A Pedestrian Speed Analysis at Signalized Crosswalk

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Abstract: In setting the pedestrian signal time, the speed term generally uses fixed values such as 1 m/s for all cycles. However, the pedestrian’s speed could vary depending on demands of crosswalk because collisions between pedestrians occur in high demand or supersaturated situations. The objective of this study is to investigate pedestrian’s travel length and speed which affect crossing time as density of crosswalk varies. For this purpose, field study is conducted with video camera and GPS equipment. Regression analysis is applied for identifying how the density of crosswalk affects the crossing time. Result shows that density – travel length relationships is not statistically significant while there is significant correlation between opposite direction density and pedestrian speed. The proposed result can be a basis for signal time model which is important for improving pedestrian’s safety.

Keywords: Pedestrian Signal time, Crossing Speed, Pedestrian Density, Crossing Demand

1. INTRODUCTION

With the rapid development in the field of transportation, various transportation-related studies have been conducted and many countries have formed a reliable transportation network. Research on behavior and safety of pedestrian, however, has been relatively weak compared to the research related to operation or communication of vehicles. Especially pedestrian signal time usually does not reflect the demands of pedestrian because the signal time generally uses the value of longitudinal length of crosswalk divided by fixed pedestrian’s speed. Unlike a case of appropriate or less demand of pedestrian, collisions between pedestrians would occur in high demand or supersaturated situations. It is possible that if walking speed is reduced because of high demand of pedestrian, not every people could make a crossing in a given time. The pedestrian’s actual crossing length also may increase as the density of crosswalk increases because to avoid a conflict with other pedestrians, people would keep turning their direction so the total travel length will be longer than longitudinal length of crosswalk. This situations are observed at many high demand crosswalks, and it is important issue for pedestrian’s safety.

Therefore, in this study, with the background of the fact that the study of pedestrian signal time is insufficient, it is intended to identify the relationship between the pedestrian walking time and the density of the crosswalk. The objective of this study is to investigate pedestrian’s travel length and speed which affect crossing time as density of crosswalk varies.

Further, it is confirmed whether the time of the current signal is properly operated by comparing with the results.

The procedure of the study is as follows. At first the observation is conducted with camera recording to find a proper site which shows various patterns of pedestrian demands. Also it is observed whether walking signal time given to pedestrians is long enough regardless of the number of people walking crosswalk. After selecting appropriate site, field study is conducted with video camera and GPS equipment. With the results, the density of crosswalk is calculated and the relationship between pedestrian density and walking speed, travel length is identified by linear regression model. At last, it is checked whether the current signal time of the site is properly operated.

2. LITERATURE REVIEW

There has been some principal research on pedestrian signal time. Pignataro (1973) suggested that the total pedestrian signal time is made up initial start-up delay (t) and crossing time ($\frac{L}{V}$). MUTCD (2000) suggested initial start-up delay as 4 to 7 second citing this concept.

$$T = D + \frac{L}{u} \tag{1}$$

where,

T = time required for crossing (sec),
D = initial start-up delay to step off curb and enter crosswalk (sec),
L = walking distance (m), and
u = walking speed (m/sec).

Virkler and Guell (1984) recommended model considering additional delay caused by platoon size and crosswalk width. This model is based on the assumption that pedestrians enter crosswalk with constant headway. Virkler (1998) suggested average headway in this model as 0.81 (sec/pedestrian/crosswalk width), this is also cited in HCM (2000)

$$T = D + \frac{L}{u} + x(\frac{N}{W}) \tag{2}$$

where

T = time required for crossing (sec),
D = initial start-up delay to step off curb and enter crosswalk (sec),
x = average headway (sec/pedestrian/crosswalk width)
N = platoon size (pedestrians)
W = crosswalk width (m)

This study focused on that crossing speed and travel length of pedestrian at crosswalk will vary depending on the density of crosswalk while existing models have used the fixed value of speed and longitudinal crosswalk length.

3. PEDESTRIAN CROSSING TIME ANALYSIS

3.1 Data Collection

For crosswalk time analysis, the video and GPS data was collected manually. The selected site is the crosswalk located in near the Yeouido subway station in Seoul, Korea. Yeouido is central business district of Seoul, so many companies and shopping malls are concentrated near the selected area, so the crosswalk shows various patterns of pedestrian demands according to time periods. The survey was conducted twice from 11:00 to 15:00 on the December, 2013. Before collecting the data, field investigation was made.

One investigator crossed the road while the other investigator was recording video at rooftop of near building to measure demand. The investigator who crossed the road carried GPS equipment and followed randomly selected person and walked keeping average speed of the entire platoon. GPS data was collected for analyze the trajectory of the investigator. After then, it can be calculated the total demand of each signal cycle from the video data. This method would show how the density of the crosswalk affects the speed and travel length of the investigator. The total sample size is 109. The survey site and site information are as follows.

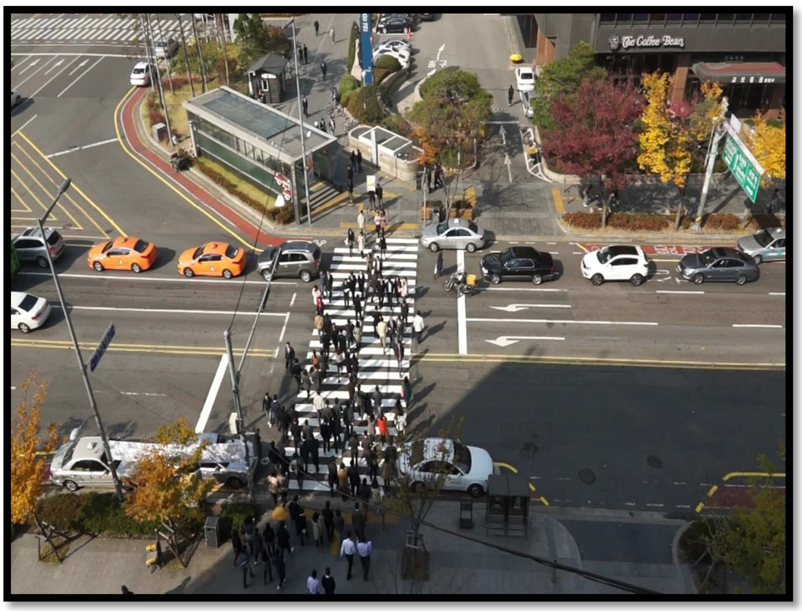

Figure 1. Survey site (Yeouido, Seoul)

Table 1. Site information

Length of crosswalk	Effective width of crosswalk	Crosswalk area	Pedestrian signal time
21.8 meters	5.8 meters	126.44 square meters	33 seconds (12 seconds for clearance interval and 21 seconds for crossing)

3.2 Results and Analysis

Pedestrian crossing time uses the value of longitudinal length (L) of crosswalk divided by fixed pedestrian speed (V). However, the travel length and the pedestrian speed may vary depending on demand of crosswalk. Regression model was applied for identifying whether and how the pedestrian demands affect the values. The investigation was conducted respectively in three types, 1) a case of forward direction density, 2) opposite direction density for investigator, and 3) total density.

3.2.1 Density-travel length results

If there are few pedestrian on crosswalk, people may traverse the road straightly, but otherwise they may change their direction so that they don't conflict with other pedestrians. With this point, it is worth to observe the relationship between actual travel length and the density of crosswalk. As travel length (L') depends on the longitudinal length of crosswalk (L), $\frac{L'}{L}$ was applied for a dependent variable instead of using just crosswalk length (L). The travel length was calculated from the GPS data. The results are as follows,

Table 2. Density-travel length ratio ($\frac{L'}{L}$) regression results

Parameter	Coefficients	R^2	Std. Error	t-statistics	P-value
Constants	1.0486	0.08968	0.014	73.178	0.0000
Forward direction density	0.1398		0.043	3.247	0.0015
Constants	1.0721	0.01107	0.015	70.528	0.0000
Opposite direction density	0.0475		0.045	1.094	0.2762
Constants	1.0370	0.07849	0.018	56.629	0.0000
Total density	0.0904		0.029	3.018	0.0003

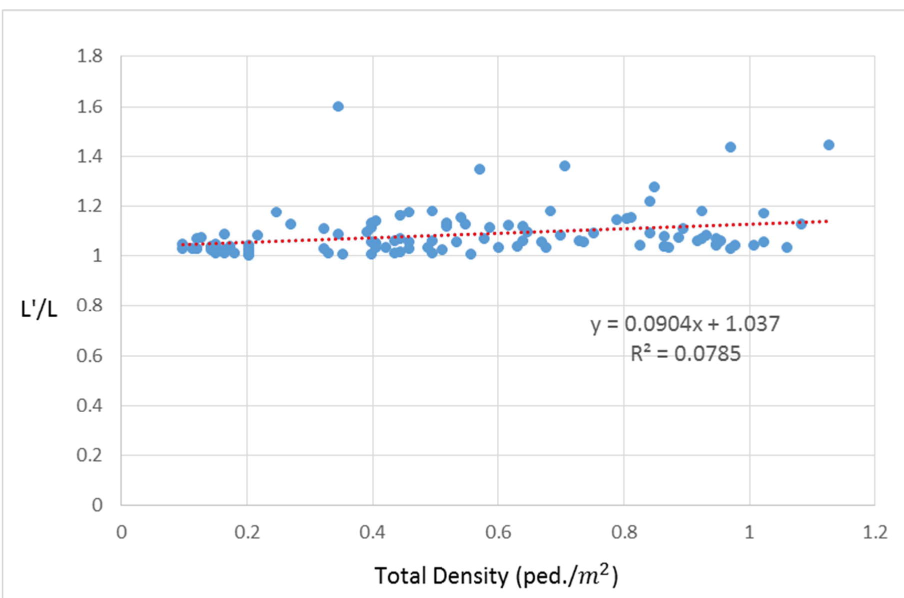

Figure 2. Total density - travel length ratio

The coefficients of independent variables have positive values all of three cases. This indicates that the actual travel length increases as the pedestrian density is increase. However, these models are not statistically significant. It doesn't seem to have clear trend according to the plotted graph, and models have very low coefficient of determination. Therefore, it is not observed that pedestrian density has a direct impact on the travel length.

3.2.2 Density-speed results

In the pedestrian signal time model, the speed term generally uses fixed values such as 1 m/s. It does not consider the demand of pedestrian, although it is expected to decrease the speed as density grow. The results of regression analysis are shown below.

Table 3. Density-speed regression results

Parameter	Coefficients	R^2	Std. Error	t-statistics	P-value
Constants	1.1626	0.07864	0.023	50.544	0.0000
Forward direction density	-0.2089		0.069	-3.022	0.0031
Constants	**1.2454**	**0.46697**	**0.018**	**69.942**	**0.0000**
Opposite direction density	**-0.5052**		**0.052**	**-9.682**	**0.0000**
Constants	1.2923	0.44814	0.023	57.158	0.0000
Total density	-0.3445		0.037	-9.321	0.0000

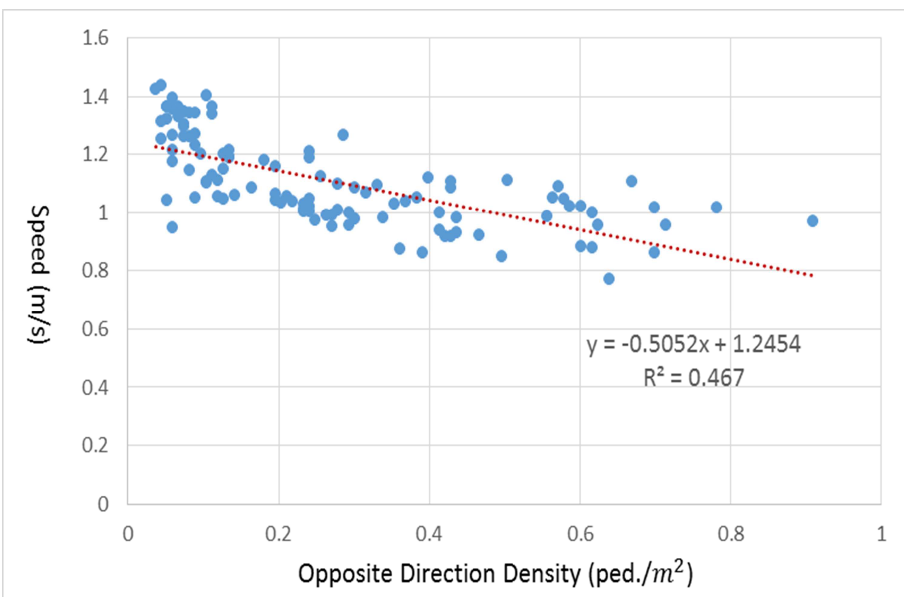

Figure 3. Opposite direction density - speed

According to the result, the forward direction density showed a tendency to decrease the pedestrian speed, but the coefficients of determination (R^2) is very low (0.07864). The opposite direction density-speed trend is more pronounced than the forward direction results. The statistics indicate that the model fits well including high correlation value. This implies that conflicts between pedestrians clearly decrease the walking speed in high demand circumstance especially with oncoming pedestrians. The total density-speed regression model also fits well, but just one primary direction's demand is enough to decide signal time.

3.2 Application on Survey Site

Many counties set the pedestrian signal time using fixed values of clearance time (t) and crossing time ($\frac{L}{V}$). The survey site in this research is using 12 seconds for clearance time and 21 seconds for crossing time. Instead of using that value for crossing time, the opposite density-speed regression model for pedestrian speed (V) can be used for setting crossing time.

$$V = 1.2454 - 0.5052\,K \tag{3}$$

where,

V : speed of pedestrian (m/s),

K : density on primary direction of crosswalk (ped. /m^2).

According to the site investigation data, the effective range of primary direction's density (K) is about 0.1 (ped. /m^2) to 1.0 (ped. /m^2). Using this model, current crossing time (21 seconds) and newly obtained crossing time which adopts above model can be compared as follows. According to the figure 4, current crossing time would not be enough at high density conditions.

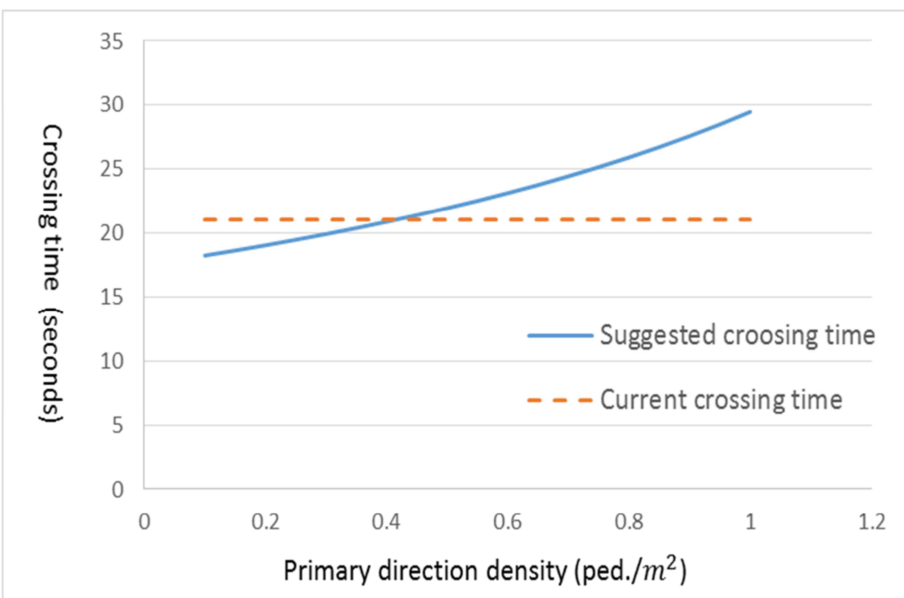

Figure 4. Suggested and current crossing time for density

4. CONCLUSION

This research suggests pedestrian crossing time under the condition that density varies. Field study was conducted with video camera and GPS equipment. Using the data, regression analysis is applied for identifying how the density of crosswalk affects the crossing time. The results drawn from this research are as follows. First, the density - travel length relationships were not statistically significant, but it is necessary to study in a more sophisticated GPS equipment. Second, increased density shows a tendency to decrease the walking speed. Especially the opposite direction density and crossing speed has significant relationship, so if measuring the primary density of particular time periods is possible, safer pedestrian signal time could be given. Finally it was identified that the current crossing time is not enough at high density conditions on the survey site.

This research has the limitation that the sample size is not enough and the survey was conducted at only one site. The findings and research concepts of this study, however, provide practical information and can be a basis for modelling and deciding signal time, which is important for improving pedestrian's safety.

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