Pedestrian's choice at mid phase of green countdown display at signalized intersections

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1. Introduction

In many countries, pedestrians are the most vulnerable road users in terms of road traffic injuries [1]. Accidents involving vulnerable users such as pedestrians are a major concern for road safety due to the high number of deaths and injuries [2]. Due to high population density, rapid urbanization, non-compliance with the rules of driving and transportation, pedestrian traffic accidents have become a major safety problem around the world, especially in developing countries [3]. Pedestrian traffic conflict is a common safety problem, especially at marked crossings where pedestrian traffic differs significantly from that of normal pedestrian areas due to intersection geometry, signal management, and vehicle availability [4]. In countries such as Sri Lanka, Vulnerable Road Users (VRU) are more prone to road accidents. Until 2015, traffic accidents involving pedestrians were in the first place among other categories of victims, according to police. Motorcyclists currently have the highest number of road traffic accident victims with pedestrians in second place [5].

Pedestrian crosswalks can be categorized into two, signalized crosswalks and un-signalized crosswalks. Signalized cross walks are expected to ensure safety by giving the right of way for traffic movement including pedestrians [2], [6]. Provision of signalized pedestrian crossing facility may not promise the pedestrian safety due to some reasons such as traffic violation and unsafe signal phasing [2]. Pedestrian countdown timers are more often used as a complement to traditional traffic lights in order to improve pedestrian behavior at the signalized pedestrian crossings, as well as their safety. Their main role is to offer more information to pedestrians on the remaining time of the red light, i.e. to display the time remaining until the phase for their safe road crossing begins. The aim is to reduce the number of illegal pedestrian crossings over the roads (during the pedestrian red light), thus increasing their safety to a higher level, and also improving traffic flow [7], [8]

Pedestrian green light is usually followed by a clearance phase, occurring before the light ultimately turns red. This phase was implemented to help pedestrians who are already in crosswalks to finish crossing before onset of a red light [9]. The message displayed during clearance phase differs from country to country; it may be signaled by flashing Don't Walk (e.g. USA), flashing Red Man (e.g. Australia, New Zealand) or flashing Green Man (e.g. Japan, China), and is sometimes coupled with countdown timers displaying the remaining time before the light turns red [8]. In Sri Lanka, signalized pedestrian crossings are usually used in intersections with high traffic volume and locations which have more vulnerable road users such as schools, hospitals, public buildings etc [6]. For the clearance phase, flashing green man is commonly used as the indicator in traffic signals in Sri Lanka.

Crossings based on remaining green time is relatively safe so long as pedestrians can finish crossing within the remaining duration. However, researchers have found that pedestrians tend to cross when the remaining time was too short, indicated by incomplete crossings after the clearance phase ended [8]. The probability of pedestrian accidents when crossing at the red light is eight times higher compared to the probability when crossing the road properly. Therefore, there is a real need to investigate the pedestrian behavior with respect to existing devices (countdown displays) that should reduce the number of illegal crossings throughout entire duration of the pedestrian red light [7]. Therefore, this study aims to analyze the pedestrian's behavior at mid phase of green display in terms of their choices and success with respect to remaining green time at arrival.

2. Methodology

An intersection located in Batticaloa district (Eastern province of Sri Lanka) was selected for this study. The intersection is located in a sub urban area surrounded with few shopping complexes and government institutions with moderate pedestrian flow. At this intersection no manual traffic control methods were applied except properly

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working traffic signals with countdown timers. Further the intersection has adequate length and considerable pedestrian flow to observe the pedestrians' movements. Attributes of the selected intersection are given in Table 1.

A video recorded survey was conducted in a good weather condition to avoid forced pedestrian movements due to adverse weather and also to obtain clear video footages for analysis. From the video recorded survey there were 391 pedestrian movements selected for analysis. Pedestrian's movement which were not clear in video footages and pedestrians whose gender or age group couldn't be estimated through video footages were not taken to the analysis. For each selected pedestrians, gender, estimated age group, remaining green time at pedestrian arrival, pedestrian's choice on cross or wait, time spend at green phase, time spend at red phase , pedestrian grouping and pedestrian involvement in other activities were observed and recorded. Average crossing speed of each pedestrian was calculated using equations 1 and 2. Descriptive analysis and binomial logistic regression analysis were performed to predict the pedestrian behavior.

$$Time\ taken\ to\ cross\ the\ road = Time\ sepnd\ at\ green\ phase + Time\ spend\ at\ Red\ phase \quad (1)$$

$$Crossing\ Speed = \frac{Cross\ walk\ length}{Time\ taken\ to\ cross\ the\ road} \quad (2)$$

Table 1: Attributes of selected intersection

Criteria	Attribute
GPS Coordinates	7°43′11" N , 81°41′48"E
Type of Intersection	4 way junction
Cross walk length	16 m
Cross walk Width	4 m
Selected cycle time	90 s
Selected green time for pedestrian	15 s

3. Analysis and Results

3.1 Pedestrians' choices

Binary logistic regression model was used to predict the pedestrian's choices. From the Hosmer and Lemeshow test (χ^2 (8) = 2.9 & p = 0.61) it was found that the model fits with 92% prediction of pedestrians' choices. As per the model output shown in Table 2 , Age group (p = 0.006) and remaining green time at pedestrian arrival (p = 0.001) affect pedestrians' choices significantly irrespective their gender. The odd ratio for gender has the value of 1.075 indicates that, choice of male pedestrians to cross the road is 1.075 times higher than female pedestrians and it elaborates that there are no significant changes in pedestrian choices according to gender demography. Further, the odd ratios of Age group (1) and Age group (2) clearly indicates that, adult and children are more reluctant than elders to cross the roads at the particular intersection.

Table 2: Binary logistic model output (pedestrians' choices)

Predictors	Estimate	Standard Error	P value	Odd ratio
Age Group			0.006	
Age Group(1)	-0.880	0.853	0.302	0.415
Age Group(2)	-3.286	1.108	0.003	0.037
Gender	0.072	0.632	0.909	1.075
Remaining Green Time at Arrival	1.258	0.231	0.001	3.517
Constant	-7.048	1.124	0.000	0.001

3.1 Pedestrians' success

The binary logistic regression model used to predict the pedestrians' success fits with 93% prediction of pedestrian success as per the Hosmer and Lemeshow test (χ^2 (8) = 3.12 & p = 0.51). From the model output shown in Table 3, it can be observed that, remaining green time at pedestrian arrival (p = 0.001), pedestrians' grouping (p = 0.005) and pedestrians' involvement in other activities (p = 0.014) are the significant factors affecting the success of pedestrians to cross the road irrespective to their age and gender. From the odd ratios for age group (1) and age group (2), children have more success rate than elders and adults while adults have least success rates among them. Odd ratio for the predictor named "pedestrians' involvement in other activities" shows that a pedestrians involved in other activities likely to fail 5.742 times than the pedestrians who are not involved in such activities. Further it shows that success rate for male and female pedestrians is nearly same as the odd ratio is 1.059.

Table 3: Binary logistic model output (pedestrians' success)

Predictors	Estimate	Standard Error	P value	Odd ratio
Age Group			0.620	
Age Group(1)	-0.103	0.067	0.856	0.902
Age Group(2)	0.518	0.144	0.486	1.678
Gender	0.057	0.074	0.904	1.059
Remaining Green Time at Arrival	1.178	0.199	0.001	3.247
Pedestrians' Grouping	-2.571	0.224	0.005	0.076
pedestrians' involvement in other activities	1.748	0.114	0.014	5.742
Constant	-11.514	1.483	0.000	0.000

3.3 Crossing speed variations

As shown in the Figure 1, it was observed that the average crossing speed of pedestrians were high when the remaining green time on arrival was short. When the remaining time was less than 80% of the allocated green time average of pedestrians' crossing speeds were laid below the required speed to success. It clearly indicates that most of the pedestrians were unable to cross the road successfully when the remaining time is lesser than 80%. Further, the Figure shows that, when the remaining time was less than 9 s (less than 60% of allocated time) all crossing speeds are laid below the required speed line and it indicates that no one was able to cross the roads when the remaining time was less than 60%. Moreover, it was found that average crossing speed of male pedestrians were slightly higher than females for each remaining green time on arrival.

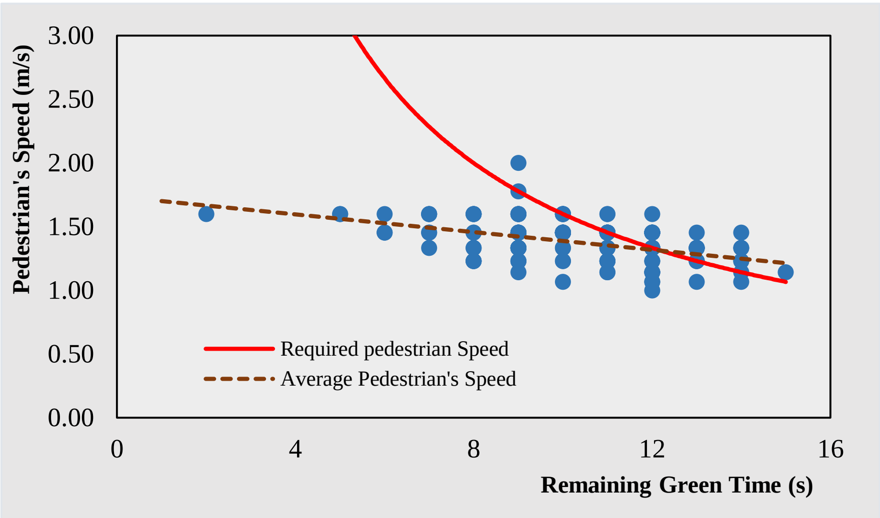

Figure 1: Pedestrians' success to cross the road

4. Discussion

It was observed that elderly pedestrians were more like to cross the road than adults and children even the remianing green time was short.There may be lack of awareness on signal countdown timers among elderly pedestrians which may be the reason for these observations. Children were more reluctant to cross with shorter remaining times and it indicates that they have more awareness through their childhood education. Based on the model predictions, the pedestrians' choices are not much depend on their gender and it is deviated from most of the previous reseraches which were performed without considering the remaining green time at pedestrian arrival.

Considering the pedestrians' success rate, children have more success rate than other are groups with respect to particular remaining green time at arrival indicates they are more vigilant and active during crossing. The model predicts, pedestrian who involved in using mobile phones or any other prohibited activities during their movements through green phase are more than 5 times fails to cross the road within the time than a usual pedestrian. This indicates the pedestrians involved in prohibited activities are more vulnerable to meet with accidents at signalized intersections due to red light running behavior. Further, the model predicts that the pedestrian who attempt to cross the roads as groups have less chance to succeed. When the number of pedestrians in the group increase, the probability of success on cross the road was decreased and this observation is most similar to previous findings in various researches.

When the remaining green time was short, irrespective their ages and gender, pedestrians are rush to cross the road with higher speeds similar to pervious findings in various researches. However, with shorter remaining green times than 80%, most of the pedestrians were unable to achieve the required speed. This indicates are more likely to be red light runners when the remaining green time was shorter than 80% of allocated time.

5. Conclusions

Taking decisions to cross or wait based on the remaining green time at arrival is much significant to reduce red-light running behavior of pedestrians. Elder pedestrians should have been given more attention than other age groups to educate regarding the usage countdown timers at signalized intersections. Pedestrians who decide to cross with short remaining green time are more vulnerable to meet accidents irrespective their age and gender. Involvement in prohibited activities at pedestrian crossings and walking as groups at crossings lead significant failure for pedestrians to cross the road within the available time at signalized intersections.

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