

The Effect of Rainy Weather on Walking Speed of Pedestrians on Sidewalks

Iraj Bargegol, Vahid Najafi Moghaddam Gilani

Abstract

The pedestrian walking speed on sidewalks is one of the most important parameters in designing pedestrian facility and also is essential information in controlling the amount of delay and traffic. The present study aims to measure and statistically analyze the pedestrian walking speed according to weather conditions which is either normal or rainy. In order to do this, the walking speeds of 7146 pedestrians have been gathered through photography of two sidewalks in Rasht city. Furthermore, these findings have been analyzed through Independent Sample T-Test. The results show that, with a 95 percent confidence, in both gender groups of men and women, the difference in the pedestrian speed according to weather conditions of either normal or rainy is statistically meaningful and the pedestrian walking speed was significantly more in the times of rain than in normal weather conditions. Meanwhile, in rainy conditions, the 15th percentile walking speeds for men and women increase 19.10 and 25.92 percent according to 15th percentile speeds in normal weather conditions respectively. So that the 15th percentile and average walking speeds of all samples in rainy weather conditions is 1.02 and 1.15 meter per second respectively.

Key words: Pedestrian, Walking Speed, Sidewalk, Normal weather conditions, Rainy conditions

© 2015 BBT Pub. All rights reserved.

Introduction

Walking speed of pedestrians on sidewalks is one of the traffic engineering parameters so that the level of their exposure to traffic flow depends on walking speed. Therefore, the correct design of sidewalks facilities requires design is based on walking speed of pedestrians safe. Individual characteristics of pedestrians such as sexuality and age (Hamed, 2001), the number of people in the form of a group (Boles, 1981), pedestrian transverse crosswalk (Papadimitriou et al, 2009), pedestrian facility width (Alhajyaseen et al, 2010) and pedestrian volume (Galiza, 2013) including cases where the behavior of pedestrians in dealing with various pedestrians facilities and their walking speed is impressive.

Rasht city is often rainy and the people of this city are accustomed to rain naturally. As the rain also including the effect on pedestrian behavior, so the need to study the pedestrians walking speed affected by this problem is essential for designing pedestrian facilities. In this study by survey 7146 pedestrian data at two sidewalks, the differences between walking speed of pedestrians in normal and rainy weather conditions were obtained. Also the effect of having umbrella on pedestrians walking speed is studied.

Literature Review

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 pedestrians' crossing speed while vehicles are approaching to them should be 1.25(m/s) which could vary to 1.22(m/s), as well. Wilson and Grayson (1980) found that average walking speed 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 age, and sexuality. Griffiths et al. (1984) found that speed of crossing in signalized Intersections for teens, adults and elderly is 1.72, 1.66, and 1.47(m/s) respectively. Tanaboriboon and Guyano (1991) in an article named "Analysis of Pedestrian Movement in Bangkok" found that men and women crossing speed is 1.31 and 1.25(m/s) respectively, by viewing the crossing speed of pedestrians in a signalized Intersection in Bangkok. O'Flaherty (1997) has proposed the speed between 1.2 of 1.25(m/s) for crowded intersections motion of different age groups. In addition, he proposed average speed of 1.6(m/s) for 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. 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, age, gender, size of group and street width is greatly effective on pedestrians speed, and male pedestrians move faster than female pedestrians in crossing the street significantly. Gates et al. (2006) have pointed out that 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 United States and there is no difference between men and women crossing speed. In 2007 in an article named "Research on Pedestrian Behavior and Traffic Characteristics at Un-signalized Midblock Crosswalk: Case Study in Beijing" Shi and his colleague have found that men crossing speed is faster than women crossing speed for 0.1(m/s) by analyzing crossing speed of 1040 pedestrians in crossing un-signalized intersection. 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. The Manual on Uniform Traffic Control Devices in both version (2003 and 2009) have proposed moving speed of 1.21(m/s) for pedestrians to cross Intersections. Due to the book of highway capacity manual (HCM 2000, HCM 2010), Pedestrians crossing speed is based on the proportion of elderly pedestrians in all users. This book in both version 2000 and 2010, for ratio of less than 20 percent 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).

Methodology

Study sites

This study has been taken place in 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 Population density in Rasht is recognized around 4340 people per square kilometer (Iran Statistical Center, 2011). Also Rasht has ranked first in rainfall between provinces of Iran and the city is famous rain (Meteorological Center of Guilan, 2013).

Data Collection

Pedestrian behavior data were collected at 2 sidewalks in the city of Rasht. Then, sidewalks were filmed by video cameras and the information of 7146 pedestrian based on table 1 has also been collected. Then by observing those films, pedestrian were numbered based on some features such as: sexuality and weather condition. Finally, it turned out that 6621 of pedestrians have walked in normal weather condition, whereas 525 of them have walked in rainy weather condition.

Table 1: Data of the cases have been studied.

Place Number	Walking Width (meter)	Cases Number	
		Normal Weather	Rainy Weather
1	8	4303	321
2	8	2318	204

Data Analysis

After collecting 7146 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 assumption about the samples in the unknown conditions of society distribution which have been examined, as well. The benefit of this test comes to 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 normal distribution; however, when the degree of freedom reduces, scattering would be more. The degrees of freedom is a function of sample size, the more number of samples, the better test would be. T-Test can be utterly used to analyze the average in 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, T-test compares the average and standard deviation of two samples to specify that if there is any chief difference between them or not.

Results

In present study, the average and 15th percentile walking speeds of pedestrians in terms of weather condition (normal, rainy) through two sidewalks was recorded based on tables 2 and 3 during peak times.

Table 2: Results from sidewalks in normal weather conditions.

Categories	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	V ₁₅ (m/s)
Male	3081	1.10	0.169	0.89
Female	3540	0.97	0.174	0.76
All pedestrians	6621	1.03	0.139	0.81

Table 3: Results from sidewalks in rainy weather conditions

Categories	Observed Sample	Average Speed (m/s)	Standard Deviation (m/s)	V ₁₅ (m/s)
Male	354	1.21	0.181	1.06
Female	171	1.12	0.139	1.01
All pedestrians	525	1.15	0.141	1.02

Due to tables 2 and 3, pedestrians walking speed in rainy conditions is higher than normal one. Also the most average and 15th percentile walking speed values in both cases is for men and female walked with lower speed through sidewalks in all condition and the lowest values of average and 15th percentile speed is for them. So the average and 15th percentile speed respectively are 1.03 and 0.81 m/s at normal condition, on the other hand; the average and 15th percentile speed respectively are 1.15 and 1.02 m/s at rainy condition suggested with respect to all pedestrians in Rasht.

Analysis and Result Comparison

Result analysis of men and women's walking speed

The speed difference results of men and women through sidewalks with Independent sample T-Test have been in table 4.

Table 4. Comparing men and women walking speed in both normal and rainy weather conditions

Weather Condition	Sexuality	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value T	Independent sample T-Test result
Normal	Male	3081	1.10	0.169	P=0.000	major difference
	Female	3540	0.97	0.174	T=6.126	
Rainy	Male	354	1.21	0.181	P=0.001	major difference
	Female	171	1.12	0.139	T=1.773	

According to the test results of Independent sample T-Test which was listed in table 4, 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 walk faster than women along sidewalks. It should be noted that before using the T-Test, normal speed data for men and women was evaluated by Kolmogorov- smirnov test.

Result analysis of comparing pedestrians walking speed in normal and rainy weather

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 walking speed of pedestrians discussed. To compare the speed of pedestrians in both normal and rainy weather conditions, 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 5.

Table 5: Comparison of pedestrian walking speed in normal and rainy condition with same Gender

sexuality	Weather Condition	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value T	Independent sample T-Test result
Male	Normal	3081	1.10	0.169	P=0.000 T=3.753	major difference
	Rainy	354	1.21	0.181		
Female	Normal	3540	0.97	0.174	P=0.000 T=1.999	major difference
	Rainy	171	1.12	0.139		

According to the results listed in Table 5, all pedestrian walking 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 walking speed affected rainfall, so that men and women walked faster in normal weather conditions compared to the rainy conditions 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.

Result analysis of comparing walking speed of pedestrian with umbrellas and without umbrella

To comparing the walking speed of pedestrians in rainy conditions, they were divided into two groups: those with umbrellas and without umbrellas, because it was supposed that umbrella is a factor influencing on pedestrians walking speed. The speed difference results of pedestrian with umbrella and without umbrella in rainy condition weather with Independent sample T-Test have been in table 6.

Table 6: Compare the pedestrians walking speed with umbrellas and without umbrella in rainy condition

sexuality	pedestrian Condition	Sample	Average Speed (m/s)	Standard Deviation (m/s)	P-Value T	Independent sample T-Test result
Male	With umbrella	153	1.18	0.159	P=0.947 T=1.437	The difference was not significant
	Without umbrella	201	1.21	0.143		
Female	With umbrella	66	1.11	0.112	P=0.773 T=1.467	The difference was not significant
	Without umbrella	105	1.14	0.156		

According to the Independent Sample T-Test results listed in Table 6, the speed difference of pedestrians with umbrellas and without umbrella in both gender groups is not significant that this indicates pedestrians walking speed was not affected by umbrella in rainy condition.

Result comparison

According to figure 1, the most average and 15th percentile walking speed values in both weather cases is for men and women walked with lower speed through sidewalks in all condition and the lowest values of average and 15th percentile speed is for them. Also pedestrians walking speed in rainy condition through sidewalk is higher than normal condition. Meanwhile, in rainy conditions, the 15th percentile walking speeds for men and women increase 19.10 and 25.92 percent according to 15th percentile speeds in normal weather conditions respectively. However, men and women walking with speed value very close to each other in rainfall condition.

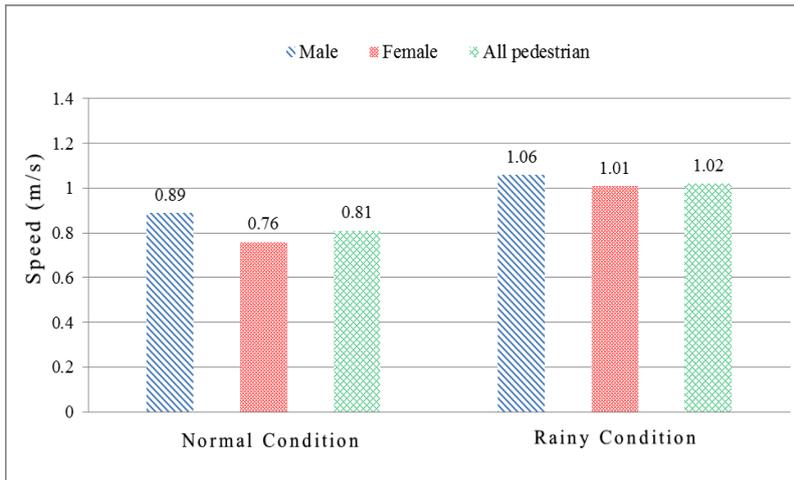


Figure 1: 15th percentile walking speed comparison in normal and rainy weather conditions

Also according to figure 2, by comparing walking speed result of present study with other studies which have been presented in the literature review are observed that the pedestrians 15th percentile speed in rainy and normal condition is much lower than the speeds reported by other researchers.

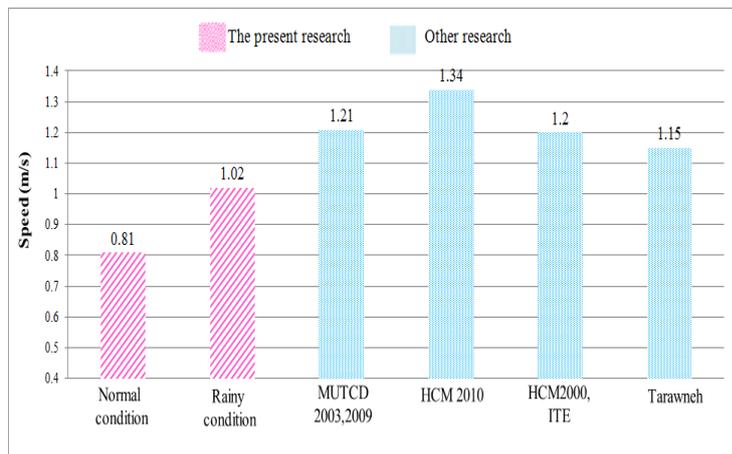


Figure 2: comparing walking speed result of present study with other studies

Conclusion

In this study by investigated the walking speed of 7146 pedestrians in normal and rainy condition at two sidewalks of Rasht city found that with a 95 percent confidence, in both gender groups of men and women, the difference in the pedestrian speed according to weather conditions of either normal or rainy is statistically meaningful and the pedestrian walking speed was significantly more in the times of rain than in normal weather conditions. Meanwhile, in rainy conditions, the 15th percentile walking speeds for men and women increase 19.10 and 25.92 percent according to 15th percentile speeds in normal weather conditions respectively. Also the speed difference of pedestrians with umbrellas and without umbrella in both gender groups is not significant that this indicates pedestrians walking speed was not affected by umbrella in rainy condition. So that the 15th percentile and average walking speeds of all samples in rainy weather conditions is 1.02 and 1.15 meter per second respectively. Considering these speed values, almost all groups pedestrian walking in rainy conditions be included in the design of facilities.

References

1. Hamed, M., 2001, Analysis of Pedestrians Behavior at Pedestrian Crossing. *Safety Science*, 38: 63-82.
2. Boles, W., 1981, The Effect of Density, Sex, and Group Size upon Pedestrian Walking Velocity. *Man-Environment Systems*, 11: 37-40.
3. Papadimitriou, E., Yannis, g., Golias, j., 2009. A critical assessment of pedestrian behaviour models, *Transportation Research Part F*, 12: 242-255.
4. W.K.M. Alhajyaseen, H. Nakamura, 2010. Quality of Pedestrian Flow and Crosswalk Width at Signalized Intersections, *IATSS Research*, 34: 35-41.
5. R. Galiza, L. Ferreira, 2013. A Methodology for Determining Equivalent Factors in Heterogeneous Pedestrian Flows. *Computers, Environment and Urban Systems*, 39: 162-171.
6. Moore, R. L, Psychological Factors of Importance in Traffic Engineering, Presented at International Study Week in Traffic Engineering, Italy, 1956.
7. Wilson, D. G. and Grayson, G. B, Age-Related Differences in the Road Crossing Behavior of Adult Pedestrians, *Transport Research Laboratory; Report No, LR 933, TRB, NCHRP, Washington D.C, USA, 1980.*
8. Griffiths, J.D.; Hunt, J.G. and Marlow, M. Delays at Pedestrian Crossings: Site Observation and the Interpretation of Data, *Traffic Engineering and Control*, 25, 365-371, 1984.
9. Tanaboriboon, Y. and Guyano, J.A, Analysis of Pedestrian Movement in Bangkok, *Journal of Transportation Research Board*, 1294, 52-56, 1991.
10. O'Flaherty, *Transport Planning and Traffic Engineering*, John Wiley & Song Inc, Arnold, London, 1997.
11. Tarawneh, M.S. Evaluation of Pedestrian Speed in Jordan with Investigation of Some Contributing Factors, *Journal of Safety Research*, 32 (2), 229-236, 2001.
12. Gates, T.J.; Noyce, D.A. and Bill, A.R, Ee Recommended Walking Speeds for Timing of Pedestrian Clearance Intervals Based on Characteristics of the Pedestrian Population, *Journal of the Transportation Research Board*, 1982, 38-47, 2006.
13. Shi, J.; Chen, Y.; Ren, F. and Rong, J, Research on Pedestrian Behavior and Traffic Characteristics at Un-signalized Midblock Crosswalk: Case Study in Beijing, *Journal of the Transportation Research Board*, 2038, 23-33, 2007.
14. *Manual of Traffic studies*, Institute of Transportation Engineers, US, 1999.
15. *Manual of Uniform Traffic Control Devices MUTCD*, Federal Highway Administration, US Department of Transportation, 2003.
16. *Manual of Uniform Traffic Control Devices MUTCD*, Federal Highway Administration, US Department of Transportation, 2009.
17. *Highway Capacity Manual*, 4th Edition; Transportation Research Board, National Research Council, Washington D.C., 2000.
18. *Highway Capacity Manual*; Transportation Research Board, National Research Council, Washington D.C., 2010.
19. Iran Statistical Center, 2011, Official Results of Census of Populations and Houses of Iran.
20. Meteorological Center of Guilan, Rasht, 2013, Guilan region.

Iraj Bargegol, Assistant Professor, Dept. of Civil Engineering, Faculty of Engineering University of Guilan, P.O.Box 3756, Rasht, Iran; E-Mail: bargegol@guilan.ac.ir.

Vahid Najafi Moghaddam Gilani, Master of Science of Highway & Transportation Engineering, Faculty of Engineering University of Guilan, P.O.Box 3756, Rasht, Iran; E-Mails: vahid.moghaddam90@yahoo.com.

*Author to whom correspondence should be addressed; E-Mail: vahid.moghaddam90@yahoo.com.