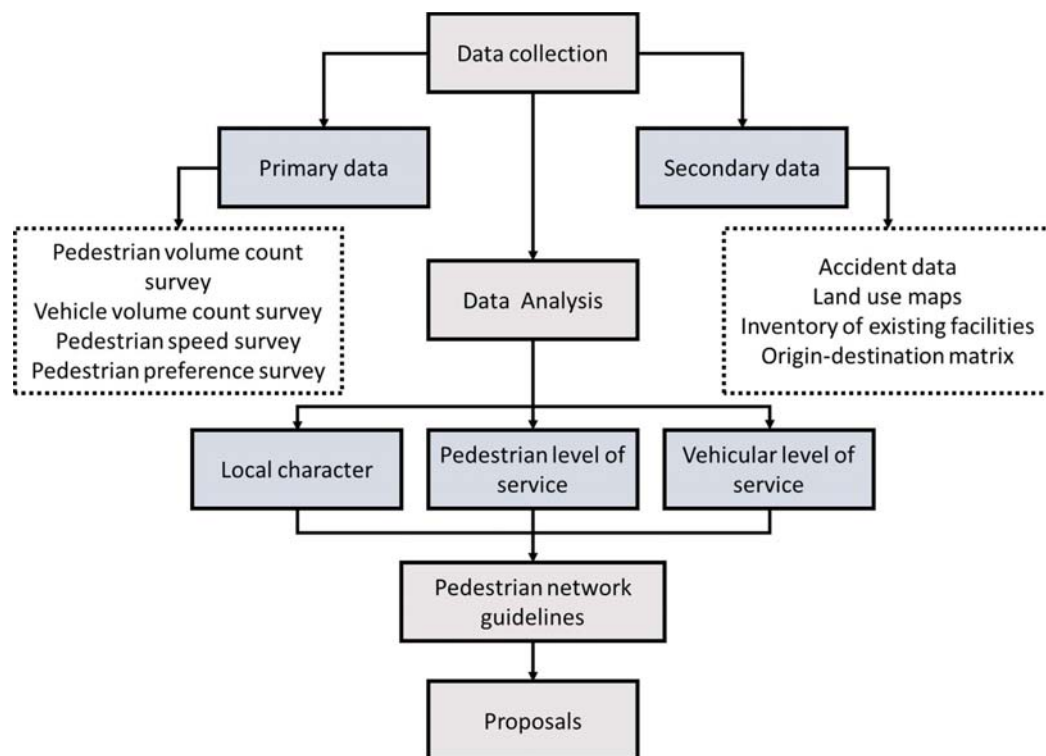
### 2.2. Pedestrian facility assessment models

Three existing pedestrian facility assessment models are studied for the review, namely HCM 2000, Australian model, and PLOS model [9]. A review highlighting a critical difference in comparing the different pedestrian assessment methodologies relies on traffic flow (motorised and non-motorised). The HCM 2000 only recognises non-motorised flow [10], while the Australian approach included specific non-motorised characteristics, but the Trip efficiency method ignores all traffic [11]. Other than another traffic factor level, the Australian system's inclusion of traffic factors did not affect the scores. The system appears to be unaffected by traffic-related factors.

The above comparison between different Pedestrian facilities assessment models shows that it is possible to receive multiple LOS ratings for the same sidewalks under the same condition by using different models. It is also recommended that the combined model be developed to address the significant factors that affect Pedestrians' quality and flow.

### 3. Materials and methods

The approach involves data collection and interpretation from both primary and secondary sources. Secondary sources included research papers, journals, books, websites about pedestrian facilities, current models, and local organisations like the Ludhiana Development Corporation, Planning Zones of Ludhiana, and Traffic Police Cell. On-site observations and surveys, such as the user assessment survey and pedestrian volume count, interviews, and conversations with domain experts and residents on pedestrian facility issues, were used as primary sources to understand their perspectives and interests better. A three-stage analysis is conducted to evaluate the local character, pedestrian LOS, and vehicular LOS in the study area (see Figure 1).



**Figure 1:** Steps involved in the study.

#### 3.1. Study area

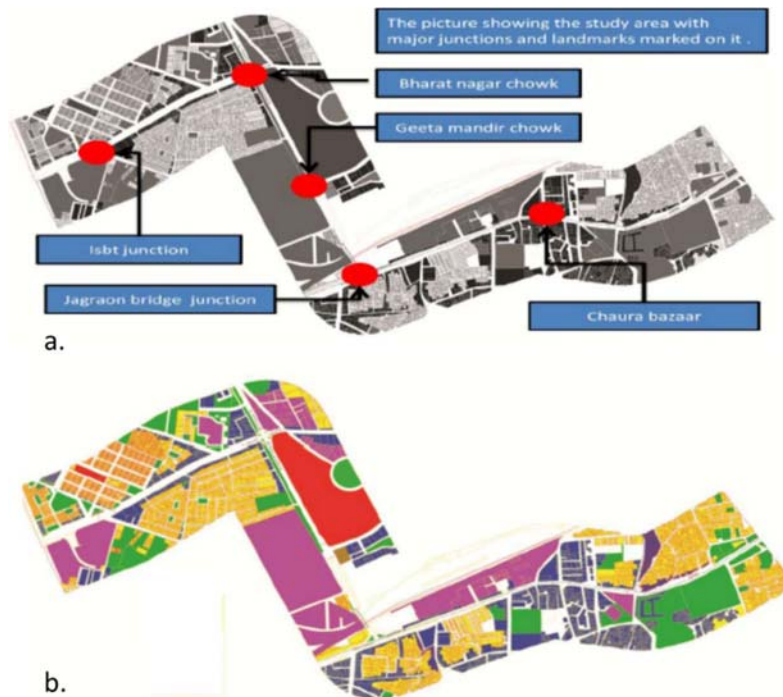
To evaluate the efficiency of existing pedestrian facilities in India, five road segments and two major junctions were selected in Ludhiana's core area with high pedestrian demand and heavy traffic throughout the day. Ludhiana is the largest city in Punjab and is situated north of Delhi, India. Ludhiana is one of India's smart cities, and it is also the most business-friendly city in the country. Ludhiana, also known as India's Manchester, is the country's most industrialised city [12].

Geographically, the city is located at 30.90N latitude and 75.850E longitude (Fig. 1), with an average elevation of 244 meters from mean sea level. The city, spread over 159 sq. km and accommodates more than 16.00 lacs population as of the 2011 census [13].

From Ludhiana's core city, seven road segments and junction areas representing various land uses were chosen. The land use is identified by significant activities happening in those areas. The land use pattern of selected areas is shown in Table 1.



**Figure 2:** Location map of Ludhiana, Punjab.



**Figure 3:** Map showing the a) major nodes/junctions b) the surrounding land use of the chosen stretch

**Table 1:** Classification of road segment based on land uses.

Road Segment \ Land-use type	Area 1 Chaura Bazaar	Area 2 Clock Tower Road	Area 3 Jagraon Bridge	Area 4 Geeta Mandir Chowk	Area 5 Ferozpur Road	Area 6 Bharat Nagar Chowk	Area 7 ISBT Road
Commercial	√	√	√	-	-	-	√
Public cum commercial	-	-	-	√	√	√	

### 3.2. User evaluation survey

User Evaluation Survey was conducted to evaluate the Level of Service of existing pedestrian facilities, thus analysing the factors that contribute to pedestrian congestion on the sidewalks of Ludhiana. The Surveys were designed to understand the people's perspective on various issues of Pedestrian facilities. The literature study identifies the parameters for inclusion in the User Evaluation (pedestrian) questionnaire. The ten qualitative parameters are Sidewalk Surface, Sidewalk Width, Sidewalk Continuity, Markings & Signage, Proper Signalling, Crossing facilities, Vehicular Conflict, Obstructions, Encroachments, and Safety.

A total of 260 pedestrians were interviewed for this survey. The direct interview form was used for all of the interviews. On a five-point scale, pedestrians were asked to rate the output of each of the parameters. A random sampling strategy was employed to select a respondent from the pedestrian stream. Respondents were asked about their age, sex, income, occupation, the trip's intent, frequency of the trip, and the distance travelled. An effort was made to interview people of different ages, sex, income levels, and occupations. The survey was conducted on weekdays from 8.00 am to 8.00 pm to capture people who use the sidewalk for various reasons. The survey was also conducted on non-working days as the stretch is majorly the market zone that is found crowded on Saturday and Sunday.

### 3.3. Pedestrian volume count surveys

Pedestrian volume count surveys were conducted on the selected seven areas in three slots from 9.00 am to 10.00 pm, 2.00 pm to 3.00 pm and 4.00 pm to 5.00 pm to understand the Pedestrian traffic variation in the morning to the evening peak hours. This survey also helped to analyse the volume, pedestrian group size, walking speed, delay and vehicular pedestrian conflict characteristics.

The purpose of the pedestrian group size analysis is to find out how long it takes pedestrians to cross a street of a certain width in a specified period. A set of observations were made to accumulate pedestrians as they wait for a safe, acceptable traffic stream gap. It is assumed that five pedestrians will walk abreast when a group crosses a road. Many pedestrians entering the roadway to cross were observed. Whether pedestrians were crossing alone or in a group was also observed. The walking speed of the pedestrians along and across the road was calculated. Psychological factors, reaction to traffic composition and trip purpose all contribute to pedestrian speed. The most significant factor that affects is traffic density. As traffic density increases, the walking speed decreases. The average walking speed ranges from 0.64m/sec to 1.33m/sec. The walking speed also depends on the gender of the pedestrian. Either Buildings or electric posts were taken as section start and endpoints depending upon the field conditions. Pedestrian crossing times of these sections were measured with a digital electronic stopwatch for counting the delay experienced by pedestrians. Further, the vehicular pedestrian conflict study was conducted for all the major road segments in the study area.

The survey aimed to identify the significant attractors and generators of Pedestrian traffic in a particular area. The video graphic method has been used for data collection from elevated vantage points. Although data reduction in this method is time-consuming, much precise information can be analysed.

## 4. Results and Discussion

The findings were based on a user evaluation survey, pedestrian volume count survey and PLOS model.

### 4.1. User evaluation survey

The age of the respondent varied from 11 to 70, with a ratio of 1:1 male-female composition. Care also has been taken even to interview physically disabled people. Of the people interviewed, 51% of the trips are shopping trips, 20% for a change of mode, 13 % of trips are work trips, 11% of trips are education trips and 5% of trips for other purposes. 52% of the trips are made by housewives, 23% by students, 15% by a serviceman, 6% by businessman and 4% of trips by others. It is found that 38 % of the women, 26 % of men make the trip once a week, and 26% of women, 22% of men make the daily trip. 36% of women and 32% of men walk a distance of (251-500m) each day, 27% of women and

26% walk a distance of (501-750m), and only 6 % of women and 5% of men walk a distance of 1551-2000m). It can be seen that work trips frequency varies from the whole week. Shopping trip also whole week and change of mode also same. Moreover, it is observed that the change of mode trips is the longest, ranging from 0 – <901, and the other trips are the shortest. People walking for a walk can travel a distance of 151 to even < 901. Shopping trips vary from 151 to 600, and educational trips are mostly 0 to 150m. User evaluation survey details are shown in Figure 4.

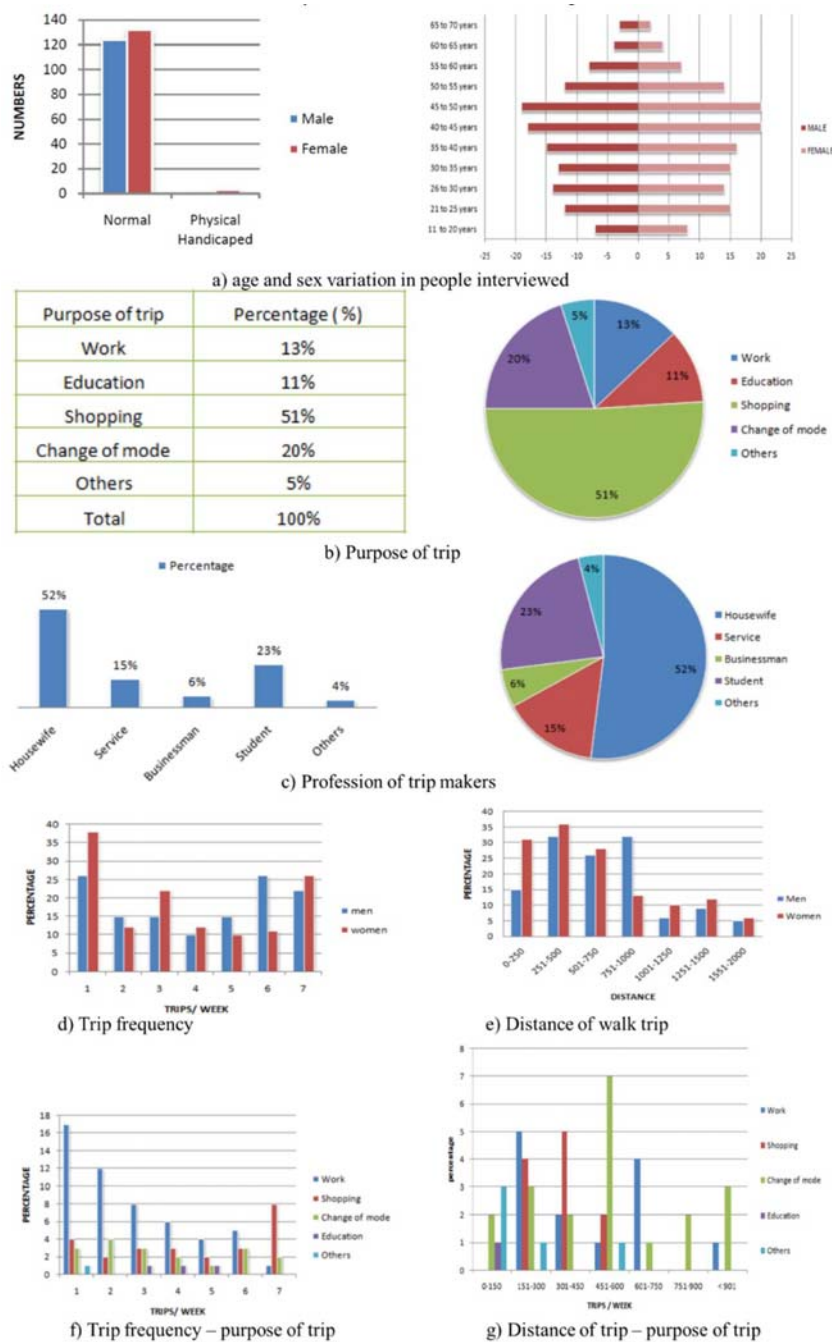


Figure 4: Results of the factors considered in the user evaluation survey. Source: Author.

4.2. Pedestrian volume count survey

It was found that in the commercial area, the walking speed of maximum women is 0.81-1.00 m/sec and 1.01-1.20 m/sec of men. In public cum commercial, the maximum number of women walks at speed 1.01-1.20 m/sec and men at 1.21-1.40 m/sec and at junctions maximum no. of men walks at a speed of 1.41-1.60 and women at 1.21-1.40 m/sec (Figure 5). Figure 6 shows that pedestrian stopping in the middle of the road is frequent (15%) at the junctions.

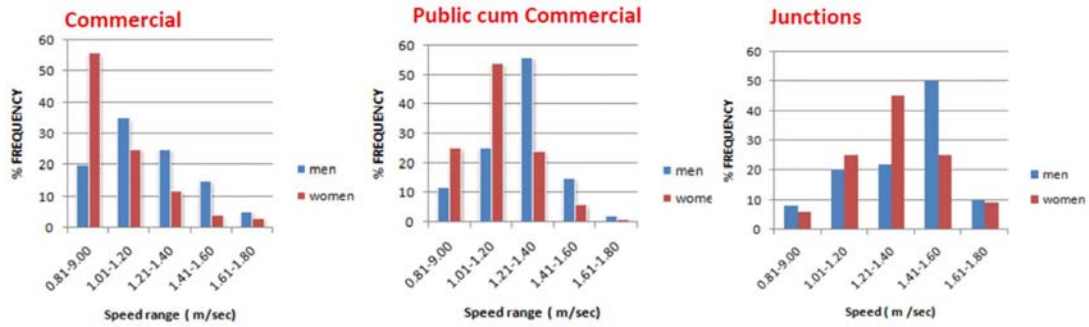


Figure 5: Pedestrian walking speed in the study area. Source: Author.

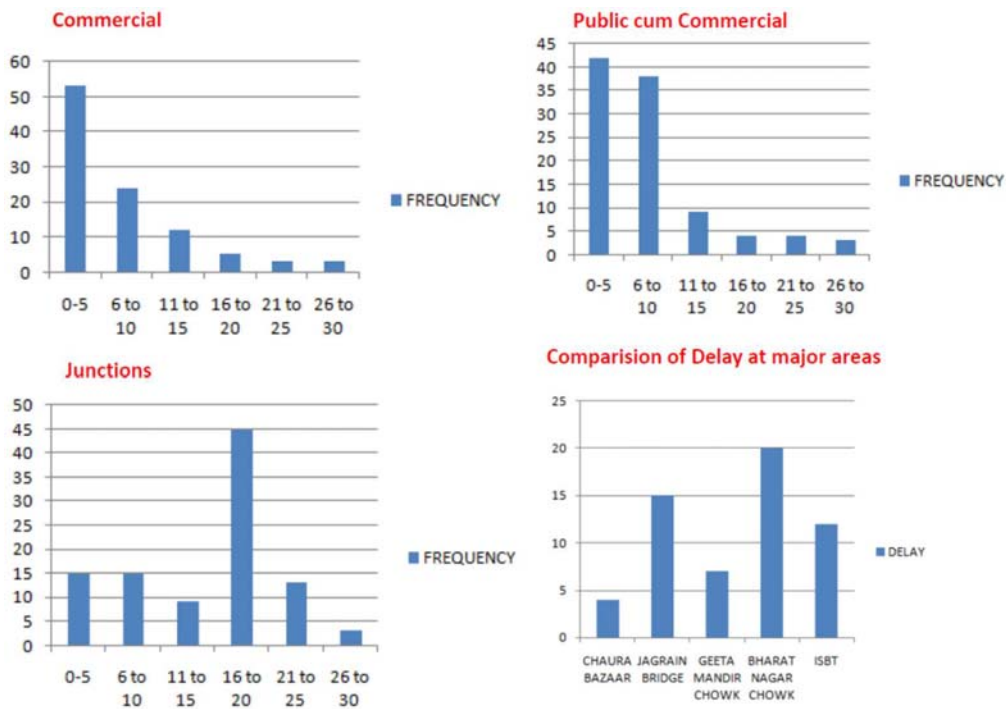


Figure 6: Pedestrian delay in the study area. Source: Author.

The most pedestrian conflicts are pleasure walking and pedestrian stopping in the middle of the road. It can be seen that the commercial area has the highest pedestrian, vehicular conflict closely followed at the junctions (Figure 7), majorly at Bharat Nagar chowk, clock tower road, Jagraon bridge and Chaura bazaar area. Figure 8 shows the pedestrian counts on the seven major study road segments.



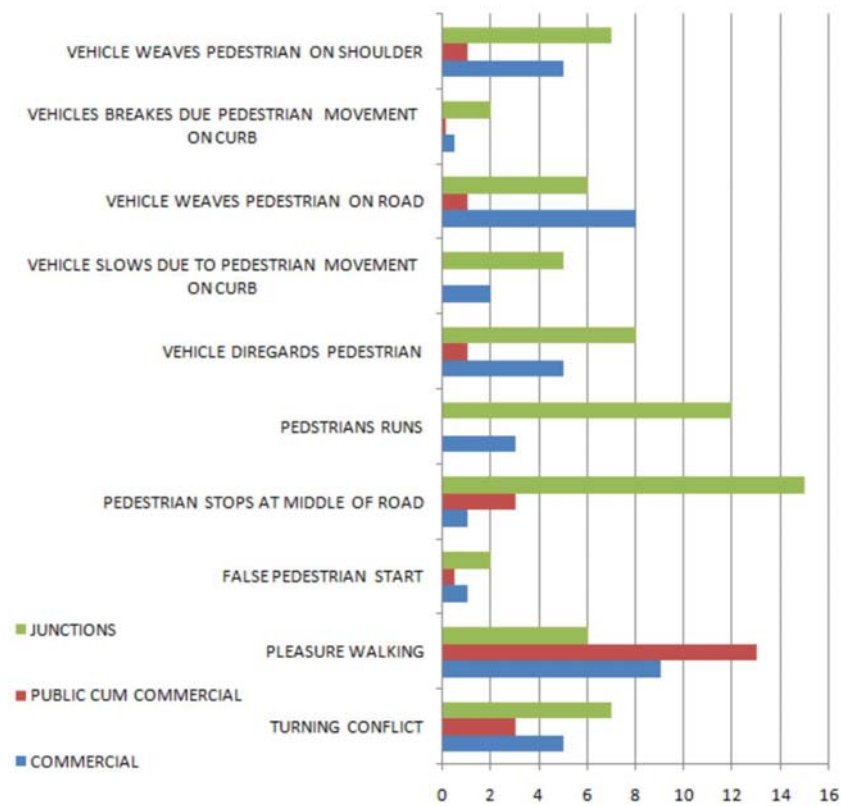


Figure 7: Pedestrian vehicular conflict in the study area. Source: Author.

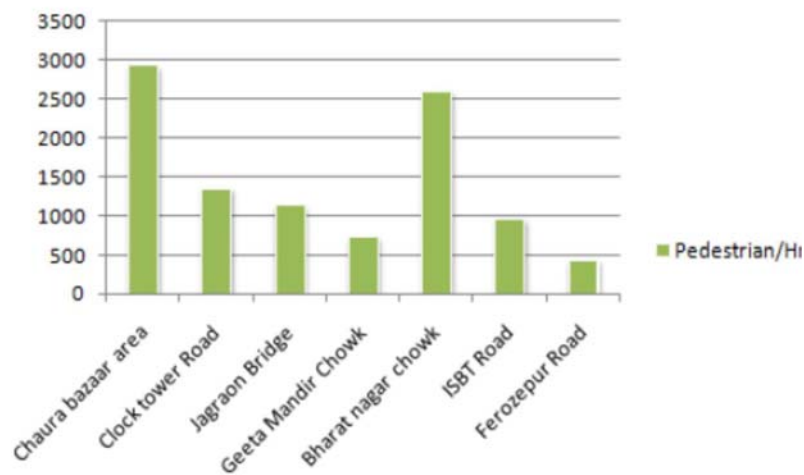


Figure 8: Pedestrian counts in the study area. Source: Author.

As per the user evaluation primary survey in Ludhiana city, preference shows that the foot over bridge is preferred over the subway, and women prefer it more than men. The maximum distance that the pedestrian can walk to use a pedestrian facility varies from 0 to 200m (Figure 9). Figure 10 is showing the pedestrian facilities available in the study area. The only one road segment in the study area is having adequate footpath width, as mentioned in IRC 103-1988 pedestrian facilities [14] (Table 2).

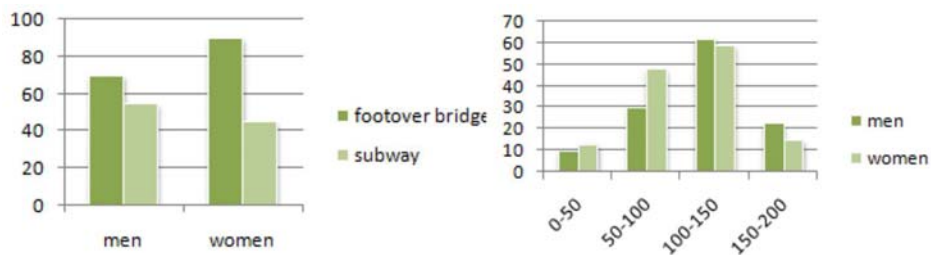


Figure 9: Pedestrian preference in the study area. Source: Author.

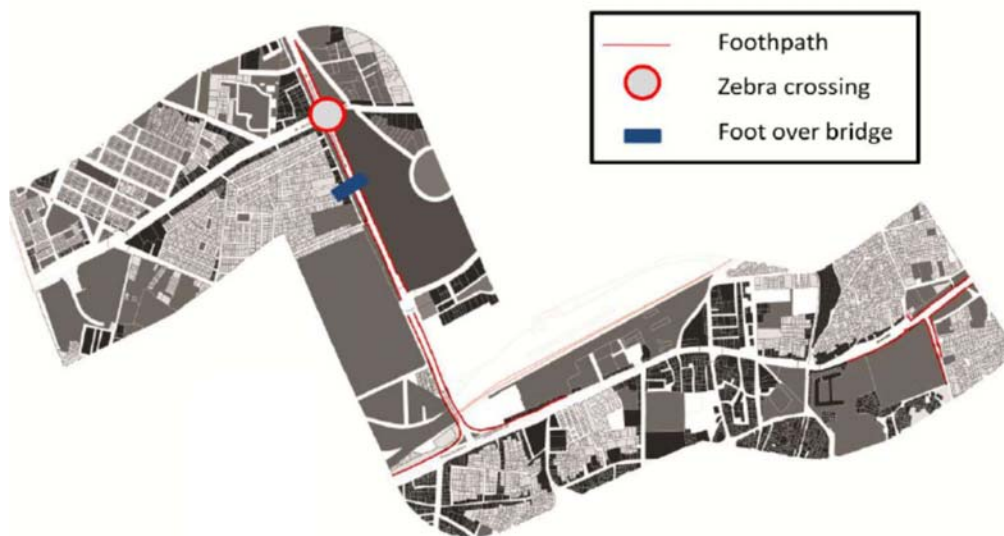


Figure 10: Pedestrian facilities available. Source: Author.

Table 2: Footpath width adequacy check.

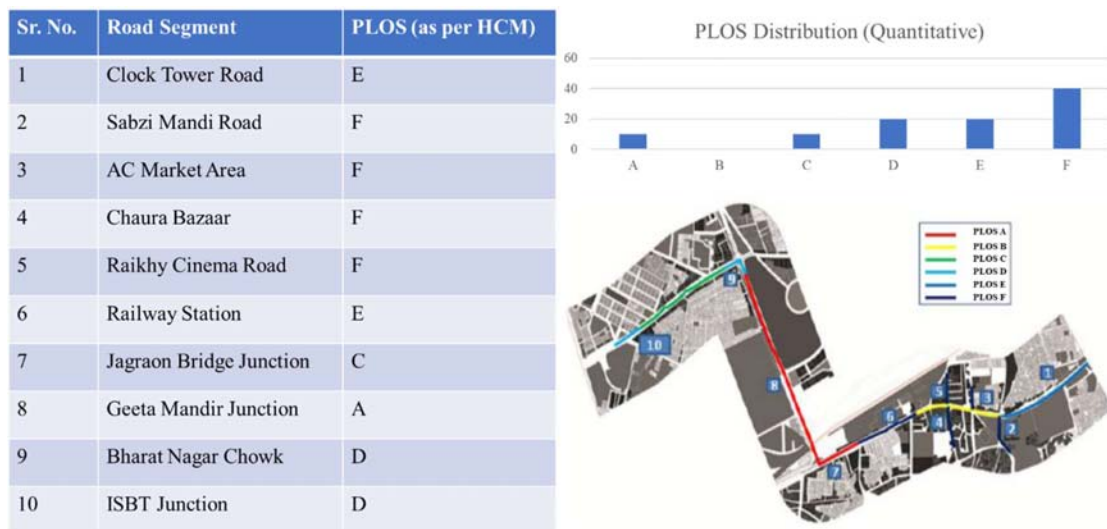
Road section	Peak hour volume	Available footpath width	Required footpath width as per (IRC 103-1988)	Adequate/Inadequate
Chaura Bazaar	2926	0	3	Inadequate
Clock Tower Road	1396	0	2	Inadequate
Jagraon Bridge Road	1132	1.2	2	Inadequate
Ferozpur Road	430	0.6	1.5	Adequate
ISBT Road	936	0	2	Inadequate
Geeta Mandir Chowk	723	1.2	2	Inadequate
Bharat Nagar Chowk	2639	1.2	2	Inadequate

#### 4.3. Pedestrian Level of Service (PLOS)

Comparing the various Pedestrian Level of Service (PLOS) assessment methods performed in the literature study shows that it is possible to receive multiple PLOS ratings for the same sidewalk under the same prevailing conditions, only by using a different method [15].

##### 4.3.1 Pedestrian Level of Service as per HCM manual

The PLOS values for respective sidewalks as per the HCM manual calculations are shown and spatially visualised in Figure 4. It is seen that four sidewalks score 40% (F level of service), and the rest six sidewalks score between 10% to 20% (A to E level of service).



**Figure 11:** PLOS values for respective sidewalks as per the HCM manual for the selected study area.

4.3.2 Pedestrian Level of Service as Per Australian method

This method is based on three types of LOS calculation factors: physical characteristics, location, and user factors. The path’s width, the quality of the sidewalk’s surface, the number of obstructions, crossing opportunities, and support facilities such as signs, markings, and rest areas are all considered physical characteristics (refer to Table 3). Calculations of a road segment that fall in the selected study area are shown in Table 4. It is seen that 40 % of the road segment having the F pedestrian level of service, which differ from PLOS by the HCM manual (refer to Table 5).

**Table 3:** Factors considered as per the Australian model.

Factors	Weight	0 point	1 point	2 point	3 point	4 point
Path width	4	No path	0-1 m	1.1 – 1.5 m	1.6 – 2.0 m	Over 2.1 m
Surface quality	5	Many bumps	Poor quality	Moderate quality	Acceptable quality	Excellent quality
Obstruction (per 200m)	3	Over 21	11 to 20	5 to 10	1 to 4	Zero
Crossing facilities	4	none	Poorly located	Not enough	adequate	Dedicated crossings
Support facilities	2	No-existent	Few and far between	Few and well located	adequate	Many and well located
Connectivity	4	No-existent	poor	reasonable	good	Excellent
Path environment	2	unpleasant	Poor, less than 1m of road	Acceptable with 1m or 2m of road	Reasonable with 2m of road	Pleasant over 3m of road
Potential for conflict	3	Over 25 per km	Poor 16 to 25 km	Moderate 10 to 15 per km	Reasonable 1 to 10 per km	No vehicle conflict
Pedestrian volume	3	Over 250 per day	226 to 250 per day	151 to 225 per day	81 to 150 per day	Less than 80 per day
Security	4	unsafe	poor	reasonable	good	Excellent

**Table 4:** Calculation of the road segment that falls in the study area.

Road segment	Path width	Surface quality	Obstruction (per 100m)	Crossing facilities	Support facilities	connectivity	Path environment	Potential for conflict	Pedestrian volume	Security	Total
Clock Tower Road	2	3	2	0	0	0	1	2	1	1	42
Sabzi Mandi Road	1	2	1	0	0	0	0	1	0	1	23
AC Market Area	0	2	2	0	0	0	0	1	1	1	25
Chaura Bazaar	0	2	3	0	0	0	1	1	0	1	21
Raikhy Cinema Road	0	2	2	0	0	0	1	1	1	2	31
Railway Station	0	2	2	0	0	0	0	1	0	1	22
Jagraon Bridge Junction	2	3	2	0	0	0	1	2	1	2	45
Geeta Mandir Junction	2	2	2	2	0	0	0	1	2	2	45
Bharat Nagar Chowk	2	4	2	2	0	0	1	2	0	1	40
ISBT Junction	0	3	2	0	0	0	1	2	0	1	31

**Table 5:** Final PLOS rating as per the Australian model for the selected study area.

LOS	Rating	No. of locations	Percentage
F	Upto 25	4	40
E	26-30	0	0
D	31-35	2	20
C	36-40	0	0
B	41-45	1	10
A	46 onwards	3	30

The findings are based on on-site surveys conducted in only one city in Northern India, Ludhiana, and can be backed up by comprehensive studies conducted in other regions.

## 5. Conclusion

Pedestrianisation of Asian cities is crucial for maintaining the quality of the natural and built environments and the long-term viability of settlement areas. The study aims to assist urban planners and transportation engineers in making informed decisions when designing road cross-sections that satisfy pedestrians' fundamental need to feel secure and relaxed when walking. It may also assist in evaluating and prioritising the needs for sidewalk retrofit development on existing roadways. However, there is still a broad scope of pedestrianisation in Ludhiana. This study is a step towards exploring the possibilities of pedestrianisation in the city. The study can be used as a benchmark to improve pedestrian facilities in the other congested streets and intersections of similar context.

## Acknowledgements

This paper is based on the master thesis (2014) of Author Paramjit Singh, submitted to IIT Kharagpur, India, under the guidance of Prof. Saikat Paul. The authors are grateful to Prof. Saikat Paul for the guidance, motivation and support.

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