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Comparative Study of Pedestrian Crossing Behaviour at Uncontrolled Intersection and Midblock Locations

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Abstract

Understanding pedestrian-vehicular interaction and individual's responsive behaviour under mixed traffic flow condition is a complex task. Individual's perception and risk taking to cross the road varies with pedestrian characteristics (age, gender, luggage, and trip purpose), environmental characteristics, vehicular flow characteristics, land use type. The present study made a comparison of average pedestrian crossing speeds at different pedestrian crossing locations in medium size cities (Warangal and Thiruvananthapuram in India) under mixed traffic conditions to investigate the major factors affecting the pedestrian road crossing behaviour. Four hours of traffic data was collected using videography method from three uncontrolled intersections and two midblock locations. Significant test was done for crossing speeds between different locations and different pedestrian types. The statistical results showed that there is a significant difference between the crossing speed of midblock and intersection. Male and middle aged pedestrians have higher crossing speeds than female and young, old aged pedestrians respectively. It is concluded that the pedestrian crossing behaviour and their perception in risk taking varies with location, pedestrian's characteristics. Simulation results showed that the average travel time delay changed with pedestrian age and gender and increased linearly with the pedestrian volume. The results can be used to understand pedestrian risk with vehicular flow.

Keywords: Pedestrian age; pedestrian gender; crossing speed deviation factor; uncontrolled intersection; midblock.

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1. Introduction

Even though the modern technology improved, the pedestrian safety at pedestrian crossings is still a severe problem. This problem is more severe in counties like India because of the mixed traffic conditions and aggressive behaviour of either driver or pedestrians (Lobjois et al. 2013). Due to the less priority and high waiting times while crossing the road, pedestrians are trying to cross the road with lot of risk and there is a possibility of incidents with different vehicle types. In India (as per the MORTH), the total number of accidents and number of pedestrians killed at the pedestrian crossings are increasing year by year and the statistics were shown in the table 1.

Table 1. Total number of pedestrians killed in road crossings from 2014 to 2016 in India.

Year	Total number of road accidents			At pedestrian crossings		
	Total accidents	Persons killed	Persons injured	Total accidents	Persons killed	Persons injured
2014	228089	51344	213819	18755	5661	17042
2015	238637	54066	223129	20320	5934	17534
2016	216638	56643	220868	28397	9486	26365

With the increased vehicular traffic, pedestrian safety is at a risk. It should be given priority to encourage walking trips with an assurance to their safety. Understanding pedestrian vehicular interaction and individual’s responsive behaviour under mixed traffic flow condition is a complex task. Individual’s perception and risk taking to cross the road varies with pedestrian characteristics: age, gender, luggage, trip purpose, environmental characteristics, vehicle characteristics and vehicular flow characteristics, land use type. Pedestrians with higher crossing speeds will cross the road very fast compared to the pedestrian with low crossing speeds. The crossing speed of pedestrian also vary with the type of pedestrian crossings and traffic composition. The demand for pedestrian facilities is influenced by a number of factors like nature of the local community, local land use activities, safety and security. Crossing speed deviation factor (CSDF) is one of the factors, which is used to analyse the pedestrian crossing behaviou. CSDF is defined as the ratio of crossing speed variation (V_{85}-V_{15}) and average crossing speed (Rengaraju and Rao, 1995).

2. Literature review

Many studies were conducted related to the pedestrian crossing behaviour at pedestrian crossings. Some of them will be briefly discussed in this section. Conducting traffic conflict studies could be an effective alternative for safety analysis because of the high correlation between the data on collected historical crashes and the observed traffic conflicts at the intersections (Yi et al. 2012). Width of the road, size of the city, climatic and temperature conditions, and time of the study play important role on pedestrian flow characteristics (Laxman et al. 2010). The pedestrian characteristics in India are different from other countries. So the design of pedestrian facility should be based on the characteristics of Indian pedestrians, rather than following other International standards. The walking speeds of pedestrians are significantly different from their crossing speeds. The crossing speeds of the pedestrians are higher than the walking speeds irrespective gender (Chandra et al., 2013). The spatial and temporal distribution of pedestrian-vehicle crashes vary for different pedestrian age groups and genders (Moridpour et al. 2018). The frequency of attempting gap and pedestrian rolling gap behaviour at uncontrolled mid-block locations increased the probability of accidents (Kadali et al. 2013). The average pedestrian crossing speed at un-signalized crossings was 1.72 m/s for the young, 1.47 m/s for the middle-aged, and 1.16 m/s for the elderly (Griffiths et al. 1984). The average crossing speed for men was 1.32 m/s and that for female was 1.27 m/s (Wilson and Grayson. 1980). The age and gender both have significant effect on the observed safety-related behaviours. Male pedestrians are less likely to wait for the signal due to the factors such as issues of trust or propensity to take the risks of waiting (Bradbury et al. 2012). Male pedestrians exhibited shorter waiting time and use crosswalks less time than the female pedestrians (Nicholas N. Ferenchak. 2016). Vehicle type, pedestrian age, weather condition, and point of first contact were significantly affect the pedestrian injury severity (PIS) at intersections for all drivers (Z. Ma et al. 2017). Even though the average waiting time can be measured in real life, the microsimulation software helps to analyse the situations for different volume combination and parameter settings. The travel time delay increases exponentially with the increase in vehicle volume. The Level of Service (LOS) with Refuge Island was better for the smaller delays (Istvan et al. 2014). The difference in delays at entry and exit legs was small for sighted pedestrians and the same was more in case of blind pedestrians who experienced higher delays on the exit side. The results from the micro simulation indicate that the pedestrian delay increases in a nonlinear fashion as the vehicle volume increases (Rouphail et al. 2005). The factors which increase the probability of fatal pedestrian injuries are increase in pedestrian age, male driver, commercial area, truck, freeway etc. and the factors which decrease the fatal injuries were increase in driver age, with traffic signal control, inclement weather, curved roadway etc. (J. K. Kim et al. 2008). There was a very less increase in the pedestrian travel time with the increase in the pedestrian demand with no vehicular traffic and the same drastically increases first and then decreases with the increase in pedestrian demand and vehicular traffic (Bonisch and Kretz. 2009).

In countries like India, different studies were conducted related to the pedestrian crossing behaviour but most of them were conducted in the metropolitan cities like Mumbai, Delhi etc. Conducting the studies and suggesting guidelines to the faster developing medium population cities (like Warangal) will help to understand pedestrian characteristics.

3. Study area and data collection

The present study was conducted at both uncontrolled intersections and mid-blocks. Two 4-legged uncontrolled intersections (One from Kazipet (intersection-1) and another from Hanamkonda (intersection-2)) in Warangal city and two mid-blocks (one from Warangal city (Hanamkonda (midblock-1)) and another from Thiruvananthapuram city (midblock-2)) were selected to study crossing speed variations. One more location was selected for simulation purpose from Warangal city (100 feet road intersection (intersection-3)). These locations are faster developing medium size cities (with respect to population) in India. Commercial type of land use was observed at all the study locations. The study locations were shown in figure 1 below. Four hours of traffic data (morning two hours and evening two hours) was collected from the study locations during the peak periods using a videography method. The video recording gives the information about the time taken by the pedestrians to cross the road, number of pedestrian samples involved in the study, pedestrian crossing behaviour (crossing alone or in group, crossing speed variations). The pedestrian crossing speed was calculated by dividing the road width with pedestrian road crossing time (excluding waiting time). The geometric details of selected study locations were shown in table 2 below. Classified volume count was done in each direction and 10,050 vehicle, and 283 pedestrian volumes were observed in four hours at 100 feet road location.

a b

c d

Fig. 1. (a) Uncontrolled intersection at Kazipet; (b) Uncontrolled intersection Hanamkonda; (c) Mid-block at Hanamkonda; (d) Mid-block at Thiruvananthapuram

Table 2. Geometric details observed pedestrian volumes at the study locations.

Location	Type of section	Number of lanes (major road)	Each lane width (m / lane)	Presence of median in study area (m)	Pedestrians observed volume (ped/hr)
Thiruvananthapuram (midblock-1)	Mid-block	6	3.5	Yes (0.2)	336
Hanamkonda, Warangal (midblock-2)	Mid-block	4	4.05 (to Warangal), 3.55 (to Kazipet)	Yes (0.4)	452
Kazipet, Warangal (intersection-1)	Uncontrolled	4	3.5	No	432
Hanamkonda, Warangal (intersection-2)	Uncontrolled	4	3.5	No	463
100 feet road, Warangal (intersection-3)	Uncontrolled	4	3.5	Yes (1.0)	283

4. Results and Discussion

4.1 Pedestrian crossing speed analysis

The pedestrian crossing speed was computed for each pedestrian by dividing the distance he/she covered by the time of crossing (by excluding the waiting time at the median to give the right-of-way to the vehicular flow). For each location, different graphs (age and gender wise) were drawn between the crossing speed verses cumulative percentage speed below the give speed. From each graph different speeds (minimum, maximum, 15th percentile, 50th percentile, and 85th percentile speeds) and crossing speed deviation factor (CSDF) were measured for all the study locations.

Table 3. Crossing speed and CSDF for different type of pedestrians at different intersections.

Location	Pedestrian attribute		Pedestrian crossing speeds (m/s)					CSDF
			Minimum	15th percentile	50th percentile	85th percentile	Maximum	
Intersection-1	Age	Young	0.87	0.97	1.11	1.27	1.60	0.27
		Middle	0.83	0.96	1.16	1.36	1.57	0.35
		Old	0.77	0.81	0.94	1.18	1.39	0.39
	Gender	Male	0.91	1.01	1.16	1.29	1.60	0.24
		Female	0.77	0.97	1.11	1.25	1.39	0.25
Intersection-2	Age	Young	0.74	0.95	1.14	1.34	1.61	0.34
		Middle	0.76	1.01	1.18	1.34	2.02	0.28
		Old	0.75	0.85	1.08	1.22	1.45	0.35
	Gender	Male	0.78	1.02	1.19	1.39	2.02	0.31
		Female	0.74	0.94	1.08	1.23	1.51	0.28

Table 4. Crossing speeds and CSDF for different types of pedestrians at midblock locations.

Location	Pedestrian attribute		Pedestrian crossing speeds (m/s)					CSDF
			Minimum	15th percentile	50th percentile	85th percentile	Maximum	
Midblock-1	Age	Young	0.68	0.78	1.16	1.46	1.81	0.41
		Middle	1.02	0.82	1.21	1.63	1.81	0.51
		Old	0.84	0.68	1.02	1.39	1.59	0.54
	Gender	Male	0.76	0.91	1.16	1.48	1.81	0.50
		Female	0.68	0.89	1.10	1.36	1.81	0.43
Midblock-2	Age	Young	0.60	0.96	1.23	1.78	2.13	0.67
		Middle	0.76	0.98	1.28	1.95	2.40	0.75
		Old	0.63	0.84	1.03	1.64	2.09	0.78
	Gender	Male	0.60	0.89	1.28	1.95	2.40	0.84
		Female	0.63	0.98	1.20	1.72	2.23	0.62

The minimum crossing speed observed at the intersection (0.74 m/s for young female) was higher than the midblock (0.60 m/s for young male) and the maximum observed crossing speed at the midblock (2.40 m/s middle aged male) was higher than the intersection (2.02 m/s middle aged male). The 15^{th} percentile crossing speeds were observed to be higher in case of intersections compared to the midblock locations. 50^{th} percentile and 85^{th} percentile crossing speeds were higher for midblock locations compared with intersection locations. Pedestrian crossing speeds were analysed using ANOVA test to investigate the major parameters that affects the pedestrian crossing speed. The test was conducted at 95% significance level. ANOVA test results for intersections and midblock locations were shown in table 5. Significant test reveals that there is a significant difference (with F value 45.654 and significance level of 0.000) between the crossing speeds of midblock and intersection. The average pedestrian crossing speed observed at the midblock (1.26 m/s) was higher than the intersection (1.13 m/s) and standard average pedestrian crossing speed (1.20 m/s suggested by IRC). Higher vehicular speeds and no control from the other traffic is the reason for higher speeds at midblock locations. Low vehicular speeds of the through traffic due to the obstructions from the right and left turning traffic were the reason for low pedestrian crossing speeds.

Table 5. ANOVA test results for crossing speeds at intersections and midblock locations.

Location	Age		Gender	
	F	Significance level	F	Significance level
Intersection-1	2.998	0.023	2.532	0.026
Intersection-2	11.983	0.000	11.301	0.001
Midblock-1	11.087	0.000	4.152	0.013
Midblock-2	3.568	0.019	2.68	0.025

From the significant results it was observed that pedestrian age is most significant factor which has significant effect on the pedestrian crossing speed. Pedestrian gender also affects the pedestrian crossing speed. The average male pedestrian crossing speed (1.235 m/s) was observed to be higher than that of the average female pedestrian crossing speed (1.155 m/s). Male pedestrians crossing speeds (1.22 m/s) were higher than the female pedestrians (1.11 m/s) (Rastogi et al. 2011). And also it was observed that, the observed average crossing speeds of male pedestrians at midblock locations (1.38 and 1.23 m/s for intersection-1 and intersection-2 resp.) were higher than the intersections (1.15 and 1.18 m/s for midblock-1 and midblock-2 resp.). Male pedestrians will take the high risks to cross the road instead of waiting to find the required gap. This might be one of the reason for higher crossing speeds for male pedestrians. The male pedestrian will wait for shorter time than female pedestrians (Tiwari et al. 2007). The average pedestrian crossing speeds were observed to be higher in case of middle age (1.26 m/s) compare to that of young (1.20 m/s) and old age (1.13 m/s) pedestrians. And also, the average crossing speed for middle aged (1.33 m/s at midblock and 1.19 m/s at intersection) pedestrian was higher compared with young aged (1.26 m/s at midblock and 1.14 m/s at intersection) and old aged (1.20 m/s at midblock and 1.07 m/s at intersection) pedestrians at both the locations (midblock and intersection). CSDF is used for better understanding of the effect of pedestrian volume on the pedestrian crossing speed. A model fit has been made for CSDF and pedestrian volumes shown in figure 2 below.

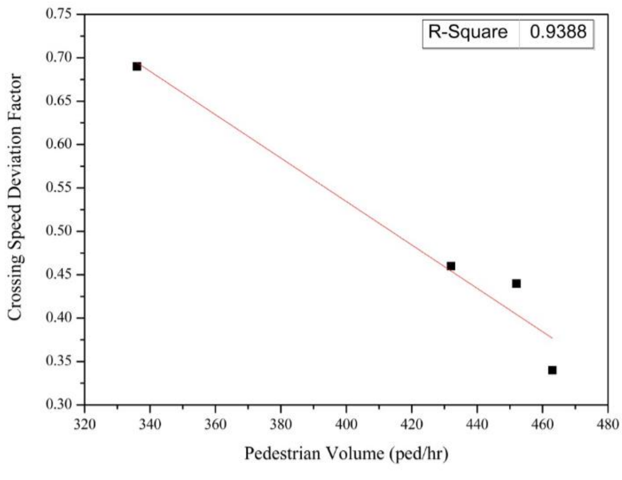

Fig. 2. Relationship between CSDF and pedestrian volume

Plot was drawn between the CSDF and the pedestrian volume per hour (Q_{ped}) using the pedestrian volumes of all the study locations and relationship was shown in equation (1) below.

$$\mathrm{CSDF} = -0.0025\mathrm{Q}_{\mathrm{ped}} + 1.5426 \quad (1)$$

Where, CSDF = crossing speed deviation factor, Q_{ped} = pedestrian volume (ped/hr).

From the equation (1), it was clear that the crossing speed deviation was decreases as the volume of pedestrian increases. A higher crossing speed deviation is possible when there is less volume of pedestrians. This may be due to the no platoon effect and there is a possibility of irregularity of crossing speeds of pedestrians.

4.2 Pedestrian travel time delay analysis at intersections

A simulation study is conducted to verify the effect of gender and age on average pedestrian travel time delay. These results will be useful for understanding the pedestrian perception and the simulation requirements to adopt to the field situations. Calibration is carried out by comparing field pedestrian volume (for 100 feet road intersection) and simulated pedestrian volume. Pedestrian crossing speeds obtained from the field analysis are used in the VISSIM simulation tool to characterize the behaviour of pedestrians. Simulation for different pedestrian volumes (25%, 50%, 75%, 100% increase in field volumes) and different pedestrian types (100% male, 100% female, 100% young age, 100%, middle age, 100% old age pedestrians) was done and results were analysed. The average travel time delay for different pedestrian types and different volumes were shown in figure 3.

a b

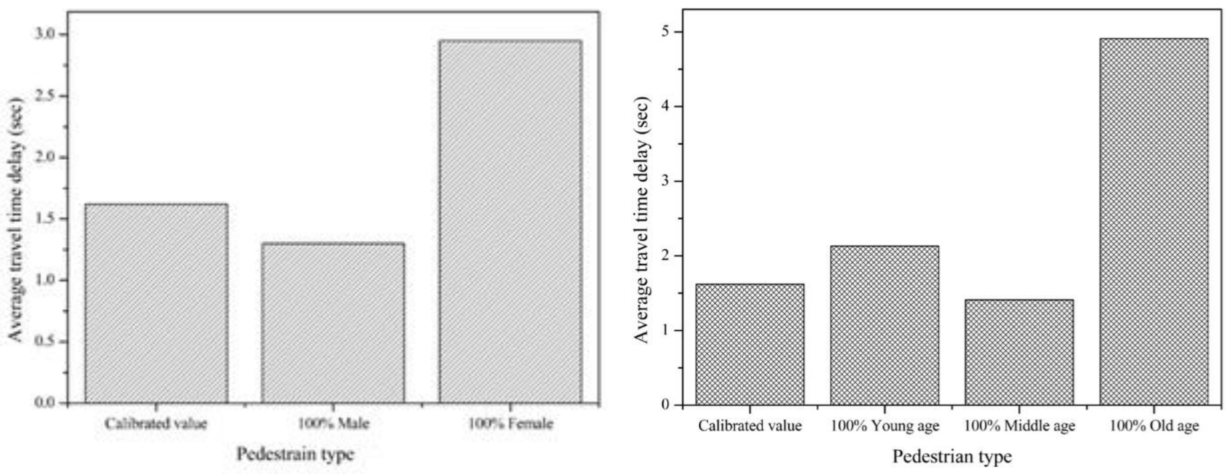

Fig. 3. (a) Average travel time delay variation with pedestrian gender; (b) Average travel time delay variation with pedestrian age

The average travel time delay was observed to be lower in 100% male (field female pedestrian volume replaced with male pedestrian volume) case and higher in 100% female (field male pedestrian volume replaced with female pedestrian volume) case when compared with average travel time delay calibrated to the field conditions. Also it was observed that average travel time delay was higher in case of 100% female compared with 100% male case. This might be due the lower crossing speeds of the female pedestrians. The average travel time delay was higher in case of 100% old age pedestrians compared with calibrated values of 100% young age, and 100% middle age pedestrian values. The lower values were observed in case of 100% middle age pedestrians. This difference in travel time delay between different age and gender pedestrians might be due to the changes in the crossing speeds. Male and middle aged pedestrians with higher crossing speed will take more risks than other type of pedestrians to cross the road.

Simulation was done to different pedestrian volumes by increasing the field volume by 25%, 50%, 75% and 100%. From the simulation results, average travel time delay was taken and plot was drawn between the average travel time delay and pedestrian volumes (shown in below figure 4). From the plot it was observed that, the average travel time increased linearly with the pedestrian volume.

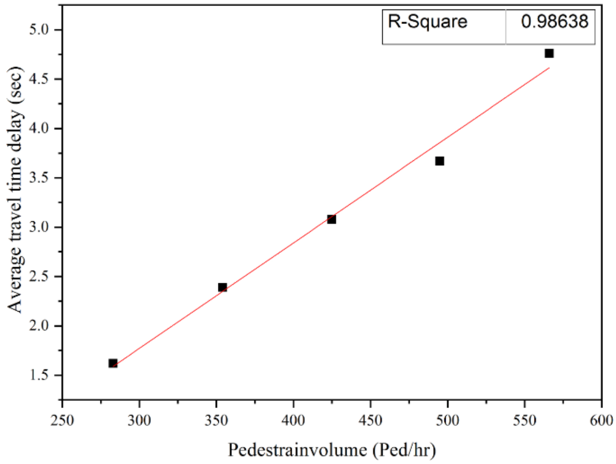

Fig. 4. Average travel time delay variation with pedestrian volume

5. Conclusions

The present study compared the average pedestrian crossing speeds at different pedestrian crossing locations in faster developing medium size cities (like Warangal and Thiruvananthapuram) under mixed traffic conditions. The pedestrian crossing speeds at two uncontrolled intersections and two midblock locations were analysed to investigate the major factors affecting the pedestrian crossing speed.

50th percentile and 85th percentile crossing speeds were observed to be higher in case of midblock locations but 15th percentile crossing speeds were higher for intersections. ANOVA test was conducted on the crossing speeds and the statistical results showed that there is a significant difference in crossing speeds between intersection and midblock locations. Average crossing speed was higher in case of midblock location (1.26 m/s), which is higher than the standard average pedestrian crossing speed (1.20 m/s suggested by IRC). Male pedestrian crossing speeds (1.23 m/s) were higher than female pedestrians (1.15 m/s). A linear regression analysis was done to fit a model for CSDF and pedestrian volume per hour. There exist a strong inverse correlation between CSDF and pedestrian volume. The increase in the sample size is the reason for inverse correlation between them. Simulation results showed that the average travel time delay changed with the change in pedestrian type and pedestrian volume. The average travel time delay increases with increase in pedestrian volume (Istvan et al. 2014). Finding adequate gaps will be difficult to the pedestrians while crossing the road (some pedestrians will cross when adequate gaps available but remaining pedestrians unable to cross due the restrictions to the width of crossing). The average travel time delay was found to be higher in case 100% female and 100% old age pedestrians.

The results can be useful to design the pedestrian facilities and to provide guidelines for the both pedestrians and vehicles at pedestrian crossings. And also, can be used to understand pedestrian risk with vehicular flow and for pedestrian-vehicle interaction analysis. Pedestrian group size and luggage were not included in this study.

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