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Research Article

The Effect of Rain on Pedestrians Crossing Speed

Mojtaba Bagheri Movahhed[1*], Jalal Ayoubinejad[2], Farid Najjari Asl[3], Mahdi Feizbahr[4]

[1] *Payame Noor University of Kish International Center, Kish, Iran*
[2] *Department of Civil Engineering, Payame Noor University, Iran*
[3] *School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran*
[4] *School of Civil Engineering, Engineering Campus, University Sains Malaysia, Nibong Tebal , Penang, Malaysia*

Keywords

Pedestrian,
Crossing Speed,
Signalized Intersection,
Rain Condition.

Abstract

The pedestrian crossing speed in the signalized intersections is one of the most important parameters in the designing intersections and also is essential information in controlling the amount of delay and traffic. The present study aims to measure and statistically analyze the pedestrian crossing speed according to the weather conditions, which is either normal or rainy. In order to do this, the crossing speed of 4381 pedestrians has been gathered through the photography of two signalized intersections in Rasht city. Furthermore, these findings have been analyzed through the Independent Sample T-Test. The results show that, with a 95 per cent confidence, in both gender groups of men and women, the difference in the pedestrian speed according to the weather conditions of either normal or rainy is statistically meaningful and the pedestrian crossing speed was significantly more in the times of rain than in normal weather conditions. Meanwhile, in Rain Condition s, the 15th percentile crossing speeds for men and women increase 3.0 per cent and 21.5 per cent according to 15th percentile speeds in the normal weather conditions respectively. Therefore, it is suggested that the pedestrian speed in the normal weather conditions be regarded as the base for designing, so that the 15th percentile crossing speeds and the average of all samples in the Rain Condition are 1.05 and 1.24 meter per second successively.

1. Introduction

Gathering and analyzing of data are two-parameter in design and fulfill of civil engineering projects and this issue is true for all fields that related to civil engineering. So that researchers follow to up to date themselves about science and novelties [1,2]. All efforts should be led to develop the infrastructure of cities and highways. Therefore, the engineers investigated the effect of all parameters such as: groundwaters, earthquake, coastal near to roads on the infrastructure subsidence [3,4]. Also, they predicted the strength of the soil by the effects of future loading and try to revise their characteristics [5-7]. Finally, pavements and sidewalks are built as the latest layer to reduce the negative effects of rain [8-11] and even the engineers improve the specification of asphalt mixtures with additive materials to resistant against the traffic loading [12,13]. Traffic engineers have played an important role in the safety of Transportation [14] and increase the saturation flow rate [15] through geometry designs [16] and optimizing the traffic lights [17].

The signalized intersections in one of the important facilities that can reduce delays in city networks. The optimum of time phasing [18], headways of vehicles [19] and traffic volume can improve performance of intersections [20], especially level of services that the pedestrians are the important users of these facilities [21]. The crossing speed of pedestrians on intersections is one of the traffic engineering parameters so that the level of their exposure to traffic flow depends on the crossing speed [22]. Therefore, the correct design of intersection facilities requires a design based on the safe crossing speed of pedestrians [23]. Individual

* Corresponding Author: Mojtaba Bagheri Movahhed
E-mail address: mbagherimovahhed@gmail.com

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characteristics of pedestrians, such as sexuality and age [24], the number of people in the form of a group [25], the pedestrian crosswalk [26], the pedestrian facility width [27] and the pedestrian volume [28] including cases where the behavior of pedestrians in dealing with various pedestrians´ facilities and their crossing speed, are impressive.

Rasht city is often rainy and the people of this city are naturally accustomed to the rain. As the rain also includes the effect on pedestrian behavior, so the need to study the pedestrians crossing speed affected by this problem is essential for designing the pedestrian facilities. In this study by survey of 4381 pedestrians' data at two signalized intersections, the differences between the crossing speed of pedestrians in the normal and Rain Condition were obtained. Also, the effect of having an umbrella reliant on the pedestrians crossing speed is studied.

Over the past decades, many researchers have studied the speed of pedestrians. Moore (1956) in his article "Psychological Factors of Importance in Traffic Engineering" have recommended that the pedestrians' crossing speed while vehicles are approaching them should be 1.25(m/s) which could vary to 1.22(m/s), as well [29]. Wilson and Grayson (1980) found that the average walking speeds for men and women are 1.23 and 1.27(m/s) respectively, by examining the relationship between the speed of the pedestrian with respect to the age, and sexuality [30]. Griffiths et al. (1984) found that the speed of crossing in signalized Intersections for teens, adults and elderly is 1.72, 1.66, and 1.47(m/s), respectively [31]. Tanaboriboon and Guyano (1991) in an article named "Analysis of Pedestrian Movement in Bangkok" found that men and women crossing speeds are 1.31 and 1.25(m/s), respectively, by viewing the crossing speed of pedestrians in a signalized Intersection in Bangkok [32]. O'Flaherty (1997) has proposed the speed between 1.2 of 1.25(m/s) for crowded intersections motion of different age groups [33]. In addition, he proposed the average speed of 1.6(m/s) for the non-crowded areas. Tarawneh (2001), in his article named "Evaluation of Pedestrian Speed in Jordan with Investigation of Some Contributing Factors", checked out the speed of 3500 pedestrians in 27 intersections in a large area in Oman [34]. Based on that he proposed the average speed and 15th percentile pedestrian speed 1.34 and 1.11(m/s), respectively. In this study, he also expressed that the age, gender, size of the group and the street width are greatly effective on the pedestrians speed, and male pedestrians move significantly faster than female pedestrians in crossing the street. Gates et al. (2006) have pointed out that the average speed of pedestrians who are younger than 65 is faster than pedestrians older than 65 years old for 0.3(m/s) by collecting 1947 pedestrians crossing speed from 11 Intersections in the United States and there is no difference between the men and women crossing speeds [35]. In 2007 in an article named "Research on the Pedestrian Behavior and the Traffic Characteristics at Un-signalized Midblock Crosswalk: the Case Study in Beijing", Shi and his colleague have found that the men crossing speed is faster than the women crossing speed by 0.1(m/s) by analyzing the crossing speed of 1040 pedestrians in crossing the un-signalized intersection [36]. Transportation Engineering Institute of America (1999) has proposed a moving speed between 1.1 of 1.2(m/s) to pedestrians for crossing the street [37]. The Manual on the Uniform Traffic Control Devices in both version (2003 and 2009) have proposed the moving speed of 1.21(m/s) for pedestrians to cross the Intersections [38]. Due to the book of the highway capacity manual (HCM 2016), the Pedestrians crossing speed is based on the proportion of elderly pedestrians in all users. For ratio of less than 20 per cent of elderly pedestrians have proposed the speed of 1.2 and 1.34(m/s), respectively. And for higher proportion both versions have proposed the speed of 1(m/s) [39].

2. Methodology

2.1. Study Sites

This study has been taken place in the metropolis of Rasht. This city is one of the metropolises of Iran and it is the center of Guilan province in northern. According to the official census in 2011 and the Population density in Rasht, there is recognized around 4340 people per square kilometer. Also, Rasht has ranked first in rainfall between the provinces of Iran and the city is famous rain [40].

2.2. Data Collection

Pedestrian behavior data were collected at 2 signalized intersections in the city of Rasht. Then, intersections were filmed by video cameras and the information of 4381 pedestrian based on Table 1 has also been collected. Then by observing those films, pedestrians were numbered based on some features such as: sexuality and weather condition. Finally, it turned out that 3816 of pedestrians have crossed in normal weather condition, whereas 565 of them have walked in rainy weather condition.

2.3. Data Analysis Method

After collecting 4381 pedestrians data have been analyzed and measured by Independent Sample T-Test. The fact of the matter is that; T-Test is considered as a distribution or also a group of distributions using an assumption about the samples in the unknown conditions of society distribution which have been examined, as well. The benefit of this test comes to the researcher who would be able to collect information about society through using small samples. T-test consists of a group or distributions including its assumption which claims that: each sample has its own distribution, and the shape of the distributions is determined by freedom's degree calculation. In other words (t) distribution follows the degree of freedom and when the degree of freedom increases, it would be closer to the normal distribution; however, when the degree of freedom reduces, scattering would be more. The degrees of freedom would be a function of sample size, the higher number of the samples, the better test. The T-Test can be utterly used to analyze the average in the single variable of a group, or two groups and also it can be several variables of two groups. The fact of the matter is that the T-test compares the average and the standard deviation of two samples to specify if there is any chief difference between them or not.

Table 1. Data of the cases have been studied.

Place	Crossing Width (meter)	Cases Number (weather)	
		Normal	Rainy
1	30	2843	451
2	20	973	114

3. Results and Discussion

In the present study, the average and 15th percentile crossing speeds of pedestrians in terms of weather condition (normal, rainy) through two signalized intersections were recorded based on Tables 2 and 3 during peak times.

Due to Tables 2 and 3, the pedestrians crossing speed in the Rain Conditions is higher than normal one. Also the most average and 15^{th} percentile crossing speed values in both cases for men and women crossed with lower speed through sidewalks in all condition and the lowest values of average and 15^{th} percentile speed for them. So the average and 15th percentile speed respectively are 1.16 and 0.97 m/s at normal condition, on the other hand; the average and 15th percentile speed respectively are 1.24 and 1.05 m/s at Rain Condition suggested with respect to all pedestrians in Rasht.

According to the basic assumption of the study, the significance of the difference between normal and rainy weather pedestrian speed, the effect of weather conditions on the crossing speed of pedestrians discussed. To compare the speed of pedestrians in both normal and Rain Condition, statistical tests were used to determine if the speed difference between them is statistically significant or not. Therefore, after determining the normal speed data with Kolmogorov - Smirnov test and ensure that the data are normally distributed; the Independent Sample T-Test test was used. In addition, comparisons between pedestrians were similar in terms of gender. The results can be seen in Table 4.

According to the results listed in Table 4, all pedestrian crossings just based on weather conditions were used to compare and statistical tests that Independent Sample T-Test result in both gender groups showed a statistically significant difference. This comparison revealed that pedestrians crossing speed affected rainfall, so that men and women crossed faster in normal weather conditions compared to the Rain Condition s and this difference was statistically significant at 95% confidence. So far as the city of Rasht is often rainy, then it is better to use design values appropriate to the weather conditions time. The crossing speed difference results of men and women through intersections in same weather conditions with Independent sample T-Test have been in Table 5.

According to the test results of Independent sample T-Test which was listed in table 5, in both weather condition (normal and rainy), the difference in men's and women's speed is statistically meaningful with a 95 percent confidence. So the result of this comparison is that men crossed faster than women along intersections. It should be noted that before using the T-Test, normal speed data for men and women were evaluated by Kolmogorov - Smirnov test.

Table 2. Results from intersections in normal weather conditions

Categories	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	V_{15} (m/s)
Male	2374	1.22	0.165	1.03
Female	1442	1.08	0.179	0.84
All pedestrians	3816	1.16	0.197	0.97

Table 3. Results from intersections in Rain Condition

Categories	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	V_{15} (m/s)
Male	331	1.27	0.196	1.06
Female	234	1.21	0.168	1.02
All pedestrians	565	1.24	0.187	1.05

Table 4. Comparison of pedestrian crossing speed in normal and Rain Condition with the same gender

Sexuality	Weather Condition	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value, T	Independent sample T-Test result
Male	Normal	2374	1.22	0.166	P=0/033	**Major difference**
	Rainy	331	1.27	0.196	T=2/140	
Female	Normal	1442	1.08	0.179	P=0/000	**Major difference**
	Rainy	234	1.22	0.168	T=4/885	

Table 5. Comparing men and women crossing speed in both normal and Rain Condition

Weather Condition	Sexuality	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value, T	Independent sample T-Test result
Normal	Male	2374	1.22	0.166	P=0/000	**Major difference**
	Female	1442	1.08	0.179	T=6/672	
Rainy	Male	331	1.27	0.196	P=0/000	**Major difference**
	Female	234	1.22	0.168	T=4/333	

To comparing the crossing speed of pedestrians in Rain Condition s, they were divided into two groups: those with umbrellas and without umbrellas, because it was supposed that umbrella is a factor influencing on pedestrians crossing speed. The speed difference results of a pedestrian with an umbrella and without an umbrella in the Rain Condition weather with the Independent sample T-Test have been presented in Table 6.

According to the Independent Sample T-Test results listed in Table 6, the speed difference of the pedestrians with umbrellas and without umbrellas in both gender groups is not significant this indicates that the pedestrians crossing speed was not affected by the umbrella in Rain Condition. the most average and 15th percentile crossing speed values in both weather cases for men and women crossed with the lower speed through intersections in all condition and the lowest

values of average and 15th percentile speed is for them. Also the pedestrians crossing speed by the Rain Condition through the intersection is higher than by normal condition. Meanwhile, in Rain Conditions, the 15th percentile crossing speeds for men and women increase 3.00 and 21.50 per cent according to 15th percentile speeds in normal weather conditions respectively. However, men and women crossing with speed value very close to each other in rainfall condition.

Also according to Table 7 [41,42], by comparing 15th percentile crossing speed of present study in rainy weather (1.05 m/s) with other studies which have been presented in the literature review are observed that the pedestrians 15th percentile speed in Rain Condition is much lower than the speeds reported by other researchers.

Table 6. Compare the pedestrians crossing speed with umbrellas and without umbrella in Rain Condition

Sexuality	pedestrian Condition	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value T	Independent sample T-Test result
Male	With umbrella	94	1.26	0.161	P=0/784	The difference was not significant
	Without umbrella	237	1.27	0.211	T=0/276	
Female	With umbrella	60	1.19	0.191	P=0/595	The difference was not significant
	Without umbrella	174	1.22	0.173	T=0/534	

Table 7. The crossing speed difference of present study in rainy weather compared to other studies

Researchers	Average Speed (m/s)	The difference of present study with other studies (m/s)
Moore	1.25	-0.20
Wilson & Grayson	1.27	-0.22
Griffiths et al.	1.72	-0.67
Tanaboriboon & Guyano	1.31	-0.26
OFlaherty	1.25	-0.20
Tarawneh	1.11	-0.06
Knoblauch et al.	1.31	-0.26
ITE	1.20	-0.15
MUTCD 2003	1.21	-0.16
MUTCD 2009	1.21	-0.16
HCM 2000	1.20	-0.15
HCM 2010, 2016	1.34	-0.29
Bargegol 2014	1.10	-0.05
Bargegol 2015	1.02	+ 0.03

4. Conclusions

In this study, by investigating the crossing speed of 4381 pedestrians in normal and Rain Condition at the two signalized intersections of Rasht city, it was found that with a 95 percent confidence, in both gender groups of men and women, the difference in the pedestrian speed according to the weather conditions of either normal or rainy is statistically meaningful and the pedestrian crossing speed was significantly more in the times of rain than in the normal weather conditions. Meanwhile, in Rain Conditions, the 15^{th} percentile crossing speeds for men and women increase from 3.00 to 21.50 percent according to 15^{th} percentile speeds in the normal weather conditions, respectively. In addition, the speed difference of pedestrians with umbrellas and without umbrellas in both gender groups is not significant so this indicates that the pedestrians crossing speed was not affected by an umbrella in the Rain Condition. So that the 15^{th} percentile and average crossing speeds of all samples in the Rain Condition is 1.05 and 1.24 meter per second respectively. Considering these speed values, almost all the groups of pedestrian crossing in the Rain Conditions are included in the design of facilities.

Conflict of Interest Statement

The authors declare no conflict of interest.

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