Pedestrian behaviour under varied traffic and spatial conditions

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Abstract

Pedestrians are an important part of urban transportation system. The pedestrian causalities have increased tremendously in last to decades due to rapid urbanization and increased traffic on roads. Data collected from 8 locations in two cities of India for sidewalks and crossing are analysed in the present study. Data were collected by videography and various pedestrian characteristics like speed, flow were extracted and relations between them were developed. Results show that the pedestrians walk at different speeds on sidewalks and crosswalks. It was found that younger pedestrians walk faster than the rest. Based on gender males are found walking faster than females. The average speed of all locations for male and female is lower than that reported in literature. It was also found that pedestrian's speeds on carriageway and on crosswalks are almost similar for younger and middle-aged pedestrians, whereas, older pedestrians walk 15% faster than their average speed on carriageway. Except at one location V the basic relation between speed and density was exponential.

Keywords: Pedestrians, Walking Speed, Crossing Speed, Accepted Gap, Critical Gap

1. Introduction

Efforts to reduce road traffic accidents in the past were mainly focused on motor vehicles as the number of pedestrian casualties was lower than that of vehicle occupants at that time. But now-a-days due to rapid urban development and succeeded by motorization, the pedestrian fatalities are substantially higher. In India, the total number of causalities in road accidents increased from 84,400 in 2003 to 114,600 in 2007 (NCRB report 2007). Seventy-two percent of all pedestrian fatalities occurred in urban areas. (National Highway Traffic Safety Administration, 2004). In Delhi, over 54% of traffic fatalities are pedestrians and 10% are bicyclists (Grebert, 2008). The share of non-motorized users in traffic fatalities in Mumbai is 87% of which almost 80% are pedestrians and 7% are bicyclists (Mohan, 2004) indicating that non-motorized users are the most vulnerable. As a result, there is a growing pressure on local highway authorities to provide better pedestrian facilities and, emphasis of road safety activity is shifting towards pedestrians. In order to provide these facilities, a thorough understanding of pedestrian behaviour is required at sidewalks and crossings. The main governing parameter in deciding pedestrian facility at sidewalk is the walking speed whereas, at crossings it is

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the speed and the gap accepted by the pedestrians. The objective of this paper is to examine the variation of these parameters at various locations of sidewalks and crossings in India. The study also involves the development of flow relations and their comparison between sidewalks and crossing.

2. Literature survey

Fruin (1971) and Finnis and Walton (2008) found that as the age of the pedestrian increases from younger to older, the walking speed decreases and females walk slower than males. Knoblauch et al. (1996) observed that pedestrians over the age of 65 years walk 10 m/min slower than the average walking speed. Tarawneh (2001) evaluated pedestrian speeds in Jordan and found that pedestrians of 21-30 years age were the fastest and pedestrians over 65 years were the slowest group of pedestrians. Male walking speeds were significantly higher than those of female pedestrians. The average and 15th percentile pedestrian speeds were 1.34 and 1.11 m/s, respectively. Fitzpatrick et al. (2006) observed that the 15th percentile walking speed of older pedestrians (0.92 m/s) is lower than that of younger pedestrians (1.15 m/s). Montufar et al. (2007) found crossing speed of pedestrians greater than their walking speed irrespective of age, gender and season.

Palamarthy et al. (1994) found that pedestrians are more likely to look for an overall gap than separate gaps in individual traffic streams during crossing. The authors estimated mean critical gaps of 3.33 s for the near traffic stream under all crossing tactics, 7.14 s for the far stream under a double-gap crossing tactic, 3.58 s for the far stream under a risk-taking crossing tactic, and 3.81 s for the far stream under a two-stage crossing tactic. Oxley et al. (1997) reported that some of the older pedestrians leave larger distance gaps than their younger counterparts, but not longer enough thus making risky crossing decisions. It was further observed that the road-crossing responses of older adults would be based on distance and not on time gap, and that they would leave smaller safety margins than younger adults. Average gap acceptance for younger pedestrian was 51.3 m and for older pedestrian it was 69.1 m for two way roads. For one way road the average gap acceptance for younger and older pedestrians was 119.2 m and 134.1 m respectively.

Polus et al. (1983) conducted pedestrian flow studies on sidewalks, in Haifa (Israel) and found that speeds are inversely proportional to densities. Tanaboriboon et al. (1986) developed relationships between walking speed, flow and density for sidewalks and walkways in Singapore and developed linear speed-density relationships. Lam et.al. (1995) examined the pedestrian flow patterns in different facilities and found that the basic relationship between speed and density is linear for indoor walkways and exponential for outdoor walkways. Kotkar et al. (2010) developed pedestrian flow relationships for mixed traffic conditions in India. The speed-density relationship was linear for and it was observed that as the friction increases, the speed of the pedestrians also increases on carriageway.

3. Data collection

The cities selected for the present study were New Delhi in North and Coimbatore in South India. New Delhi, the National Capital Territory, is the largest metropolis by area and the second-largest metropolis by population in India whereas Coimbatore is the second largest city in the South Indian state of Tamil Nadu. The data were collected by Videography. Locations within the city were identified based on pedestrian flow, traffic flow, land use and width of facility. The details of study locations selected in each city are given in Table 1. Various pedestrian parameters like speed, gap acceptance, flow etc. were extracted from the videos and stored for further analysis.

Table 1. Details of study locations

City	Location	Width of the facility, m	Traffic, pcu/h/lane	Sample Size	Land use
New Delhi	I - Connaught Place (Wide-sidewalk)	7.8	-	458	Shopping
	II - I.S.B.T (Sidewalk and on Carriageway)	3.0	-	634	Commercial
	III - Connaught Place (Crossing)	8.4	829	142	Shopping
	IV - Near Mothy Bagh Fly over	9.6	1250	194	Residential

	(Crossing)				
Coimbatore	V - Gandhipuram (On Carriageway)	5.3	-	946	Commercial
	VI - Coimbatore Bus station (Wide-sidewalk)	6.1	-	851	Commercial
	VII - Gandhipuram (Crossing)	7	907	254	Commercial
	VIII - Coimbatore Bus station (Crossing)	7.6	608	101	Commercial

4. Pedestrian Speed Analysis

The analysis for speed is carried out separately for sidewalks, wide-sidewalks and crossings. The literature suggests that the pedestrian speed varies mainly with age and gender. Therefore data were classified based on age and gender. Pedestrians were classified based on their age as Young pedestrians (<20 years), Middle aged (20 - 50 years) and old pedestrians (>50 years). The analysis is presented in the following sections.

4.1 Walking speed on different types of facilities

Based on the width of exclusive pedestrian facility, the study locations are categorized as sidewalks (1.5 to 4.0 m) and wide-sidewalks (4.1 to 9.0 m). In the absence of sidewalks, pedestrians are forced to walk on the carriageway and two such locations are also included in this study (II and V). Walking speeds under the influence of age, gender and type of facility are given in Table 2.

Table 2. Effect of Gender and Age on average walking speed

Groups	**Average walking speed, m/s**			
	On sidewalks	**On wide-sidewalks**	**On carriageway**	**Overall**
Male	1.26	1.14	1.19	1.20
Female	1.12	1.07	1.13	1.11
Young	1.28	1.20	1.25	1.24
Middle-aged	1.18	1.12	1.23	1.20
Old	0.92	0.90	1.00	0.96

As may be seen, male pedestrians are walking faster than female on all facilities considered. Females are walking slower than males by 12% on sidewalks, 7 % on wide-sidewalks and 6% on carriageway. Females are walking faster on carriageway, whereas, males are walking faster on sidewalks. However speeds of male and female pedestirans in the present study are lower than those reported by Morrall et al. (1991), Knoblauch et al. (1996), Finnis and Walton (2008) and Kotkar et al. (2010).

The overall walking speed averaged for all facilities, is found as 1.13 m/s. Younger pedestrians walk faster and older pedestrians walk slower than the rest irrespective of type of facility. The average speed of pedestrians on sidewalk, wide-sidewalk and carriageway is 1.17 m/s, 1.07 m/s and 1.16 m/s respectively. Young and midlle aged pedestrians are walking faster by 10% and 6% respectively than the average walking speed, whereas, old pedestrians are walking 16% slower than the average walking speed. The difference between young and old pedestrians is higher for sidewalks. The speeds of young and middle-aged pedestrians are comparable on carriageway. Higher speeds of older and middle-aged pedestrians are observed on carriageway because that they are walking faster to get out of the situation as fast as possible with minimum interactions with the vehicular traffic.

The normality tests and tests for checking homogenity of variance is peroformed using SPSS 17.0 and it is found that the pedestrian speed data of different facilities are following a normal distribtuion and hence parametric tests like F-test can be employed to find whether a significant difference exists in the speeds of pedestrians in different age groups and gender. Hypothesis that group means are equal and they do not differ from the population mean is tested using F-test. The results of the hypothesis testing for different facilities are given in Table 3.

Table 3. Hypothesis testing using F-test

Facility	Young vs. Middle vs. Old	Male vs. Female
	Test Statistic	**Test Statistic**
Sidewalk	F(2, 631) = 36.21, p < 0.01, Rejected	F (1, 633) = 3.28, p > 0.05, Not Rejected
Wide-sidewalk	F (2,1306) = 38.23, p <0.01, Rejected	F (1, 1308) = 3.93, p >0.05, Not Rejected
Carriageway	F (2, 943) = 20.91, p < 0.01, Rejected	F (1, 945) = 0.17, p > 0.05, Not Rejected

The results indicate that a significant difference exists between the speeds of pedestrians in different age groups on all facilities at 99% confidence interval. Further analysis revealed that young pedestrians walk significantly faster than the rest and older pedestrians walk significantly slower than middle-aged pedestrians at all study locations.

Even though males walk faster than females, the difference is not significant on sidewalks, wide-sidewalks and carriageway. The results of the present study support the existing literature that there is no significant difference between male and female pedestrian walking speeds (Fruin, 1971, Knoblauch, 1996, Montufar et al., 2007), but it is contrary to the findings of Kotkar et al. (2010).

4.2 Crosswalk

Crossing speed and gap accepted are the main parameters that decide pedestrian provisions. Crossing speed is mainly used in the design of signals and also in the estimation of risk analysis. The speed variations at crossing locations based on gender and age are given in Table 4 and 5 respectively. Based on gender it is found that male pedestrians speed is higher in all locations. Their speed varies from 1.18 to 1.41 m/s. The crossing speed of the pedestrians increases with width of the road. The minimum value for crossing speed for female pedestrians is at location VII. The average crossing speed of all pedestrians is 1.25 m/s. The standard deviation is found higher at location IV (0.45) due to heavy vehicular traffic at this location and these forces the pedestrians to accept lower gaps by increasing their speed. Even though the traffic at location VII is low the deviation is found high due to more number of heavy vehicles in the traffic stream at this location. The average speed at all locations for male and female is 1.30 and 1.22 m/s respectively. This is lower than the speed reported by Wilson and Grayson (male -1.32 m/s, female -1.27 m/s, 1980) and Tarawneh (Male -1.35 m/s, Female – 1.33 m/s, 2001).

Table 4. Mean and standard deviation of speed based on gender

Location	Male		Female		Young		Middle Age		Old	
	Mean (m/s)	**SD**	**Mean (m/s)**	**SD**	**Mean (m/s)**	**SD**	**Mean (m/s)**	**SD**	**Mean (m/s)**	**SD**
III	1.31	0.31	1.25	0.34	1.49	0.31	1.24	0.32	0.99	0.27
IV	1.41	0.45	1.28	0.31	1.43	0.52	1.32	0.33	1.29	0.26
VII	1.18	0.28	1.06	0.23	1.24	0.32	1.15	0.26	1.05	0.22
VIII	1.29	0.36	1.28	0.36	1.32	0.23	1.16	0.38	1.14	0.27

Based on the age, the older pedestrians cross a road slower than others at all the four locations (refer Table 4). The average crossing speed of young, middle aged and old is 1.37, 1.22 and 1.12 m/s respectively. The younger pedestrians have 14.5 % higher speed than that of older pedestrians. The minimum crossing speed is found to be 0.99 m/s for old pedestrians and maximum is 1.49 m/s for young pedestrians. The crossing speeds in the present study are comparable to those reported by Knoblauch (Middle age – 1.25, Old – 0.97, 1996) and Tarawneh (Middle age – 1.22, Old – 0.97, 2001).

ANOVA-test is used to examine whether the group means are significantly different from each other at 95% confidence level and no significant difference is found in the mean speeds of male and female pedestrians. The results are given in Table 5.

Table 5. ANOVA-test statistics for pedestrian speeds within gender

Location No	**Male x Female**		**Young x Middle Age x Old**	
	Test Statistic	**Remarks**	**Test Statistic**	**Remarks**
III	$F(1,142) = 1.654, p>0.05$	Not Significant	$F(2,141) = 4.121, p<0.05$	Significant
IV	$F(1,98) = 1.684, p>0.05$	Not Significant	$F(2,97) = 2.657, p>0.05$	Not Significant
VII	$F(1,254) = 0.001, p>0.05$	Not Significant	$F(2,253) = 3.365, p<0.05$	Significant
VIII	$F(1,101) = 0.010, p>0.05$	Not Significant	$F(2,100) = 4.858, p<0.05$	Significant

The significant difference is found between young and old pedestrians at location VII and between middle and old at location III and VIII. This is mainly due to availability of critical headway at these locations. Here pedestrians are forced to cross the road with adjusted speed based on the availability of the gap

Based on the present study, an average speed of 1.25 m/s is recommended for the design of various pedestrian crossing facilities and if the percentage of women and older pedestrians are higher then a lower value of 1.1 m/s is recommended in mixed traffic conditions like prevailing in India.

5. Flow relations

The most important part in any traffic analysis is the estimation of flow parameters, i.e. speed, flow and density. These are mainly used in the estimation of capacity and level of service of a traffic facility. The basic dependence is made between speed and density and other relations are implied relations. The basic speed-density equations for different facilities are given in Table 6 with corresponding parameters and test statistic. Generally, speed density relation is exponential except on carriageway where it is found to be linear. The equations for crossings are similar to that developed by Underwood for unsignalized cross walks.

Table 6. Speed-Density Relation at various locations

Location	Relation	R^2	F value	p-value
Sidewalks	$\mu = 98.16*e^{-0.27*k}$	0.570	72.894	0.000
Wide-sidewalks	$\mu = 87.84*e^{-0.30*k}$	0.805	470.11	0.000
Carriageway	$\mu = 89.93 - 20.85*k$	0.895	831.00	0.000
III	$\mu = 95.564e^{-0.2.616k}$	0.555	65.860	0.000
IV	$\mu = 86.389e^{-1.206k}$	0.823	66.244	0.000
VII	$\mu = 65.253e^{-0126k}$	0.281	6.469	0.024
VIII	$\mu = 71.192e^{-0.720k}$	0.534	44.571	0.000

Applying the boundary condition in the above equations, the optimum values of flow parameters are estimated and these are given in Table 7. Figure 1 and 2 shows the flow characteristics of pedestrians walking on different types of facilities and for crossing.

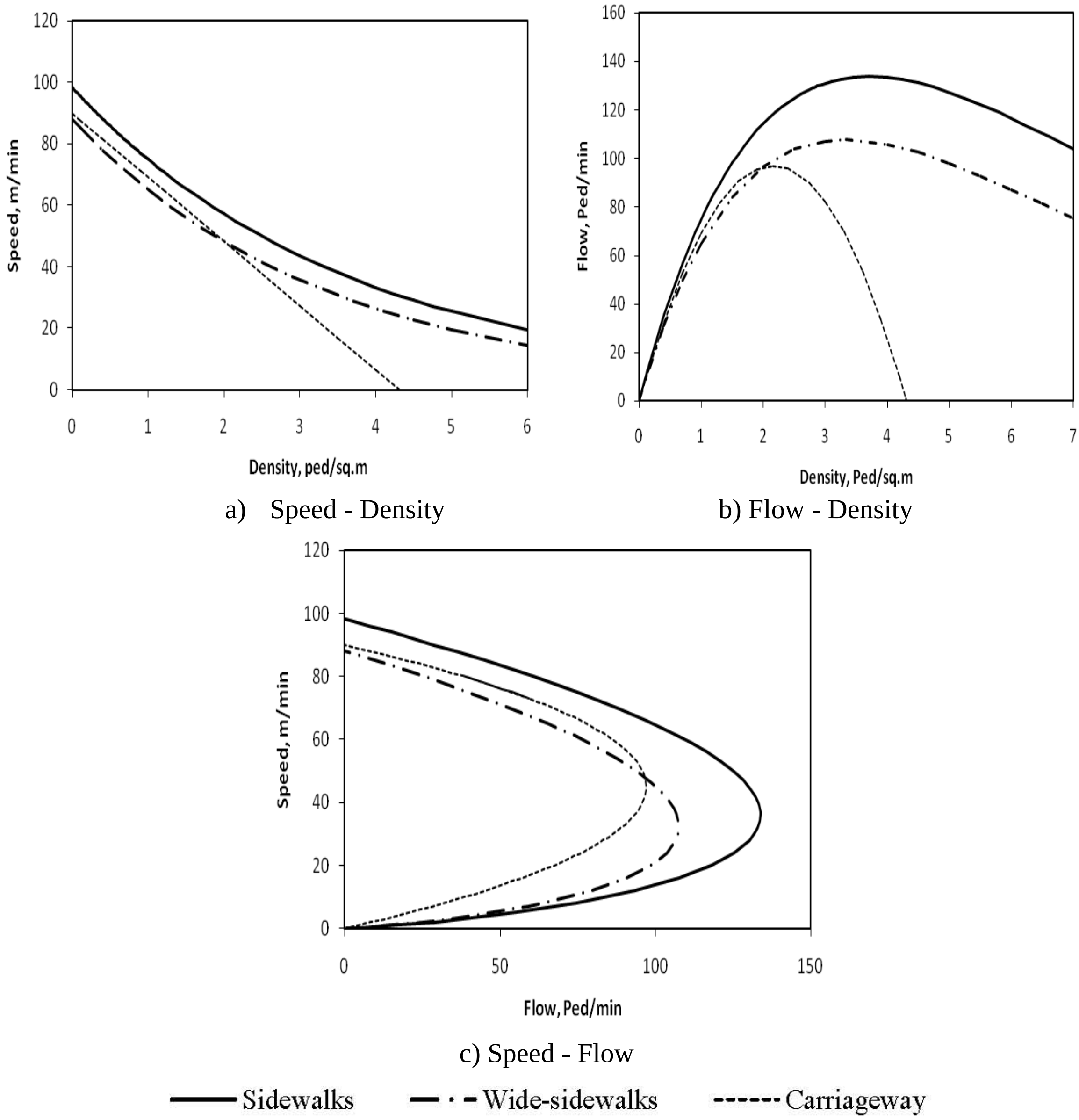
Table 7. Flow characteristics at different conditions

Location	Free flow Speed (u_f) m/s	Optimum Density (k_O) ped/m	Maximum Flow (q_{max}) ped/min	Optimum Speed (u_O) m/s
Sidewalks	1.64	3.70	133.75	0.60
Wide-sidewalks	1.46	3.33	107.72	0.54
On Carriageway	1.50	2.16	96.97	0.75
III	1.59	1.00	13.00	0.59
IV	1.45	1.00	26.00	0.53
VII	1.09	8.00	191.00	0.40
VIII	1.19	2.00	36.00	0.44

The free flow speed is found to vary from 1.46 to 1.64 m/s for walking conditions and 65.25 to 95.56 m/min for crossing conditions. This shows that the sidewalk free flow speed is much higher than crossing speed under free state conditions.

The optimum density for crossing is found to be maximum at location VII where a higher pedestrian flow is observed compared to sidewalks. The maximum flow rate is found to vary from 13 ped/min to 191 ped/min for crossing facilities, whereas, the variation is low on walking facilities. The presence of the bus terminuses and commercial centre nearby location VII generated greater pedestrian flow. The maximum flow is higher on sidewalks than wide-sidewalks which is contrary to the belief that increase in the width of the facility will result in increased flow. The reason for this variation is that the squeezing effect (pedestrians trying to squeeze past his predecessor or squeeze between the pedestrians in opposite flow) is greater on sidewalks than wide-sidewalks. As a result of the squeezing, more pedestrians are walking in the available area leading to higher optimum density and lower space requirement (0.27 sq.m/ped) under maximum flow conditions.

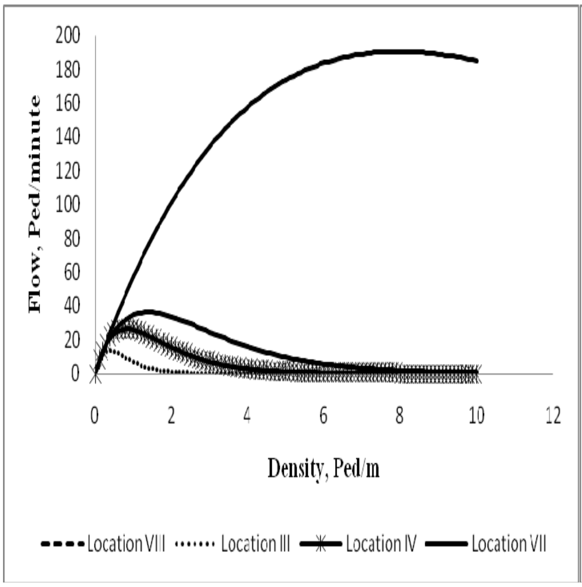
The optimum speed is higher for carriageway when compared with the rest. The presence of parked vehicle on the carriageway reduced the effective width of the facility forcing the pedestrians to walk farther on the carriageway. In order to minimize the interactions with the vehicular traffic on carriageway, pedestrians are observed walking faster to get out of the influenced situation as soon as possible. Pedestrians at location VII are observed to follow their predecessor mostly as the chances of overtaking the slower pedestrians are minimal due to heavy bi-directional flow, which led to lower optimum speed (24.01 m/min) at this facility.



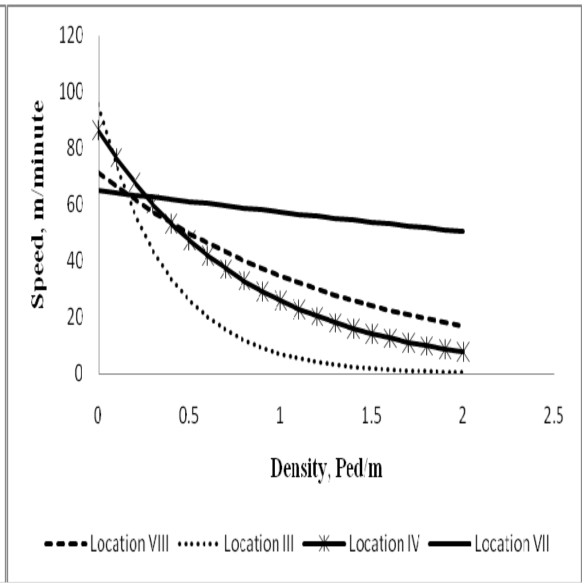
a) Speed - Density b) Flow - Density

c) Speed - Flow

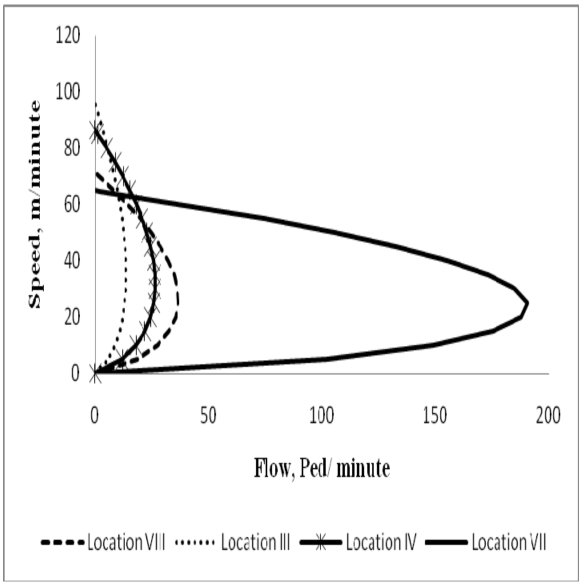
Fig.1 Flow characteristics of pedestrians on different types of walking facilities



a) Speed - Density



b) Flow - Density



c) Speed - Flow

Fig. 2 Flow characteristics of pedestrians during crossing

6. Gap Acceptance

One of the most important factors that distinguishes walking with crossing behaviour of pedestrians is the gap acceptance. This gap acceptance is the most important part in accident risk analysis. If a gap accepted is less than the minimum safe value, then it creates confusion to driver and results in accident. This section deals with estimation of gap acceptance of pedestrians by estimating the minimum gap and average gap of pedestrians for different pedestrian characteristics.

6.1 Critical Gap

Critical gap is defined as the minimum gap required between the vehicles for safe crossing of pedestrians. Critical gaps at each site was estimated from their gap acceptance (Fa) and crossing time (Ft) distribution curves as shown Figure 3. The intersection of the curves (Fa) and (1-Ft) gives the value of the gap which is just equal to the crossing time of a pedestrian. This is the critical gap. Critical gap at four locations for various categories of pedestrians are given in Table 8.

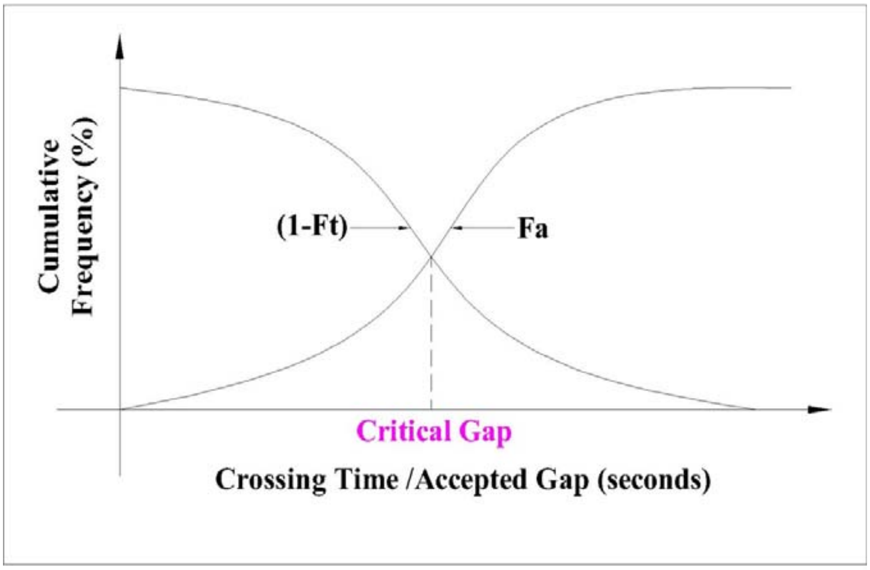


Fig.3 Critical Gap Estimation

Table 8. Critical Gap

Location	Critical Gap (Seconds)
III	6.68
IV	5.90
VII	7.60
VIII	6.25

It is found that critical gap decreases with increasing road width. This is due to the fact that the crossing speed increases with width of the road as explained in Section 4.2. Critical gap at location IV is minimum due to increased crossing speed of pedestrian at that location.

6.2 Average accepted Gap

The accepted gap is the main parameter that has impact on the risk taken by the pedestrians during crossing the road. The variation in accepted gap based on the age and gender is given in Table 9. The value varies from 7.2 to 11.3 s. The average gap accepted by male pedestrians at location III is found close to their critical gap. This shows the risky nature of crossing by male pedestrians. Table 9 gives the average gaps accepted by pedestrians based on their age. The accepted gap is lowest for Young at location III and the highest for Old at Location VII. The percentage deviation of accepted gap from critical gap is also lowest for younger pedestrians at location III (4.4 %). It is found that the older pedestrians exhibit a higher level of deviation in accepted gap from critical gap than the other two categories.

Table 9. Mean and standard deviation of accepted gap based on gender

Location	**Male**		**Female**		**Young**		**Middle Age**		**Old**	
	Mean (s)	**SD**	**Mean (s)**	**SD**	**Mean (s)**	**SD**	**Mean (s)**	**SD**	**Mean (s)**	**SD**
III	7.2	3.77	8.6	2.62	7.0	2.63	8.0	3.90	10.3	2.86
IV	9.7	4.45	9.5	6.85	9.7	4.12	9.7	5.26	10.0	5.47
VII	10.8	3.62	11.3	3.98	10.0	3.88	11.2	3.88	10.8	2.24
VIII	10.0	4.08	8.8	6.56	10.4	5.63	9.3	5.42	8.3	2.68

The ANOVA-statistics (Table 10) indicated that the average accepted gaps by male and female are statistically different at location III only and there is no significant difference at other three locations. At location III the gap accepted by male is about 16 % less than female. Further the vehicle speed is low at this location and male pedestrians take higher risk by accepting smaller gap than their female counterpart.

Table 10. ANOVA-test statistics for accepted gap within gender

Location No	**Male × Female**		**Young x Middle Age x Old**	
	Test Static	**Remarks**	**Test Static**	**Remarks**
III	$F(1,142) = 4.899, p<0.05$	Significant	$F(2,141) = 1.020, p>0.05$	Not significant
IV	$F(1,98) = 2.313, p>0.05$	Not Significant	$F(2,97) = 0.495, p>0.05$	Not significant
VII	$F(1,254) = 0.270, p>0.05$	Not Significant	$F(2,253) = 0.593, p>0.05$	Not significant
VIII	$F(1,101) = 1.524, p>0.05$	Not Significant	$F(2,100) = 0.346, p>0.05$	Not significant

Statistical Significance was tested at 95% confidence level by ANOVA test and no significant difference was found in the mean accepted gap of pedestrian for different age groups. The results are given in Table 10.

Further, the pedestrians in field were observed making three types of crossing patterns namely; single stage, two stages and rolling. When a pedestrian accepts a gap which is large enough to make crossing without stopping, it is called single stage gap acceptance. In rolling gap, a pedestrian will not wait to cross when all lanes are completely clear, but he anticipates that lanes would be clear as he crosses and uses the rolling gap available to cross the street. Whereas in two stage crossing the pedestrian will cross up to centre by accepting a gap and wait there until he gets a suitable gap.

Table 11 gives the gap acceptance behaviour of pedestrians under different types of crossings. Single stage gap acceptance was found not to vary much from critical value. Higher deviation (almost 84 %) from critical gap was found for two stage gap acceptance. For lesser road width (location IV) rolling gap is higher than the other two. It was observed that two stage crossing is least used and most people preferred rolling type of gap for crossing.

Table 11. Gap acceptance based on type of crossing

Location	Single		Rolling		Two stage	
	Mean (s)	Standard Deviation	Mean (s)	Standard Deviation	Mean (s)	Standard Deviation
III	7.40	5.45	9.10	3.59	8.28	4.37
IV	8.30	4.03	11.30	3.36	9.14	4.22
VII	10.90	4.91	10.70	4.79	*	*
VIII	9.40	3.63	8.70	2.98	11.46	2.34

Statistical significance is tested at 95% confidence level by ANOVA test (Refer Table 12) and no significant difference is found in the mean accepted gap of pedestrian for different type of crossings.

Table 12. ANOVA-test statistics for gap acceptance within type of crossing

Location	Single x Rolling x Two	
	Test Static	Remarks
III	$F(2,164) = 1.000$, $p>0.05$	Not Significant
IV	$F(2,121) = 3.212$, $p>0.05$	Not Significant
VII	$F(2,401) = 0.677$, $p>0.05$	Not significant
VIII	$F(2,106) = 1.919$, $p>0.05$	Not significant

The average gap accepted by the pedestrians in the present study varies from 7.20 to 11.30 s based on gender, 7.00 – 10.80 s based on age and 7.40 – 11.46 s based on type of crossing. These are higher than the values reported in literature. Moore (1953) reported 3 to 7 s, Palmarthy (1994) reported 3.33 to 7.14 s and Brewer et al (2006) reported 5.3 – 9.4. Considering the safety of pedestrians an average value of 8 s is recommended to provide pedestrian facility at crossing in India. At locations where female or older pedestrians are more, a higher value of 12 s is recommended.

7. Conclusions

The speed analysis of pedestrians on different facilities revealed that pedestrians walk differently at different facilities. Irrespective of type of facility, young pedestrians are always fast. The speeds of male pedestrians are greater than the female pedestrians on all pedestrian facilities. This goes with the available literature also (Fruin, 1971; Polus et al., 1983; Tarawneh, 2001; Kotkar et al., 2010). Further, the walking speeds of pedestrians on narrow facility (sidewalks) are higher than that on wider facilities (wide-sidewalks). The reason could be that the increase in the space and freedom result in leisure walking behaviour of pedestrians on wider facilities when compared with the narrow facilities. Females, middle aged pedestrians and old pedesrtians are found walking faster on carriageways. The average crossing speed for male and female pedestrians was 1.25 m/s. Based on the study, an average speed of 1.3 m/s is recommended for the design of various pedestrian crossing facilities and if the percentage of women and older pedestrians are high then a lower value of 1.1 m/s is recommended in mixed traffic conditions especially in India. The walking speeds are found to be significantly lower than the crossing speeds.

Pedestrian flow characteristics change depending on the type of available facility. As the width of the walking facility increases, pedestrians are found walking comfortably. The flow relationships developed in this study suggest that increase in the width of a facility does not necessarily result in increased flow. The higher optimum speed indicates that pedesrians are trying to get out of the influenced situation as soon as possible. In mixed traffic conditions also the observed free-flow speed (1.50 m/s) is comparable to that of German pedestrians (1.49 m/s) (Oeding, 1963). Further, the maximum flow rate in the present study is comparable to the findings of Yu (1993). This study also suggests that under maximum flow condition space occupied by pedestrians in India is lower than that reported for Germany (Oeding, 1963) and Philippines (Gerilla, 1999) and higher than that of Singapore (Tanaboriboon et al., 1986) and China (Yu, 1993). The flow characteristics developed will aid in better design of pedesrian facility meant for specific purposes like school trips etc.

Three types of crossings were observed in field; single stage, two stage and rolling gap. Single stage gap acceptance was found to have less deviation from critical gap. Two stage crossings were less in number and people preferred rolling gap crossing as compared to the other two types of crossing. The average gap accepted was found to be the lowest for Young and the highest for Old pedestrians. It was found that the older pedestrians exhibit a higher level of deviation in their accepted gap from critical gap than the other two categories. Based on age, it was found that young pedestrians take higher risk while crossing the roads. The critical gap at four locations was between 5.90 and 7.60 s and it decreases with increasing road width. It suggests that crossing speed of pedestrian increases with road width. Considering the safety aspect a general value of 8 s is recommended for design of crossing facilities (like signal) and a higher value of 12 s is recommended at locations where female or old pedestrians are substantial.

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