Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Applications of Nanotechnology In Civil Engineering-2019.

Volume 6, Special Issue 01, Feb.-2019.

EVALUATION OF PEDESTRIAN WALKING SPEED AT DIFFERENT LAND USE UNDER INDIAN CONDITIONS

Rathva Dipak M.[1], Jain Manish P.[2]

[1,2] *Assistant Professor, Civil Engineering Department, Faculty of technology & Engineering, The M. S. University of Baroda*

Abstract-*Pedestrians are an important part of urban transportation system. Every trip starts and ends with the walk trip. Despite that, they are one of the neglected parts of transport system in terms of the requisite facility in developing economies like Indian cities. Data was collected at two different locations based on land used activity namely; industrial and commercial. 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. In addition, due to lack of dedicated sidewalk, pedestrian speed was extracted through virtual trap marked on the carriageway.*
From the study, it was observed that the male pedestrian dominant at both areas. The pedestrian walking speed is observed lower than that reported for other parts of India and higher compare to the Middle East and Western countries. 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, Trip, Land use, sidewalk, Walking speed*

I. INTRODUCTION

Industrialization plays an important role in growth of the city and its infrastructural development. For better prospective of living, people migrate from countryside to the urban vicinity in a clustered configuration at various locations. Persons those prefer to settle nearby their workplace to reduce trip length or to reduce the cost of trip, travel most of the distance through walk. 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 motorized 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 are 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 cities are 20 % Delhi, 14.02 % in Kolkata, 38 % in Chennai and 64% in Mumbai. Among them 60% of the total pedestrians involved in fatal accidents, indicating that pedestrians are the most vulnerable component of the transportation system in Indian urban road network. It shows that there is urgent need to provide exclusive dedicated pedestrian facility coupled with importance on road safety activity, in order to provide safe, convenient, and better environment for pedestrian movement.

II. 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) [1]. Lam and Chang (2000) observed that pedestrians walking speed is higher at commercial areas compare to residential areas [2]. The surrounding environment is an important factor which affects the walking speed of pedestrian [3, 4, & 5]. They also observed that the walking speed is differing with land use such as educational area, business area and residential area.

Some researcher found that pedestrian speed also varies on facilities like side walk, wide sidewalk, and zone etc. Chandra et al. (2010) found pedestrian free flow speed is high on sidewalks (1.576 *meter/second*) and low on grounds (1.340 *m/s*), also observed Maximum flow rate is observed to be higher on the carriageway (2.067 *pedestians/second*) as compared to an exclusive pedestrian facility (1.493 *ped/s*).[6]. 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* [7]. In Singapore, it is observed to be 1.23 *m/s* [8]. Koushki (1988) found that the walking speed of pedestrians in Riyadh 1.08 *m/s* and thus categorized to be slightly lower [9]. The walking speed of pedestrians at 1.25 *m/s* in Colombo (Sri Lanka), and 1.4 m/s in Calgary (Canada) [10].

Dammen and Hoggendom (2005) observed that pedestrian walking speed depends on walkway characteristics such as width, and type of facility [11]. Researchers found the country wise variation in speed of pedestrian, from 1.31 to 1.50 in European countries and from 1.31 to 1.37 *m/s* in the US [12, 13 & 14].. Shah 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 [15 & 16]. Researchers developed the pedestrian flow relationship and most of the models are based on a linear speed-density relation. The relation between speed and density becomes exponential under heavy pedestrian flow [17, 18 & 19]. Polus et al. (1983) estimated that the relationship between speed and density was found to be linear while flow-density and flow-speed relationships were quadratic [7]. The average walking speed of pedestrians during nonworking day was lower than normal working day as the former were primarily leisure or recreational trip [20].

III. SITE SELECTION

Surat is the second-largest city in Gujarat with a population of 4.6 million (Census 2011), spread over 326.5 Sq. km. It is also known as the diamond capital of the world and the textile capital of India.

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 compose nearly 60% of the total city population and settled near work place resulting into generation of the different trips. 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 collapse of new development of areas covering 55.61 sq. kms in outer periphery produce 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. However, as discussed in previous section, due to lack of dedicated pedestrian facilities, pedestrian walk unwillingly on main carriageway. Particularly, during peak hours, pedestrian movement as well as vehicular movement are significantly high due to their respective desires for reaching their destination on time. As a result, pedestrian cannot achieve their desired walking speed. Also, characteristics of pedestrian in term of individual speed, flow and space, is different at different points of time and it is primarily dependent on the land use and corresponding user.

A survey was conducted at two different locations, one is industrial land use (Udhana) and other is commercial land use (Varachha). Based on the pilot survey, peak hour has been decided as a representative period to identify activity based pedestrian flow characteristics.

IV. DATA COLLECTION

Video graphic technique was adopted for the pedestrian flow data collection Video camera was installed at vantage point so as to cover the pedestrian movement on the test section as shown in Figure 2. In India, due to the lack of dedicated walkway facilities, pedestrians are forced to walk on the carriageway which is considered as non-exclusive facilities.

Industrial Land Use (Udhana) Commercial Land use (Varachha)

Figure 1. Selected study locations

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 as suggested in IRC: 103 (2012). Pedestrian movement in both the directions was recorded as per the selected time duration.
In order to determine, pedestrian walking speed, randomly selected 5 pedestrian 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. Variation in speed with respect to pedestrian personal characteristic like gender and with respect to land use and time of the day are analysed in detail.

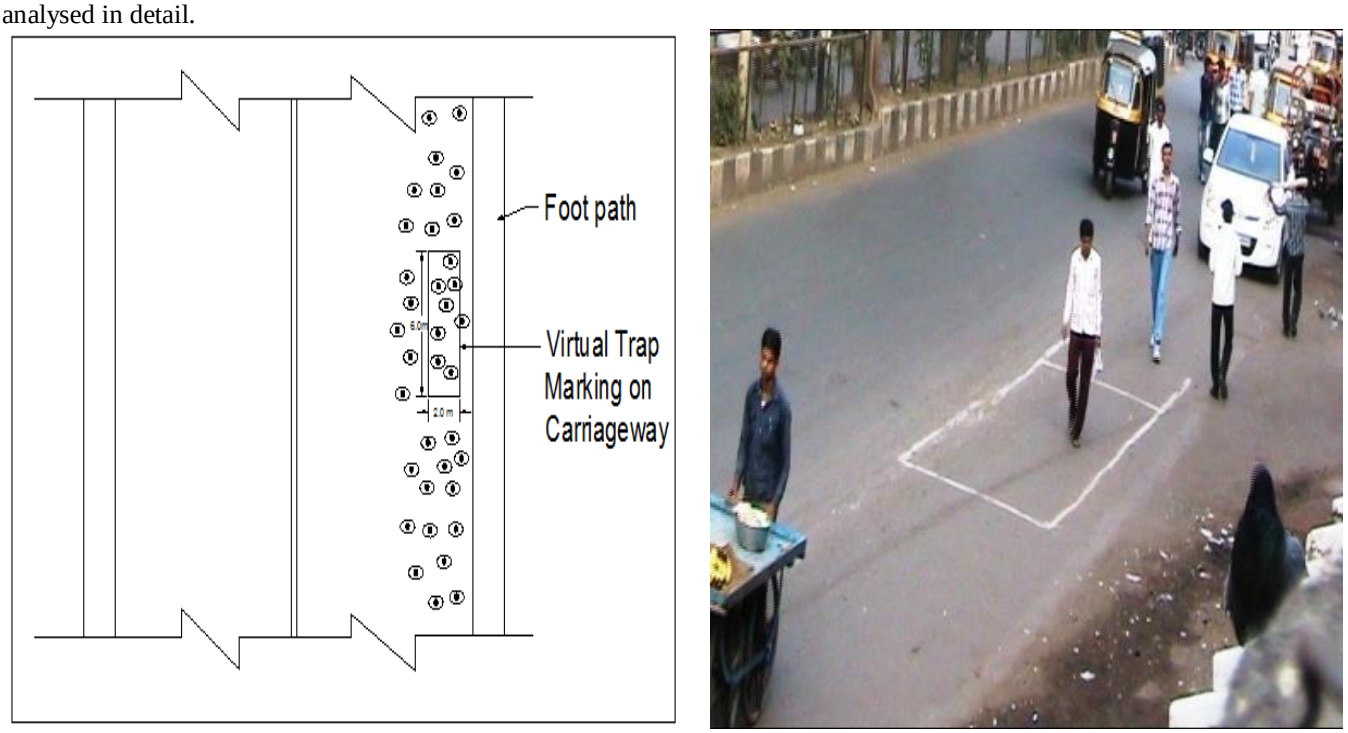

Figure 2. Pictorial view of Camera set up and virtual trap mark on roadway

V. DATA ANALYSIS

The analysis of pedestrian speed were computed at each study locations. The literature suggests that the pedestrian speed varies with gender. Analysis is presented in the following sections.

5.1 Pedestrian flow at different study locations

A. Varachha Road

At Varachha road pedestrian flow found high during evening peak hour compare to morning peak hour. Male pedestrian are found higher as much as 95% during morning and evening peak hour and only 5% are female pedestrian.

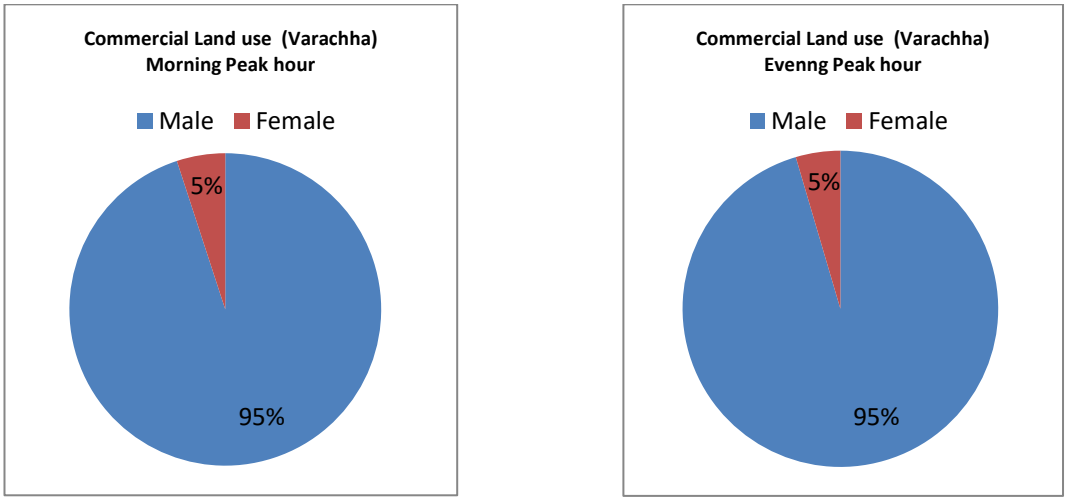

Figure 3 Male Vs Female Comparison of Varachha Road

B. Udhana road

Udhana road is purely industrial area which is little far away from residential area there for pedestrian flow is low compare to Varachha. Morning peak hour time observed between 6:00 am to 8:00 am and evening peak hour time between 7:00 pm to 9:00 pm. Here male pedestrian are higher but female pedestrian are found 14 % during morning peak hour and 28% during evening peak hour which is higher compare to Varachha.

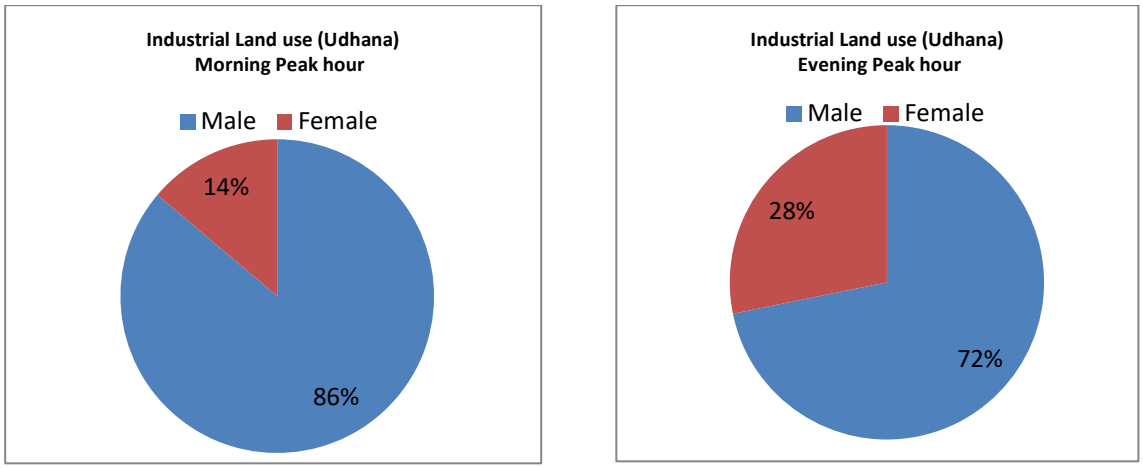

Figure 4 Male Vs Female Comparison of Udhana Road

5.2 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. Walking speed of pedestrian on different location are extracted and analysed. Table-1 shows the pedestrian frequency with their speed. Also cumulative frequency v/s speed is plotted and shown in figure 5.

Table 1 Frequency distribution of Walking speed

Udhana		**Varachha**	
Nos of sample	Speed m/sec	Nos of sample	Speed m/sec
5	0.8	9	0.8
14	0.9	47	0.9
48	1	143	1
137	1.1	257	1.1
205	1.2	362	1.2
301	1.3	347	1.3
148	1.4	312	1.4
146	1.5	175	1.5
61	1.6	92	1.6
33	1.7	46	1.7
9	1.8	15	1.8
6	1.9	8	1.9
4	2	5	2

Figure 5 represented the frequency distribution of the walking speeds. Figure shows that the walking speed is distributed from 0.8 m/sec to 2.0 m/sec for both the location. It is observed that the 50th percentile speed is 1.25 m/sec for Udhana and 1.22 m/sec for Varachha. It is also observed that the 85th percentile speed is 1.48 m/sec for Udhana and 1.45 m/sec for Varachha. From the results, it can be revealed that walking speed of pedestrian is higher at industrial area compare to commercial area.

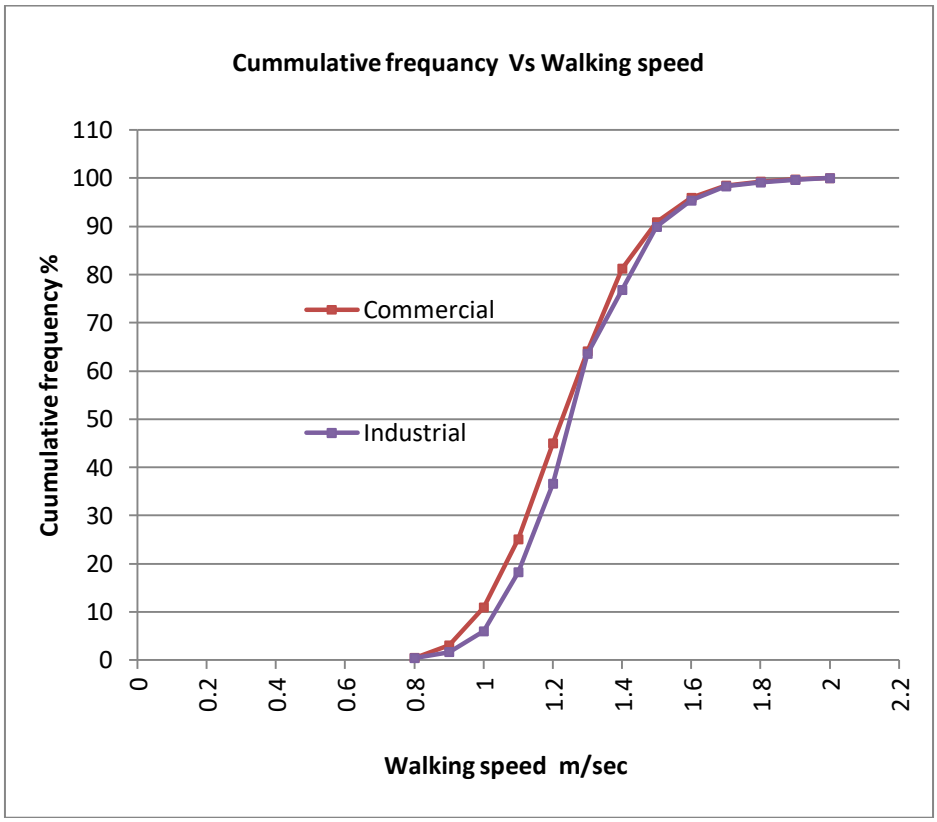

Figure 5 Cumulative frequency v/s Walking speed

Table 2 Effect of gender on average walking speed at different land use

Group of pedestrian	Average walking speed, (m/sec)	
	Varachha Commercial	Udhana Industrial
Male	1.27	1.29
Female	1.22	1.24

Table 2, shows that there is no significant difference observed in the walking speed of pedestrian at commercial and industrial land use. It is also observed that the male pedestrian walk at higher speed of 1.27 m/sec compared to female pedestrian having walking speed of 1.22 m/sec.

Table 3 Walking Speed based on land use with time

Location	Peak Hour	Land use	Direction of Flow	Average Speed m/sec
Varachha	Morning	Commercial	Bidirectional	1.27
Varachha	Evening	Commercial	Bidirectional	1.21
Udhana	Morning	industrial	unidirectional	1.28
Udhana	Evening	industrial	unidirectional	1.25

Analysis shows that walking speed of pedestrian varies slightly with the time of the day, which is found to be approximately 1.27 m/sec during morning and approximately 1.21 m/sec during evening at commercial land use where as it is found to be 1.26 m/sec during morning and 1.27 m/sec during evening at industrial land use.

Table 4 Walking Speeds Observed in Various Studies

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

Table 4, shows that at commercial zone in India, average speed of pedestrian is found to be 1.37 m/sec which is quite higher than the result obtained from the present 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 present study, at both 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.

VI. CONCLUSION

Pedestrian flow characteristics are analyses at two different locations in Surat, Gujarat. Study sites were selected based on land use characteristic exhibiting different activities. Pedestrian walking speed data were analysed based on gender and land use activity by marking virtual trap on the road. Results of the present study shows 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 commercial and industrial land use. Based on the analysis, it is found that pedestrian average speed changes slightly from 1.27 m/sec at morning to 1.21 m/sec at evening peak hour at commercial land use and from 1.28 m/sec at morning to 1.25 m/sec at evening peak hour at industrial land use. It means walking speed during morning is more compare to evening because pedestrians are in hurry to reach at job place. The results of this study can be used as input parameter for planning and designing of pedestrian facility for various types of land uses.

REFERENCES

[1] Rajat Rastogi, Thaniarasu and Satish Chandra, (2011) "*Design Implications of Walking Speed for Pedestrian Facilities*," DOI: 10.1061/ (ASCE) TE.1943-5436.0000251. © 2011 American Society of Civil Engineers

[2] Lam, W.H.K. and CHEUNG, C., (2000). "Pedestrian Speed/Flow Relationships for Walking Facilities in Hong Kong." *Journal of Transportation Engineering* 126, pp 343-349.

[3] Al-Masaeid, H.R., Al-Suleiman, T.I. and Nelson, D.C., (1993). "Pedestrian Speed Flow Relationship for Central Business Areas in Developing Countries." *Transportation Research Record 1396*, National Research Council, Washington, 69-74.

[4] Hardik Sukhadia, Sanjay M Dave, Jiten Shah, Dipak Rathva (2014) "The Effect of Events on Pedestrian Behavior and its Comparison with Normal Walking Behavior in CBD Area in Indian Context." *11th Transportation Planning and Implementation Methodologies for Developing Countries, TPMDC 2014, 10-12 December 2014, Mumbai, India.*

[5] Singh K., Jain P.K, (2011). "Methods of Assessing Pedestrian Level of Service." *Journal of Engineering Research and Studies.*

[6] Satish Chandra and Anish Kumar Bharti (2013) *"Speed Distribution Curves for Pedestrians during Walking and crossing"* Procedia - Social and Behavioral Sciences 104 (2013) 660 – 667

[7] Polus, A., Schofer, J. L., and Ushpiz, A. (1983). "Pedestrian flow and level of service." J. Transp. Eng., 109(1), 46–56.

[8] Tanaboriboon, Y., Hwa, S. S., and Chor, C. H. (1986). "Pedestrian characteristics study in Singapore." J. Transp. Eng., 112(3), 229–235.
[9] Koushki, P. A. (1988). "Walking characteristics in Central Riyadh, Saudi Arabia." J. Transp. Eng., 114(6), 735–744.
[10] Morrall, J. F., Ratnayake, L. L., and Seneviratne, P. N. (1991). "Comparison of central business district pedestrian characteristics in Canada and Sri Lanka." Transportation Research Record 1294, Transportation Research Board, Washington, DC, 57–61.
[11] Dammen, W., and Hoogendoorn, S. P. (2003). "Experimental Research of Pedestrian Walking Behaviour." Proceedings of *Annual Meeting of Transportation Research Board*, CD-ROM, National Academy Press, Washington.
[12] Dammen, W. (2004) "Modeling Passenger Flows in Public Transport Facilities," *Doctoral thesis submitted to Department of Transport and Planning*, Delft University of Technology, Delft, The Netherlands, ISBN 90-407-2521-7.
[13] Navin, F. P. D., and Wheeler R. J. (1969), "Pedestrian flow characteristics", *Traffic Engineering and Control*, 39(9), 30-36.
[14] Finnis K.K., Walton D., (2007). Field Observations of Factors Influencing Pedestrian Walking Speed."
[15] Helbing, D., Molnar, P., Farkas, I.J. and Bolay, K., (2001) "Self-organizing pedestrian movement," *Environment and Planning B: Planning and Design*, 28, 361 – 383
[16] 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, 2013.
[17] Virkler, M.R. and Elayadath, S. (1994) "Pedestrian Speed-Flow-Density Relationships *"Transportation Research Record* 1438, 51-58.
[18] Weidmann, Ulrich (1993). "Transport Technique for Passenger". *ETH Zuerich, Shrift enriched IVT-Berichte 90*, Zuerich (In German).
[19] Kotkar, K. L., Rastogi, R., and Chandra, S. (2010). "Pedestrian flow characteristics
[20] Seyfried, A., Passon, O., Steffen, B., Boltes, M., Rupprecht, T. and Klingsch, W. (2009) "New Insights into Pedestrian Flow through Bottlenecks," *Transportation Science*, 23, Elsevier, 395-406.
[21] Highway Capacity Manual (2010).
[22] IRC : 103 (2012) "Guidelines for Pedestrian Facility in Urban