Library Progress International
Vol.42 No.1, January-June 2022: P.259-271

Print version ISSN 0970 1052
Online version ISSN 2320 317X

Original Article

Available online at www.bpasjournals.com

Pedestrian Flow Dynamics Across Urban Land Uses Under Mixed Traffic Conditions

[1]Singh Upendrasingh R, [2]Patil Gaurav Kumar B

[1]Assistant Professor, Civil Engineering, Vishwakarma Government Engineering College, Chandkheda, Gujarat, 382424. us4678@gmail.com
[2]P.G. Student, The M.S.U of Baroda, Vadodara Gujarat, gaurav.civil2015@gmail.com.

How to cite this article: Singh Upendrasingh R, Patil Gaurav Kumar B (2022). Pedestrian Flow Dynamics Across Urban Land Uses Under Mixed Traffic Conditions. *Library Progress International,* 42(1), 259-271

Abstract:
Pedestrians are an important part of urban transportation system. Every trip starts and ends with the walk trip. Still, they have neglected part of system. Data was collected at four different locations based on land used activity namely; industrial, educational and mixed land use of residential and industrial. A time-lapse photography technique was adopted for the data collection for two hours in morning and evening peak hour at selected land use on normal working days. The recorded videos were converted to digital files to analysed walking time and the corresponding pedestrian flow data in the laboratory with the aid of a computer. In addition, due to lack of dedicated sidewalk, pedestrian flow data such as speed, flow, density is extracted through virtual trap marked on the carriageway. Further data was analysed for further analysis and development of flow-density relationship.
From the study, it is observed that the male pedestrian dominant at industrial and mixed land use whereas, female was overriding at educational area during observation period. It is also noted that mean walking speed of pedestrian is found to be higher in morning at mix land use and industrial zone compared to the educational area. Study results also revealed that at educational land use walking speed of the children found to be lowest of 0.85m/s. Findings of the present study gives interesting results compared with those given in literature. The pedestrian walking speed is observed to be higher than that reported for other parts of India as well Western countries. It is also noted that at a given flow rate observed density found to be higher at mixed land use. Empirical results and findings highlighted in the study can be useful to understand pedestrian flow behaviour and can also be useful in designing of pedestrian facility base on land use.
Keywords: Pedestrian flow, Land Use, Density, Virtual trap.

1. Introduction

Industrialization plays an important role in augmentation of the city and its infrastructural development. For better prospective of livelihood, people migrate from countryside to the urban vicinity in a clustered configuration at various locations. Eventually, it generates trip from residence to work place. Particularly, Low Income Group (LIG) and Medium Income Group (MIG) who prefers to settle nearby their workplace to reduce trip length or to reduce the cost of trip by execute most of the distance through walk. Surat in Gujarat is one of those cities, which attracts high migration from rural population. In addition, city has been ranked as fourth fastest growing cities in India having rapid growth of industrial activities such as diamond and textile. A walking is one of the important elements of the transportation for such set of categories like LIG and MIG. Moreover, walk trip may be either end trip or

intermediate trip of any mode of transportation and average share walk trip is found to be 31%.Furthermore, it increases in the provision and use of public transit is likely to increase walking and thus the number of pedestrians. However, urban road infrastructure in India is biased in favour of motorised vehicles. Wilbur Smith Associates and Ministry of Urban Development (2008) argued that a significant number of trips in Indian cites are made by foot, for different purposes such as shopping, work, educational, recreation etc. However, pedestrian infrastructure, amenities and services are neglected and are not given adequate importance. In addition, it is experience that the most of the cities in India, most of the space of exclusive pedestrian facilities occupied by the vendors, shopkeepers for advertisement of their products and also by some of the fixtures like electric & telephone poles, trees etc. which offers lower space for the pedestrian movement. Hence, due to lack of dedicated walkways or sidewalks, pedestrian is forced to use non-exclusive facilities (main carriageway), resulting into interaction between different modes of transportation which leads to serious safety issues.

Pedestrian walk on non-exclusive facility is quite common scenario in Indian condition. As a result, leads to the fatal accident between different modes. Due to inadequate pedestrian facilities for their movement and rapid growth of vehicular traffic on urban streets has posed a serious problem concerning the safety of pedestrians. During the year 2012 the percentage of pedestrian involved road accident in a major city are 20 % Delhi, 14.02 % in Kolkata, 38 % in Chennai and 64% in Mumbai. Among them 60% of the total pedestrian involved in fatal accidents, indicating that pedestrian is most vulnerable component of the transportation system. It shows that there is urgent need to provide exclusive dedicated pedestrian facility and, emphasis of road safety activity, in order to provide safe, convenient, and better environment for pedestrian movement.

2. Review of earlier studies

There have been several studies carried out to understand the pedestrian behavior, which are affected by different factors such as age, gender, carrying baggage while walking, facilities, time of day and land use etc. Land use is also important topic of research. Rastogi et al. (2011) found Pedestrian speed in an educational area (1.42 m/s) and in shopping areas (1.00 m/s) Lam and Chang (2000) observed that pedestrians walking speed is higher at commercial areas compare to residential areas. Al-masuied et al. (1993), Singh and Jain (2011) found that surrounding environment is an important factor which affects the walking speed of pedestrian. They also observed that the walking speed is differing with land use such as educational area, business area and residential area. Some researchers have found that the separation of sidewalk and the attractiveness of the location are more important to pedestrians than pedestrian congestion (Dixon, 1996; Khisty, 1994).

Some researcher found that Pedestrian speed also varies on facilities like side walk, wide sidewalk, and precinct etc. Chandra et al. (2010) found pedestrian free flow speed is high on sidewalks (1.576 m/s) and low on precincts (1.340 m/s), also observed Maximum flow rate is observed to be higher on the carriageway (2.067 ped/s) as compared to an exclusive pedestrian facility (1.493 ped/s). The pedestrian speeds are also influenced by the type of facility. Polus et al. (1983) found that the average walking speed of pedestrians on sidewalks in Haifa, Israel, is 1.31 m/s. In Singapore, it is observed at 1.23 m/s. (Tanaboriboon et al. 1986). Koushik (1988) found that the slowest pedestrians are in Riyadh, who walk at a speed of 1.08 m/s Morrall et al. (1991) found the walking speed of pedestrians at 1.25 m/s in Colombo, Sri Lanka, and 1.4 m/s.

Dammen and Hoggendom (2005) observed that pedestrian walking speed depends on walkway characteristics such as width, type of facility. Researchers found the country wise variation in speed of pedestrian, from 1.31 to 1.50 in European countries (Oeding 1963, Older 1968); and from 1.31 to 1.37 m/s in the US (Navin and Wheeler 1969, Fruin 1971). Walton

(2007) found that younger pedestrians are faster than older and children. K. K. Finnis and Walton (2007) observed that commuters have significantly higher walking speed than othersShah et al. (2013) found that pedestrian walk faster during the afternoon or day time compared to evening, also presence of the pedestrian with luggage has potential effect on reduction in the average walking speed of pedestrian. Researchers developed the pedestrian flow relationship and most of the models are based on a linear speed-density relation. Virkler and Elayadath (1994), Weidmann (1993) (as quoted in Daamen 2004) and Kotkar et al. (2010) the relation between speed and density becomes exponential under heavy pedestrian flow. Polus et al. (1983). The relationship between speed and density was found to be linear while flow-density and flow-speed relationships were quadratic. Seyfried et al. (2009). Zhang et al. (2009) found that average walking speed of nonworking day is lower than normal working day considering leisure or recreational trip. Helbing et al. (2001) found that under bi-directional flow, pedestrian's density was an important factor affecting the pedestrian flow. Kertz et al. (2006b) found that in case of bidirectional flow, the pedestrian flow depends on the directional ratio. For a given density, as counter flow increases, the capacity losses decrease and total flow therefore increases (Navin and Wheeler 1969).

3. study area profile

Surat is second-largest city in Gujarat with a population of 4.6 million (Census 2011). City spread into 326.5 km². It is also known as the diamond capital of the world and the textile capital of India. On the economic front, GDP of Surat is 12% which is 4% higher compared to the national GDP. Even the international bodies like UN are aware of the growth rate of Surat, at an alarming 400% and termed as the "Fastest Growing City of the World"(SMC report). Textile industries has around 381 dying and painting mills and 41,000 power looms units (Collectorate Surat District, Government of India), enlarge job opportunities.

Large scale migration from counterparts of the country for the better job prospective has resulted in a mixed population in the city with people belonging to different socio-cultural and religious backgrounds having variation in behaviour. Migrants constitute nearly 60 per cent of the total city population and settled near work place resulting into generation of the different trips. Table 1 shows the physical and socio-economic facts and figures of Surat City.

Table. 1 Statistics for Surat Municipal Corporation

Oldest Municipality	1852 AD
Area	326.515 Sq.km.
Population	28,76,374 (2001) 44,66,826 (2011)
Density	13680 Persons/Sq. km
No. Of Slum Pockets	334
Zones (Ward)	7
Sex Ratio	756/1000 Male
Literacy Rate	87.89%
Male	91.22%
Female	83.44%
Decadal Growth Rate	55.29%

Note: Census (2011)

Surat city can be broadly classified into three parts; the old city, the inner periphery and the outer periphery. Population reached at saturation level in old city and also increases drastically in inner peripheries, resulting into sprawl of new development of areas covering 55.61 sq. kms in outer periphery engender different work zones. Majority of citizens with diverse socio-economic background commute daily from residential area toward work place, generate huge amount of movement for different activities. About 10% of the ward population are noted as a slum population, breathe below poverty level and works in various

industrial sectors and likely starts and ends their trip with the walk trip. Despite of this, even middle-income group of people as well as school children also walk a distance of 0.5 km from public stand to their destination to complete their trip. However, as discussed in previous section, due to lack of dedicated pedestrian facilities, pedestrian walk unwillingly on main carriageway. Particularly, peak hours, pedestrian movement as well as vehicular movement is significantly high to reach their destination in time. During this period, everyone are in hasten and reduce consecutive gap between vehicle and pedestrian and also increase constant conflicts in sharing of main carriageway. As a result, pedestrian cannot achieve their desired walking speed. Also, characteristic of pedestrian in term of individual speed, flow and space, is different at different point and it is depended on the land use and corresponding user.

With this motivation, study has been carried out at four different land uses having variation in activities, to understand the macroscopic phenomena. A setup has been installed at vantage point as presented in section 4. The methodology of data collection and extraction is explained in section 5. Further, macroscopic analysis has been described in section 6. Finally, inferences have been derived based on the results obtained.

4. Site selection

A survey was conducted at different land uses such as mix land use, industrial land use and educational land use having different activities. Based on the pilot survey, peak hour has been decided as a representative period to identify activity based pedestrian flow characteristics. From, pilot survey it has been observed that the pedestrian movement is significantly high between 7:00 to 9:00 am in morning and 7:00 to 9:00 pm in evening, that is opening and closing hours of the Industrial area. Whereas, at mix land use, closing time found to be earlier than industrial zone that is 6:00 to 8:00 pm. Contrary, at educational land use such as school, high pedestrian flow observed at the time of interchanging of two shifts. Consideration of that study location for educational land use has been selected near government school. The interchange of morning shift and afternoon shift is found around 12:00 noon and children are move put forward their step for further activity. Locations within the city were identified based on pedestrian flow, traffic flow and type of land use. Figure 1 shows the selected study locations considering different land uses.

(a) Mix Land use (Katargam)

(b) Mix Land use (Varachha)

(c) Educational Land Use (Navagam)

(d) Industrial Land Use (Udhana)

Figure 1. Selected study locations

5. DATA COLLECTION and Methodology

Video graphic technique was adopted for the pedestrian flow data collection. A survey was conducted in mid-October of 2021 at different locations as shown in Figure 1. High mega pixel (14.0 MP) video camera was installed at vantage point so as to cover the pedestrian movement on the test section as shown in Figure 2. An angle of camera was turned in such that it minimizes the effect of parallax. Lens of Camera was zoomed such that it magnifies each pedestrian movement, also helps in detection of pedestrian faces.

In India, due to the lake of dedicated walkway facilities, pedestrian have to force, walk on the carriageway which is considered as non-exclusive facilities. Significant amount of work has been carried out by different researcher on exclusive as well as non-exclusive pedestrian facilities. However, it is very difficult to estimate the density on non-exclusive facility (on roadway) because of unconstraint boundary condition.

A virtual longitudinal trap of 2m X 6m was marked on the road by epoxy paint for measurement of density and speed as shown in Figure 2. A width of trap was selected in view of an ideal width of the sidewalk suggested in IRC: 2012. Pedestrian movement in both the directions was recorded as per the selected time duration. Semi-automatic laboratory based pedestrian flow parameters were extracted for selected time duration.

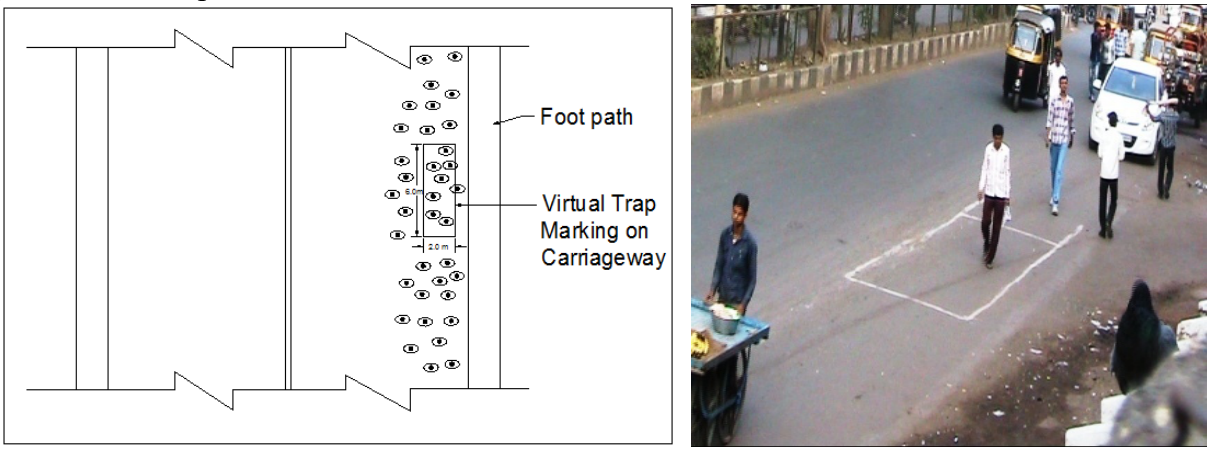


Figure 2. Pictorial view of Camera set up and virtual trap mark on roadway

As seen, number of pedestrians passing a first line of the test trap provided the information of pedestrian flow. In order to determine, pedestrian walking speed, randomly chosen 5 pedestrians of the total count in one minute and the time taken by them to cross the trap length provide the speed measurement of individual pedestrian. Video film was paused at every 3s to determine the density as an average number of pedestrians occupied the trap length. Further, analyses of the flow measurements were carried out one-minute bases. Variation in flow and speed with respect to pedestrian personal characteristics like age and

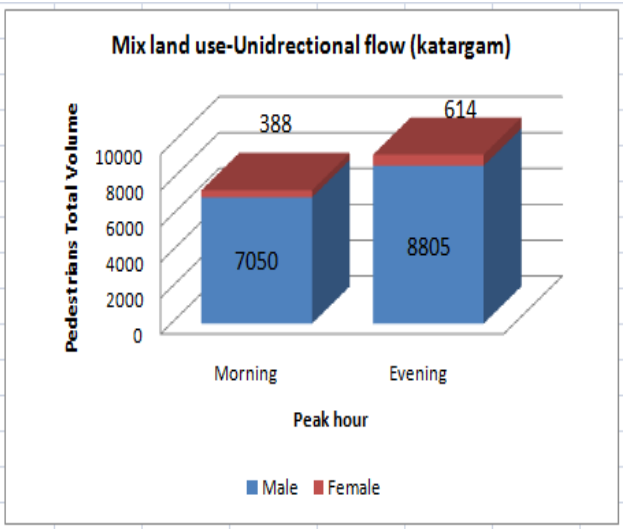
gender, and flow conditions at different time duration was also analysed in detail for further investigation

6. Data analysis

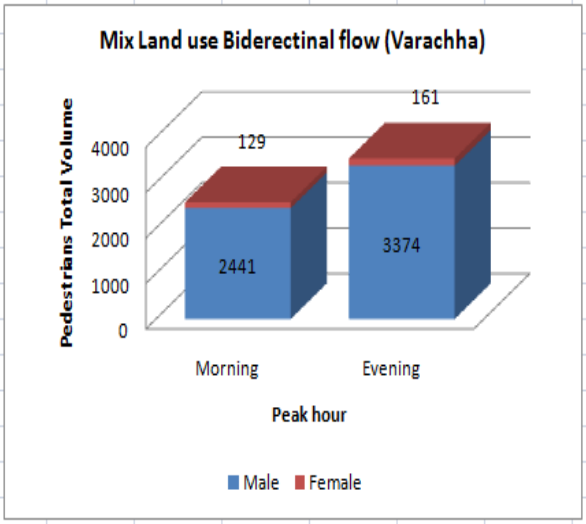
The analysis of pedestrian flow, pedestrian speed, density, and area module were computed at each study locations. The literature suggests that the pedestrian speed varies mainly with age and gender. Therefore, data were classified based on age and gender. The age group is categorized in to three different groups of children (age < 15 years), middle age/adult (age 15-60 years) and the elder (age>60 years) (Shah el al. 2015). Further, analysis is presented in the following sections.

6.1 6.1 Pedestrian flow at different study locations

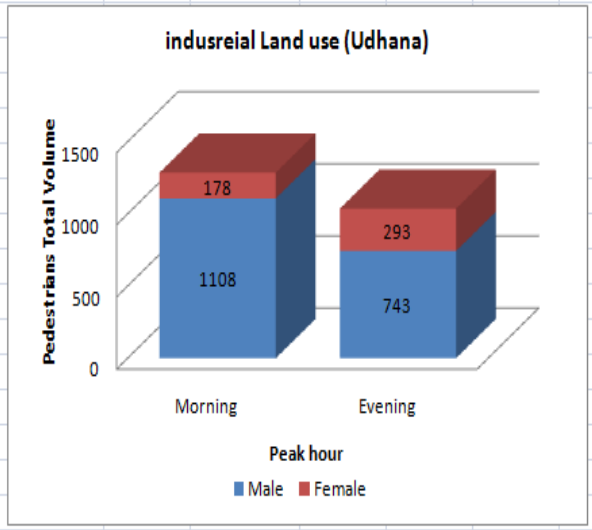
Pedestrian flow data at different pedestrian zones were measured depending on the direction of the movement. At Katargam (mix land use of residential-commercial) unidirectional pedestrian flow was observed, whereas, at Varacha, bidirectional flow is observed in morning and evening. As Varacha is a mix land use of residential and industrial, where, pedestrian walk trip found toward work place in morning and same opposite flow observed at evening. The same scenario also observed in Udhana (Industrial area). On the other hand, pedestrian movement is found in both the directions at educational area. Pedestrian volume at different time of the day under the influence of age, gender is shown in Figure 3.



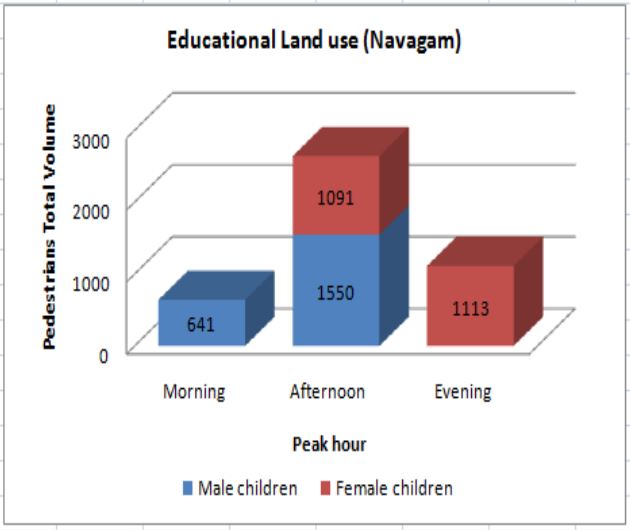
(a)



(b)



(c)



(d)

Figure 3. Pedestrian volume at different land uses

From Figure 3, it can be observed that at mix land use volume of pedestrian is found to be very high as compare to other land uses as shown in Table 2. From interview survey of pedestrian, it is come to know that most of the people whose, work place less than 1.5 km from residence. They want to reduce their trip length to reach earlier at their work place are made trip through a congested area, comprising mixed use of land. And most of them are preferred walk as mode of transport, to reduce the cost of trip.

At different land uses male pedestrian are the dominant group whereas female constitute small in proportion of 5% at mix land use, 15 % at Industrial land use. Despite of this, quite diverse scenario is observed at educational land use where, male pedestrian (children) found dominant in morning and female pedestrian in evening, whereas 60/40 ratio observed in afternoon. And, it may be due to interchange of two shifts, generate mix pedestrian flow near educational area.

Table 2. Pedestrian volume at different land use

Location	Peak Hour	Land use	Direction of Flow	Total Volume on Road	Volume on Trap Marking
Varachha	Morning	Mix	Bidirectional	5583	2570
Varachha	Evening	Mix	Bidirectional	7224	3535
Udhana	Morning	industrial	unidirectional	1286	1286
Udhana	Evening	industrial	unidirectional	1036	1036
Katargam	Morning	Mix	unidirectional	7388	4307
Katargam	Evening	Mix	unidirectional	9419	3469
Navagam	Afternoon	Educational	Bidirectional	2641	2064

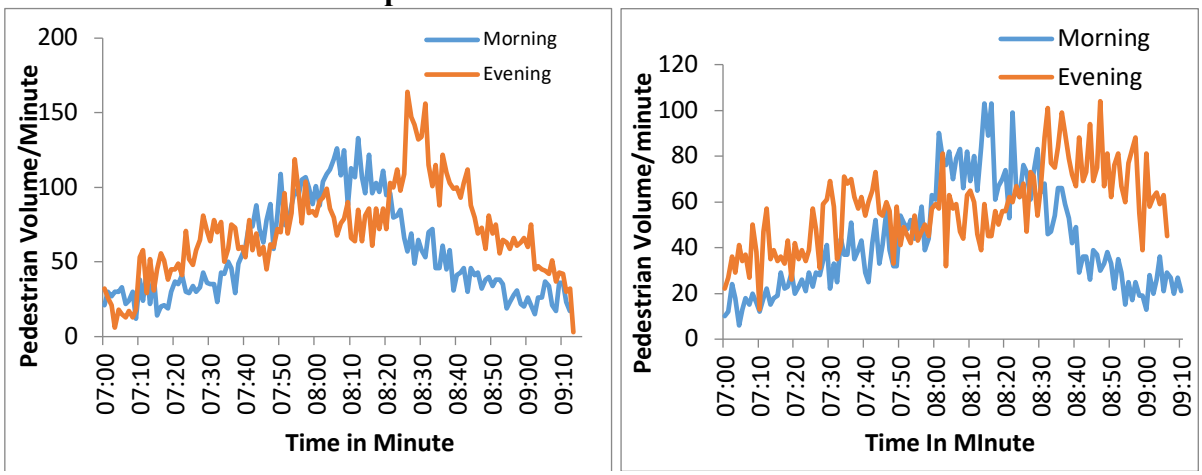
As par the IRC: 103, width of side walk depends on number of pedestrian per hour occupied, subject to a minimum width of 1.5 meter. However, flow of the present study gives an idea about the inadequacy of the existing width sidewalk to cater flow of pedestrian as shown in Table 3.

Table 3. Comparison of existing and required side walks

Land use	Direction of Flow	Hourly Flow Rate	Existing width of sidewalk (m)	As per IRC:103, Required Width (m)
Mix-Katargam	Unidirectional	5928	1	4
Mix-Varachha	Bidirectional	2842	2	4
Educational	Bidirectional	2546	1.5	2.5
Industrial	Unidirectional	724	1	1.5

Table 3, shows that the existing widths of side walk is insufficient to cater the demand. Present width of sidewalk may be designed based on past volume. However, as increases in the pedestrian flow, planner or local government has to consider and redevelop the width of sidewalk. And it may be possible that the pedestrian shift their movement from main carriageway to the sidewalk, which can reduce conflict between vehicle and pedestrian.

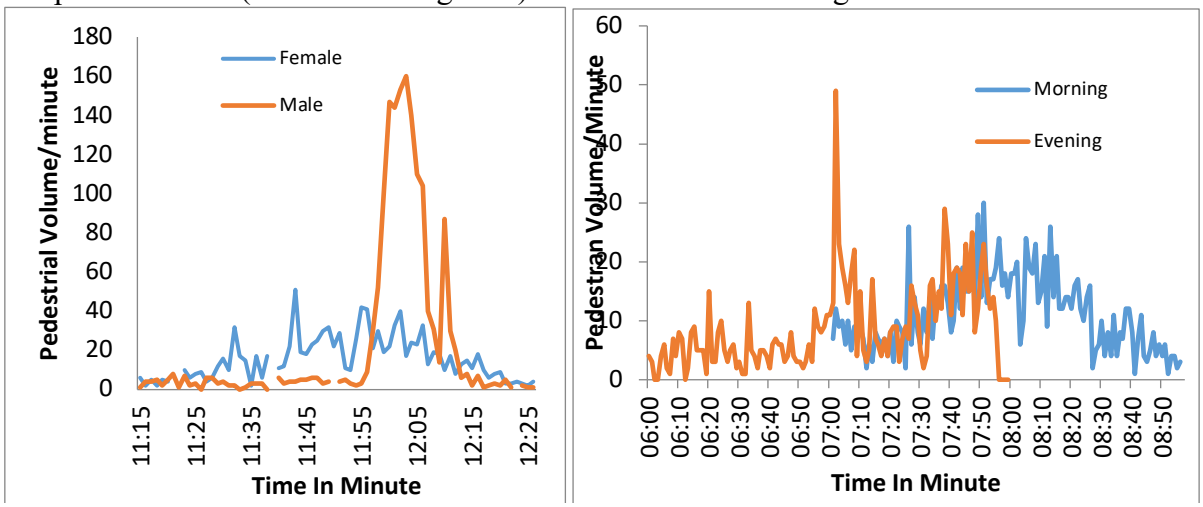
6.2 6.2 Pedestrian flow over period of time



(a) Katargam (b) Varachha

Figure 4. Pedestrian volume at Mix Land Use

From Figure 4 (a & b), it is noted that maximum pedestrian volume observed at 8:00 am in morning and 8:30pm in evening. Because of all diamond and power loom industries almost started between 7:00 am to 9:00 am and close at around 8:00 pm in evening. It is also noted that pedestrian flow is found to be higher at evening hours compare to morning hours. As in addition to work trip, pedestrian is also come out for the other trips such as shopping, recreation etc. as a result, increase in the volume corresponding increase in density with reduction in the average walking speed. Despite of this, at educational it reaches maximum of 194 p/min at noon (as shown in Figure 5) at the time of interchange of shift.



(a) (b)

Figure 5. Pedestrian volume (a) Educational and (b) Industrial land use

During survey, it is observed that the footpath near school is fully covered by hawkers and other stalls. Hence, students have enforced to use main carriageway and they covered almost half of the way, which involves high risk of accident. In addition, particularly, students are more susceptible and innocent, also behaviour is different in consideration of walking speed, walk in platoons, than the other group of pedestrians. Hence, at the time of designing of pedestrian facility, it is prerequisite to understand the behaviour of such type of groups.

6.3 6.3 Pedestrian walking speed

As per literature, walking speed is the important factors which affect the overall efficiency of the facility. Hence, it emphasizes more in designing of any facility. Walking speed of

pedestrian varies with the site condition and type of the activities they performed. Variation in walking speed at different land uses are presented in Figure 6.

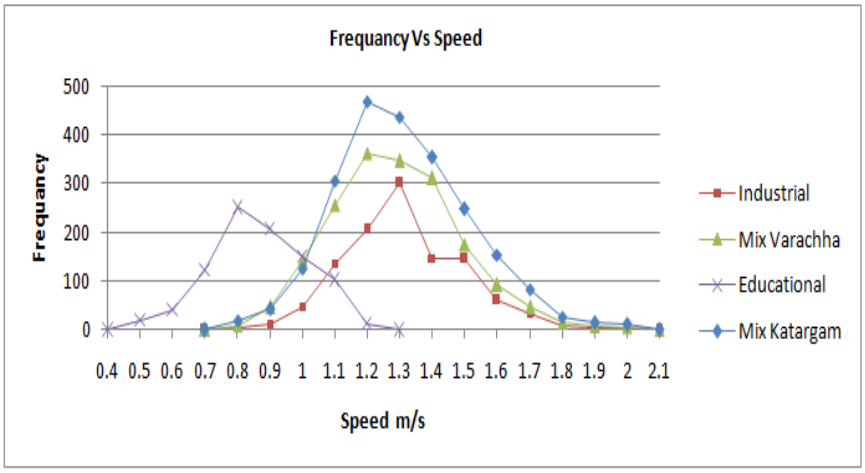


Figure 6. Frequency distribution of walking Speed

Figure 6, represented the distribution of the walking speeds. Figure shows that the walking speed is normally distributed from 0.7m/s to 2.1m/s in the mix and industrial land use. Whereas, at educational land use, distributed within the 0.4m/s to 1.3m/s. It is also observed that the pedestrian is walk at highest frequency at speed of 1.2m/s for mix land use (Katargam and Varacha), 1.3m/s at Industrial and 0.8m/s at educational zone. From the results, it can be revealed that walking speed of pedestrian is higher at mix land use followed by industrial and educational zone. Further, walking speeds under the influence of age and gender are given in Table 4.

Table 4. Effect of gender and age on average walking speed at different land use

Group of pedestrian	**Average walking speed, (m/s)**			
	Mix (R-I)	Mix (C-I)	Industrial	Education
Male	1.31	1.32	1.33	0.96
Female	1.25	1.26	1.26	0.85
Children (male)	---	---	---	0.78
Children(Female)	---	---	---	0.86
Over all	1.28	1.29	1.29	0.86

Note: R: Residential; I: Industrial; C: Commercial

Table 4, show that there is no significant difference observed in the walking speed of pedestrian at mix and industrial land use at 5% level of significance. It is also observed that the male pedestrian walks at higher speed of 1.3m/s compared to female pedestrian having walking speed of 1.2m/s. However, walking speed of male and female at educational land use found significantly lower (male; 0.96m/s, female 0.85m/s) than other land uses, comprising higher proportion of children. Analysis shows that walking speed of pedestrian also varies with the time of the day and found that pedestrian walk faster during morning (1.3m/s) compare to evening (1.2m/s) at mix and industrial land use as shown in Table 4.

Table 5. *Walking Speed based on land use*

Location	Peak Hour	Land use	Direction of Flow	Average Speed m/s
Varachha	Morning	Mix (R-I)	Bidirectional	1.33
Varachha	Evening	Mix (R-I)	Bidirectional	1.24
Udhana	Morning	industrial	unidirectional	1.33
Udhana	Evening	industrial	unidirectional	1.26
Katargam	Morning	Mix (I-C)	unidirectional	1.30
Katargam	Evening	Mix (I-C)	unidirectional	1.28
Navagam	Morning	Educational	unidirectional	0.85
Navagam	Afternoon	Educational	Bidirectional	0.85
Navagam	Evening	Educational	unidirectional	0.92

Based on the analysis, it is found that at all locations in morning peak hour free speed is found of Pedestrian but in evening peak hour pedestrian would like to walk little slowly on the carriageway due to insufficient lighting and safety purpose compare to day light.

Table 6. Walking Speeds Observed in Various Studies

Sr. No.	Author	Country	Type of facility	Land use	Average walking speed (m/s)
1	Rastogi et al. (2011)	India	Sidewalk	Shopping (C)	1.00
2	Rastogi et al. (2011)	India	Sidewalk	Educational	1.42
3	Chandra et al. (2010)	India	Wide Sidewalk	Commercial	1.37
4	Kotkar et al. 2010	India	Sidewalk	Mix	1.40
5	Lam and Cheung(2000)	China	Sidewalk	Mix	1.23
6	Tanaboriboon et al. (1986)	Singapore	Sidewalk	Mix	1.23

Table 6, shows that at commercial zone in India, average speed of pedestrian is found to be 1.00 m/s and at educational area 1.42 m/s, which is quite higher (1.29m/s at commercial and 0.86 m/s at educational) than the result obtained from the study. Whereas, at mix land use; walking speed found to be significantly higher than the obtained in China and Singapore. It may be due to pedestrian are hurry to reach at destination as early as possible. Pedestrian walking speed is mainly dependent on flow and surrounding density. Pedestrian can achieve its desired walking speed at lower flow and density level. As increases in flow and density; resulting in reduction in walking speed. However, looking to the results obtained from the study, at all locations pedestrians are walking on the carriageway, because there is no boundary condition for walking. Although, there are several types of frictions experienced by a pedestrian in mixed traffic conditions. These includes friction with nearby pedestrians, parked vehicles, moving vehicles, and with road side developments which put the pedestrian are in conscious about the surrounding condition which can also be influence on the average speed. And it may simulate the boundary condition at some extent.

6.4 6.4 Flow and Density Relationship

Density is directly proportional to the flow rate. As pedestrian flow increases, the density of pedestrian increases proportionally as shown in Figure 7.

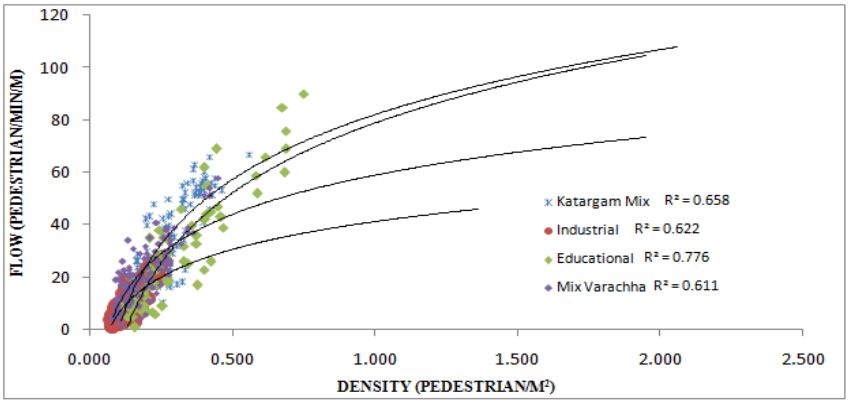


Figure 7. Flow and Density Relationship

Figure 7, shows flow and density relationship follows parabolic function, as flow increases with increase in density up to certain maximum level and there after it reduces with further increase in density. Further, pedestrian movement decreases until flow becomes zero and consequent density is identified as jam density. However, due to unconfined boundary condition flow cannot reach up to the optimum level. Hence, due to inadequacy of the data points at optimum flow, trend shows further increment in flow with increase in density. From the figure, it is also revealed that density gets higher in mix land use compared to industrial and educational zone. Maximum density of 0.558 p/m^2 is observed at corresponding flow rate of 67/p/m/min at katargam and 0.729 p/m^2 for the flow rate of 90 p/m/min at education land use. The detailed comparison of flow parameters is represented in Figure 8.

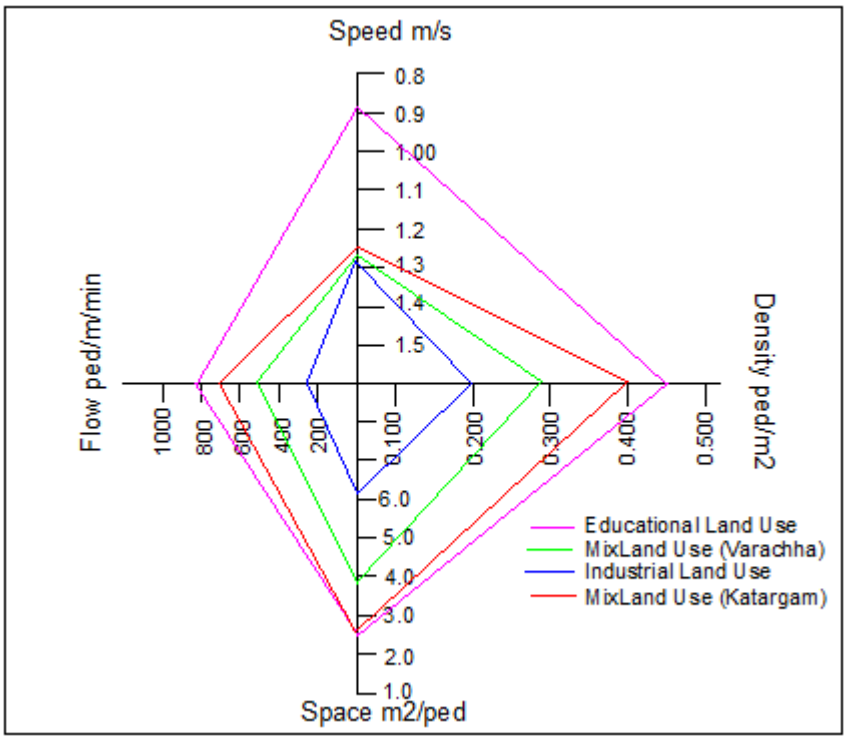


Figure 2. Spider Graph of flow parameters for different land use

Spider graph can be used as a planning and designing tool, where 15-minute highest flow and other corresponding values of different parameters need to be consider. Figure 8, shows that educational and mix land use (C-I) average density value of 0.45 p/m^2 and 0.40 p/m^2 corresponding space of 2.6 and 2.7 m^2/p obtained respectively. It is also observed that educational area has highest 15-minute flow of 816p/m/min. Based on

data when the periphery of this spider graph is high planner can focus on that particular land use side walk. This spider graph can be used for planning and designing tool for side walk.

7. Conclusion

Pedestrian flow characteristics are analyses at four different locations in Surat, Gujarat. Study sites were selected based on land use having different activities. Study shows that peak hour is different for the different site condition. Pedestrian flow data were analysed based on age, gender and land use activity by marking virtual trap on the road. Results of the present study show that the pedestrian characteristics changes depending on the land use. It is also observed that there is no significant difference in the walking speed of pedestrian at mix and industrial land use. However, walking speed at educational land use found significantly lower comprising higher proportion of children. Analysis shows that pedestrian walk faster during morning (1.3m/s) compare to evening (1.2m/s) at mix and industrial land use. Whereas, at educational zone, speed of female pedestrian decreases of 0.85 m/s, due to walking with children.

It is also observed that at mix land use pedestrian flow is found to be high and present foot path is insufficient to accommodate the demand. The results of this study can be used as input parameter for planning and designing of pedestrian facility based on land use.

References

1. Al-Masaeid, H. R., Al-Suleiman, T. I., & Nelson, D. C. (1993). Pedestrian speed-flow relationship for central business areas in developing countries. Transportation Research Record, 1396, 69–74.
2. Chandra, S., & Bharti, A. K. (2013). Speed distribution curves for pedestrians during walking and crossing. Procedia - Social and Behavioral Sciences, 104, 660–667.
3. Dammen, W. (2004). Modeling passenger flows in public transport facilities (Doctoral thesis). Department of Transport and Planning, Delft University of Technology, Delft, The Netherlands. ISBN: 90-407-2521-7.
4. Dammen, W., & Hoogendoorn, S. P. (2003). Experimental research of pedestrian walking behaviour. Proceedings of the Annual Meeting of the Transportation Research Board, CD-ROM, National Academy Press, Washington, D.C.
5. Finnis, K. K., & Walton, D. (2007). Field observations of factors influencing pedestrian walking speed.
6. Helbing, D., Molnar, P., Farkas, I. J., & Bolay, K. (2001). Self-organizing pedestrian movement. Environment and Planning B: Planning and Design, 28, 361–383.
7. Highway Capacity Manual (HCM). (2010). Transportation Research Board, National Research Council, Washington, D.C.
8. Huang, L., Wong, S. C., Zhang, M., Shu, C.-W., & Lam, W. H. K. (2009). Revisiting Hughes: Dynamic continuum model for pedestrian flow and development of an efficient solution algorithm. Transportation Research Part B: Methodological, 43(1), 127–141.
9. Indian Roads Congress (IRC). (2012). IRC:103 – Guidelines for pedestrian facilities.
10. Kotkar, K. L., Rastogi, R., & Chandra, S. (2010). Pedestrian flow characteristics in mixed flow condition. Journal of Urban Planning and Development, 136(3), 22–23.
11. Koushki, P. A. (1988). Walking characteristics in central Riyadh, Saudi Arabia. Journal of Transportation Engineering, 114(6), 735–744.
12. Kretz, T., Grünebohm, A., Kaufman, M., Mazur, F., & Schreckenberg, M. (2006). Experimental study of pedestrian counter flow in a corridor. Journal of Statistical Mechanics: Theory and Experiments, 10001.

13. Lam, W. H. K., & Cheung, C. (2000). Pedestrian speed/flow relationships for walking facilities in Hong Kong. Journal of Transportation Engineering, 126, 343–349.
14. Morrall, J. F., Ratnayake, L. L., & Seneviratne, P. N. (1991). Comparison of central business district pedestrian characteristics in Canada and Sri Lanka. Transportation Research Record, 1294, 57–61.
15. Navin, F. P. D., & Wheeler, R. J. (1969). Pedestrian flow characteristics. Traffic Engineering and Control, 39(9), 30–36.
16. Polus, A., Schofer, J. L., & Ushpiz, A. (1983). Pedestrian flow and level of service. Journal of Transportation Engineering, 109(1), 46–56.
17. Rastogi, R., Thaniarasu, I., & Chandra, S. (2013). Pedestrian flow characteristics for different pedestrian facilities and situations. European Transport \ Trasporti Europei, (53), Paper no. 6.
18. Rastogi, R., Thaniarasu, I., & Chandra, S. (2011). Design implications of walking speed for pedestrian facilities. Journal of Transportation Engineering. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000251
19. Seyfried, A., Passon, O., Steffen, B., Boltes, M., Rupprecht, T., & Klingsch, W. (2009). New insights into pedestrian flow through bottlenecks. Transportation Science, 23, 395–406.
20. Shah, J., Joshi, G., & Parida, P. (2010). Walking speed of pedestrian on stairways at intercity railway station in India. Proceedings of the Eastern Asia Society for Transportation Studies, Vol. 9.
21. Singh, K., & Jain, P. K. (2011). Methods of assessing pedestrian level of service. Journal of Engineering Research and Studies.
22. Tanaboriboon, Y., Hwa, S. S., & Chor, C. H. (1986). Pedestrian characteristics study in Singapore. Journal of Transportation Engineering, 112(3), 229–235.
23. Virkler, M. R., & Elayadath, S. (1994). Pedestrian speed-flow-density relationships. Transportation Research Record, 1438, 51–58.
24. Weidmann, U. (1993). Transporttechnik der Fussgänger (Transport Technique for Passengers). ETH Zürich, IVT-Berichte 90. (in German)