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Spatio-temporal distribution of crossing pedestrians in urban cities of developing countries

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Abstract

With the increment of population in urban cities, city centres have heavy pedestrian flows. Thus, pedestrian density in pedestrian route networks has increased resulting immense pedestrian-pedestrian conflicts and pedestrian-vehicle conflicts, hence those were affected on the pedestrian safety and crossing speed. In that context, the aim of the current research is to evaluate the spatio-temporal distribution of crossing pedestrians due to incoming moving obstacles. (i.e., opposite pedestrians). The secondary objective is to assess the change in crossing speed due to such obstacles. Video survey technique was used as the method of data collection and one-hour video survey was conducted in a non-signalized crosswalk in Kandy city during a peak hour. Authors have identified three major crossing patterns; 1. pedestrians who are entirely on the crosswalk during the crossing (*pattern X*); 2. pedestrians who are deviate from the crosswalk after crossing half (*pattern Y*); 3. pedestrians who are not using the crosswalk to cross (*pattern Z*). Average crossing speed was found by considering above three crossing patterns and number of obstacles meet while pedestrian crossing the road. According to that analysis, crossing speed is increasing from pattern X to pattern Z. When considering the crossing speed that related to a one crossing pattern decreases with increasing number of obstacles. A regression model was developed to predict average crossing speed of the pedestrian at non-signalized cross walk considering above three main crossing patterns, number of obstacles, age, gender, attire, and whether carrying a weight or not. Validation of the model justifies the applicability of the developed regression model to estimate the crossing speed of the pedestrian with incoming obstacles at a non-signalized crosswalk.

Keywords: Spatio-temporal distribution; Crossing patterns; Crossing pedestrians

1. Introduction

Pedestrian density in urban cities has been increased since recently due to higher level of mobility needs. This generates higher pedestrian demand for crosswalks, which creates safety issues for pedestrians and exemplifies lower pedestrian crossing speed. Fig1 shows an un-signalized crosswalk near to a major bus hub in an urban city center of a developing country. When the numbers of crossing pedestrians are higher, numbers of pedestrian-pedestrian conflicts go higher. With this scenario, pedestrians are unable to move freely when crossing the road. It creates uncomfortable for the pedestrians since they need to change the walking path trajectory several times during one crossing. Sometimes this tends pedestrians to show up many different crossing patterns on and vicinity of crosswalks to avoid aforesaid pedestrian-pedestrian conflicts. The primary issue is the higher exposure time of pedestrians to vehicles which creates accident risk and vehicular delays. In that context, the primary objective of this research is to evaluate the spatio-temporal distribution of pedestrians due to on coming obstacles (i.e., opposite moving pedestrians and stopped vehicles on the crosswalk). The secondary objective is to estimate the change in crossing speed due to obstacles and pedestrian characteristics.

Fig1: Un-signalized crosswalk in an urban city centre of a developing country

2. Literature review

Many literatures can be found extensively related to the field of pedestrian safety in both signalized and non-signalized crosswalks. However, only few numbers of literature on spatio-temporal distribution of the pedestrians. Jamila *et al* (2015) studied pedestrians' crossing patterns at non-signalized crosswalk near to a bus station. According to them, pedestrians travel along a curved trajectory most of the time rather than on a straight path. The influenced reasons for such behaviour were; pedestrians search for shortest distance and pedestrians try to avoid incoming group of pedestrians. However, they have not studied on travel time, travel length or traveling velocity variations of the pedestrians. Galanis and Nikolas (2012) examined pedestrians crossing behaviour in signalized crosswalk. Pedestrians' crossing time and velocity together with illegal crossing behaviour (i.e., start crossing during red signal) were studied according to age and gender. Ferenchak (2016) studied the pedestrian crossing behaviour in terms of age, gender, waiting time, and vehicle-pedestrian conflicts. Only individual pedestrians were observed excluding group pedestrians. The main conclusion is that male takes lesser waiting period than female. Millionig and Gartner (2007) had monitored the pedestrian spatio-temporal behaviour at both indoor and outdoor areas. Data of pedestrian trajectories were analysed for number of stops, velocities, turns and visual appearance. Rastogi et al (2013) analysed pedestrian flow characteristics at different pedestrian facilities. Pedestrian walking speed was observed by changing the width of the pedestrian sidewalks. Kumara et al (2013) analysed pedestrian walking speed variations according to gender, attire, and group size in sidewalks and stair ways. Perumal et al (2014) attempts to analyse the crossing behaviour in terms of crossing speed, compliance with signal and pedestrian-vehicular interaction under mixed traffic condition. Further, they identify the influencing factors based on statistical tests. However, none has focused on the effect of crossing trajectory changes to the crossing speed with pedestrian characteristics and travel patterns.

3. Methodology:

The scope of this research is limited only to spatio-temporal distribution of crossing pedestrians at un-signalized crosswalk. The selected crosswalk for the study is located very close proximity to the main bus hub of an urban city in Sri Lanka. The video surveillance survey was performed from 4.00 PM to 5.00 PM during a weekday. From visual observations; age, gender, attire, group size, and whether carrying bags or not, number of times a moving obstacle or static obstacle meet during the crossing, and crossing type were extracted. Three crossing types were identified as shown in Fig 2.

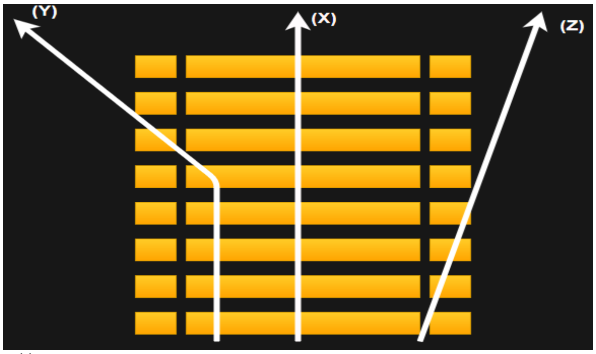

Fig 2: Crossing patterns[*†‡] of pedestrians

The crossing length and crossing time were obtained from Tracker 4.96 software. By that individual crossing speed is calculated. Totally 888 pedestrians were captured from the video surveillance survey. Fig 3 shows a snap shot of the Tracker view page. Once a pedestrian was tracked during the full crossing, the crossing pattern, travel distance and travel time can be obtained directly.

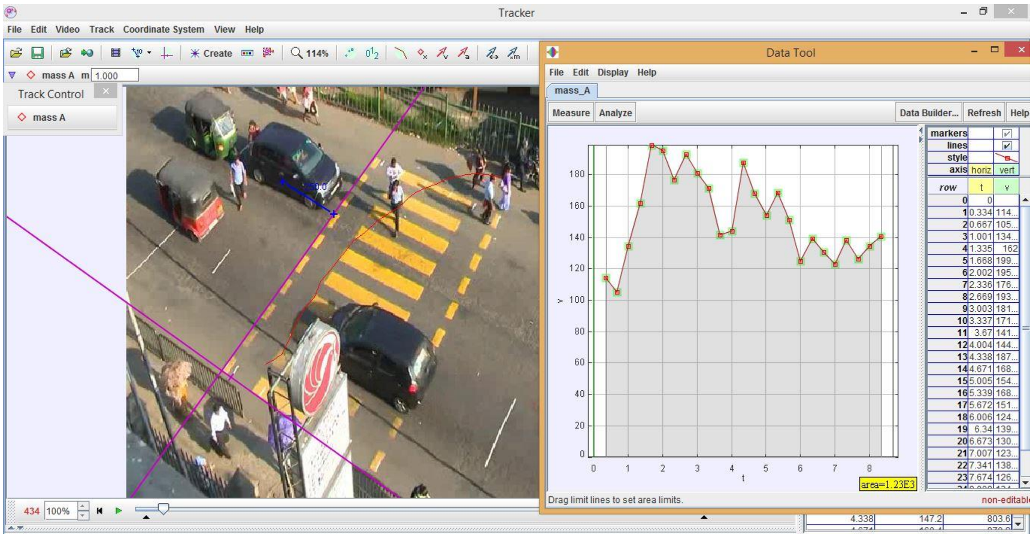

Fig3: Interface of the Tracker software

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[*] Pedestrians who are entirely on the crosswalk during the crossing (***pattern X***)
[†] Pedestrians who are deviate from the crosswalk after crossing half (***pattern Y***)
[‡] Pedestrians who are not using the crosswalk to cross (***pattern Z***)

4. Results:

Initially results were summarized with respect to crossing pattern and number of obstacles met during the road crossing. For that the following notation is used; **α (β)**

α – Crossing pattern (X,Y, or Z); β – Number of obstacles (0, 1, 2 or more)

Table 1 shows the percentage of pedestrians according to crossing pattern and number of obstacles. Nearly 55% of the pedestrians follow straight crossing pattern, out of which 23% of the pedestrians face at least one obstacle during the road crossing. On the other hand 35% of the pedestrians deviate from the crosswalk after crossing half. The rest 10% of the pedestrians do not use the crosswalk at all even though they start the journey from one end of the pedestrian crossing.

Table 1. Percentage of pedestrians according to crossing pattern and number of obstacles

Crossing pattern and no. of obstacles	% of pedestrian
X(0)	32.39
X(1)	19.12
X(2)	3.72
Y(0)	23.76
Y(1)	10.02
Y(2)	1.69
Z(0)	7.09
Z(1)	1.47
Z(2)	0.79

Fig 2 and Fig 3 show the total crossing length and total travel time variation with different travel patterns and number of obstacles respectively. From the results, it is revealed that irrespective of the crossing pattern, with the number of obstacles, the travel length increases. The significant finding from the result is that though the pedestrians travel more distance with travel pattern Z, in terms of travel time pattern Z shows a low value. However, still with the number of obstacles, travel time increases as of the travel distance. Figure 4 shows the travel speed variation with different travel patterns and number of obstacles. The results reveal that irrespective of the crossing patterns, with conflicts the travel speed reduces. Speed reduction is significant; when crossing pattern is X and number of conflicts are two or more.

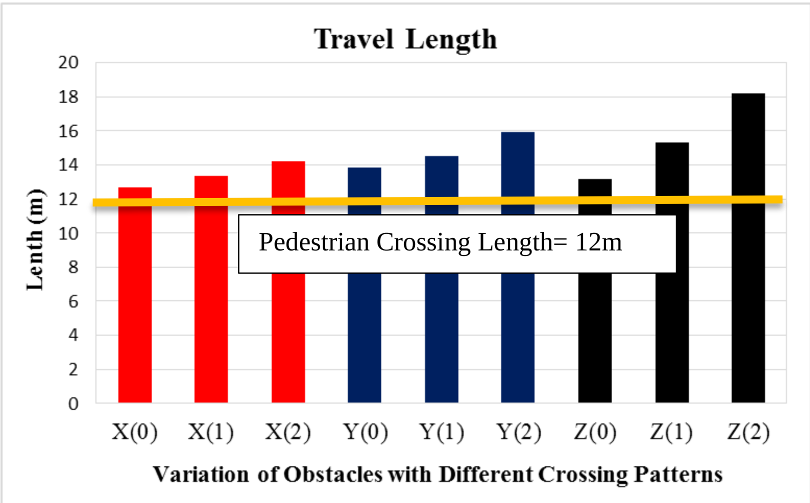

Fig2: Variation of the total travel length with different travel patterns and number of obstacles.

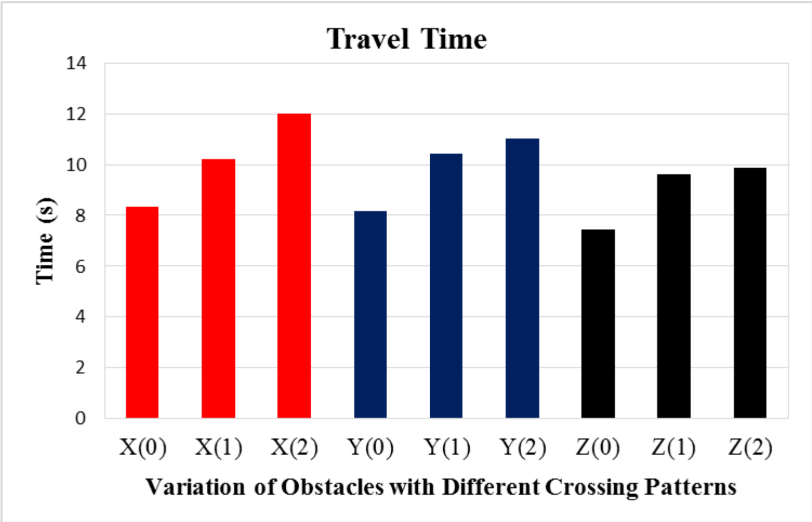

Fig3: Variation of the total travel time with different travel patterns and number of obstacles.

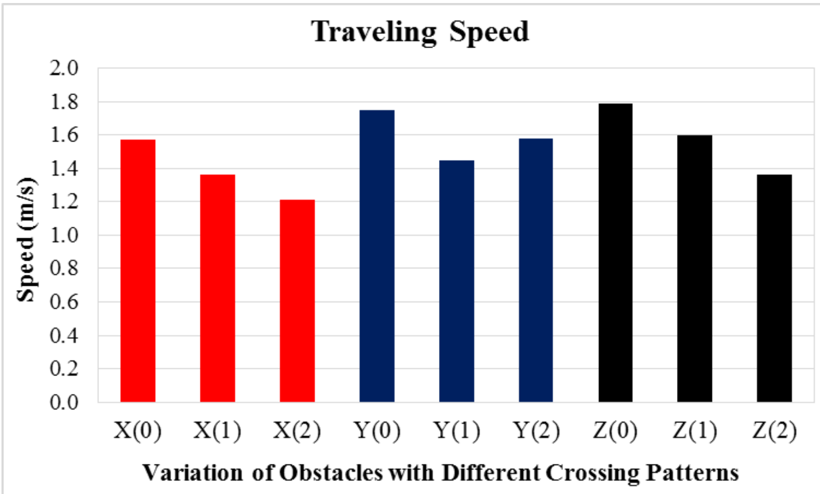

Fig4: Variation of the travel speed variation with different travel patterns and number of obstacles.

5. Statistical Approach

The data analysis was further extended to estimate the crossing speed with pedestrian related characteristics, travel pattern, and number of obstacles encountered. All the independent variables are categorical variables except the pedestrian density and they are adopted the following notations for that purpose.

Table 2. Notations used for the model development

Factor	Category	Notation
Gender	Male	0
	Female	1
Crossing pattern	X	2
	Y	1
	Z	0
Number of obstacles	0	0
	1	1
	2	2
Age	<20	0
	20-30	1
	30-40	2
	40-50	3
	>50	4
Attire	Trouser/Jean/Shorts	0
	Saree/Skirt/Sarong	1
Carrying a weight	No	0
	Yes	1
Pedestrian density	Continuous data	

The stepwise multivariable regression analysis was used to express the pedestrian crossing speed. The collections of factors with statistical reliability were used to form the mathematical expression. The pedestrian crossing speed in an un-signalized crosswalk can be expressed in an equation format as follows;

$$Crossing\ Speed = 1.9619 - 0.087 * Gender + 0.0741 * Dress - 0.1 * Carrying\ Weight - 0.1928 * No.of\ Obstacles - 0.1203 * Crossing\ Pattern - 0.05578 * Age\ Category$$

The model validation with RMSE shows the developed model is a good predictive model since RMSE is closer to one (RMSE = 0.14).

6. Conclusions

From the analysis following conclusions can be obtained; Pedestrians' crossing length and crossing time increase with number of obstacles irrespective of the crossing patterns. During a rush hour, little more than one third of the pedestrians change the crossing trajectory due to obstacles. However, crossing speed increases for the pedestrians deviating from the crosswalk, though they are much exposed to higher risk. Overall, male and female are having crossing speed of 1.59 m/s and 1.49 m/s respectively during a crossing at an un-signalized crosswalk in an urban city centre. The regression model developed to predict average crossing speed of the pedestrian at non-signalized crosswalk verifies the accuracy since the validation is success.

References

Jamil, R., Xiong, S., Kong, X., Zheng, S. and Fang, Z., 2015. Pedestrian crossing patterns preference at a non-signalized crosswalk. Procedia Manufacturing, 3, 3353-3359

Galanis, A. and Nikolaos, E., 2012. Pedestrian Crossing Behaviour in Signalized Crossings in Middle Size Cities in Greece.

Ferenchak, N.N., 2016. Pedestrian age and gender in relation to crossing behavior at midblock crossings in India. Journal of Traffic and Transportation Engineering (English Edition), 3(4), 345-351

Millonig, A. and Gartner, G., 2007. Monitoring pedestrian spatio-temporal behaviour. BMI, 296, 29-42

Rastogi, R., Ilango, T., and Chandra, S., 2013. Pedestrian flow characteristics for different pedestrian facilities and situations, European Transport/Trasporti Europei ,Issue 53, Paper 5,ISSN 1825-3997