



AENSI Journals

## Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: <http://www.aensiweb.com/AEB/>

### Analysis of The Effect of Vehicles Conflict on Pedestrian's Crossing Speed In Signalized and Un-Signalized Intersection

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#### ARTICLE INFO

##### Article history:

Received 4 September 2014

Received in revised form 24 November 2014

Accepted 1 December 2014

Available online 25 December 2014

##### Keywords:

Pedestrian, Crossing Speed, Signalized Intersection, Un-Signalized Intersections, Conflicted crossing, Un-conflicted crossing, Age

#### ABSTRACT

Pedestrian's crossing speed in signalized and un-signalized intersection is an important factor in design of intersection which is effective on a number of cases including dimensions of intersection, necessity of installation of mediocre and the kind of controlling. The purpose of this investigation is to measure and also analyze the statistics of pedestrian's crossing speed to the effect of vehicle's conflict. Due to this, the crossing speed of 5675 pedestrians was both collected and examined through filming two signalized and two un-signalized intersection in Rasht city. Then these crossing speeds were analyzed by Kolmogorov- Smirnov, Anova and Spearman Correlation tests. The conclusion has revealed this fact that the crossing speed of pedestrian in un-conflicted crossing is more in compare with conflicted crossing in signalized and un-signalized intersection. In signalized intersection with conflicted crossing, the 15<sup>th</sup> percentile man and woman and group of pedestrian's speed reduced about 19/4, 17/0 and 15/9 percent in compare with 15<sup>th</sup> percentile pedestrian in un-conflicted crossing.

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**To Cite This Article:** Iraj Bargegol, Vahid Najafi Moghaddam Gilani and Sadra Farghedayn., Analysis of The Effect of Vehicles Conflict on Pedestrian's Crossing Speed In Signalized and Un-Signalized Intersection. *Adv. Environ. Biol.*, 8(21), 502-509, 2014

#### INTRODUCTION

Going on foot is the simplest way to transfer between the origin and destination and it could be considered as the only way of transportation which is independent and does not need to any Sort of tools. In general, people start on foot and end by this way, and it can be occurred by any means of vehicles. Therefore, pedestrians are the inseparable part of transportations system in cities. A large number of important parts of traffic engineering such as: flat intersection, crosswalks etc. are designed and controlled based on pedestrians features. Intersection has an important role in transportation system because of crosswalks. As a result, pedestrian's traffic behavioral traits like speed and kind of driving movement are essential for their safety .Finally, Factors which are thought effective on pedestrian's behavior to face different facilities, crossing speed and the volume of pedestrian could be counted like: Individual features like age and sexuality [1], The number of pedestrian in group [2], Crosswalk [3], The length of crosswalk [4] and The volume of pedestrian [5].

Due to lack of traffic signal, there could not exist particular time for an un-conflicted crossing in un-signalized intersection. Therefore, in rush hours, pedestrian and vehicles damage right of crossing ,for instance; to exit from intersection the rotation to right of vehicle, pauses of vehicles on crosswalks, and movement effect on crossing speed of pedestrian in signalized intersection. As a result, it is supposed that the conflicted crossing reduce the crossing speed in compare with un-conflicted crossing. To design facilities, it is extremely crucial to consider the crossing speed of pedestrian. The fact of the matter is that the conflicted and un-conflicted crossing differences are obtained through studying the crossing speed of 5675 pedestrians in two signalized and un-signalized intersection in Rasht. Needless to say, the effect of pedestrian's age on crossing speed in intersections is studied.

##### Literature Review:

In his article, Moore, (The Importance Of Mental Factor On Traffic Engineering, 1956.) has declared the fact that when the vehicle is approaching towards, crossing speed for pedestrian is estimated about 1/52 m/s and

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in other hand is about  $1/22$  m/s [6]. In 1980, Wilson and Grayson, through examining the connection between crossing speed and pedestrian features, have discovered that the average walking speed for male is  $1/32$  m/s and for female is  $1/27$  m/s [7]. Moreover, a few years later, in 1984, Griffiths and his colleagues have learned that the average walking speed in signalized intersection for young, middle-aged, and elderly is  $1/72$  m/s,  $1/66$  m/s,  $1/44$  m/s, respectively [8]. In 1991, in their article "Analysis of Walking of Pedestrian in Bangkok In" Tanaboriboon and Guyano through studying pedestrian's crossing speed in one of the signalized intersection in Bangkok have realized that the average of crossing speed for male is  $1/31$  m/s and for female is  $1/23$  m/s [9]. In the year 1997, O'Flaherty has suggested a certain number of crossing speed almost about  $1/2$  to  $1/25$  for all ages in crowded intersections and also he has suggested  $1/6$  m/s for uncrowded intersections [10]. In 2001, acclaiming that there are some effective factors on crossing speed such as: age, sexuality, the volume of pedestrian, and the width of roads, in his article "The Assessment of Pedestrian Walking Speed Through studying some effective factors" Tarawneh has studied the walking speed of 3500 pedestrians in 27 different intersections of large zone in Oman and has concluded that the average crossing speed is about  $1/34$  m/s and 15<sup>th</sup> percentile which affirms pedestrian's speed as  $1/11$  m/s. It goes without saying, he also explained this fact that male pedestrians could pass the intersection approximately faster than female pedestrian [11]. In 2006, by means of collecting the crossing speed of 1947 pedestrian from 11 intersection in America, Gates and his co-researchers pointed out the average of walking speed for pedestrian who are under 65 years old is  $0/3$  m/s more than those who are over 65 and there is not any distinguishing differences between male and female crossing speed [12]. In 2007, examining the crossing speed of 1040 pedestrians in un-signalized intersection, Shi and his colleagues have pointed out this fact that the crossing speed for male is  $0/1$  s more than female's, (study about pedestrian's behaviors and features of traffic in un-signalized intersection in Beijing) [13]. In 1999 the Laboratory Transportation Engineering in America has suggested that the crossing speed for pedestrian in intersection is about  $1/1$  to  $1/2$  m/s [14]. The Manual on Uniform Traffic Control Devices, in both copies (2003 and 2009) has also suggested  $1/21$  m/s for crossing speed of pedestrians [15, 16]. Needless to say that these numbers are totally based on the book of highway capacity manual regard to aged pedestrian in front of all users. In copy of 2000, this book has suggested  $1/2$  m/s for elderly pedestrian who are under 20 percent which this number was increased to  $1/34$  in 2010 and in both two copies the number has been suggested  $1/0$  m/s for upper 20 percent [17, 18].

#### Methodology:

In this present paper, the condition of un-conflicted crossing suggests those conditions in which pedestrian cross the crosswalk without any conflicted when the traffic light is green for them, however "conflicted crossing" signifies the inconvenience for pedestrian by vehicles whether the light is red or green. Conflicted of vehicles including: rotation to right side, pauses of vehicles on crosswalk, and their movements because of their exit in phases when they face the changing the phases. In addition, in accordance with the guide book of road's capacity (HCM 2010), the 15<sup>th</sup> percent of speed usually has been used in designing which shows that 85 percent of pedestrians walk faster than this speed [18].

#### The Place of Studying :

This investigation has been undertaken in Rasht. It is one of the cities of Iran and center of Guilan. This city is the biggest and busiest city in north of Iran. Based on official statistics in 1390, its population is about 639951 and Its compression is about 4340 person in each kilometer, as well [19].

#### Data Gathering:

In this research, first of all, four important and busy intersection of Rasht have been chosen. Second, the intersections were filmed by video cameras and the information of 5675 pedestrian (based on table 1) have also been collected. Then by observing those films, pedestrian were numbered based on some features such as: age, sexuality, weight, kind of crossing and conditions of crossing (conflicted and un-conflicted crossing). Finally, it turned out that 3074 of pedestrians have crossed in an un-conflicted crossing condition, whereas 2601 of them have crossed in conflicted crossing condition.

**Table 1:** Data of the cases have been studied.

Place Number	Crossing Width	Type of Intersection	Cases Number
1	30	Signalized	2320
2	20	Signalized	2843
3	22/5	Un-signalized	354
4	18	Un-signalized	158

Regards to crosswalk, by the means of those films which have been taken in intersections, the speed of pedestrians was measured by using Chronometer. The table number 2 depicts some categories for age, for this purpose the aged standard category was used which is presented in World Care Organization in 2000. The age

of pedestrian was estimated by their appearance [20]. People are divided into 3 groups based on their weight: thin, average, and fat. These groups are easily recognizable by people's appearance.

**Table 2:** Age Introduction.

Group Name	Group Features
Teenager	Under 18
Young	18-44
Middle-aged	45-59
Elderly	60 to upper

#### *Tools of Information's Analysis:*

After collecting the information, 5657 pedestrians have been analyzed by statistics tests such as: Kolmogorov- Smirnov, Anova and Spearman Correlation.

#### *Kolmogorov-smirnov test:*

One of the main assumption for most statistical tests, is normality of data distribution that kolmogorov-smirnov test is intended to used for this purpose. This test is a nonparametric test for data distribution. Approximate significance test, be viewed after performance in output that by comparison with  $\alpha$  can do test in significant level decide into normality of data distribution. If  $\alpha = 0/05$  (means with 95% certainty) if  $P\text{-value} > 0/05$  can be assumed, data distribution is normal. Indeed this test is a compliance testing distribution for quantitative data. Normality distribution test, is the most common test for examples that researchist doubts to normality of it.

#### *One way ANOVA:*

To compare two or more society (means influence of a independent variable regimentation on a dependent variable) used this test. Analysis of variance is more learner way than T test. T test be used just in the absence that goal be comparison of average between two group, but analysis of variance is a way that be used for comparison of average between more than two group, in other words it compares average of a quantitative trait in three or more than group. Indeed this analysis, help us to understand difference between groups

#### *Spearman correlation test:*

Analysis of correlation is a statistical tools for determination the type and intensity of relationship between quantitative variables. The correlation of coefficient is one of the used criteria in determination correlation between two variable . The correlation of coefficient show the intensity of relationship and kind of relation (inverse or direct).this factor is between 1and-1.if there is no linear relationship between two variables, the value of it will become zero. Usually in survey of correlation between two variables, the values of one are dependent on one another. For example in survey of relationship between age and speed of pedestrians, the speed is dependent on age. Variable dependent is showed by y and variable that values of it has influence on values of variable dependent named independent variable and it is showed by X.

#### *Harvest results:*

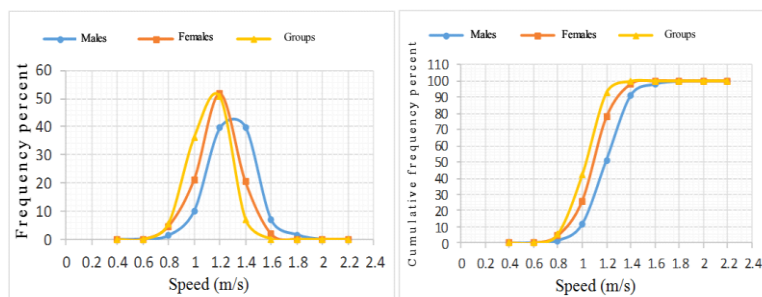
In this study people crossing at the signalized intersections at the time of the morning , noon and afternoon and two un-signalized intersections during peak traffic according to sexuality, age , weight, movement of a person or group were recorded.in two signalized intersections , terms crossing were classified in two condition of un-conflicted crossing (without conflicted affecting of vehicles) and conflicted crossing of vehicles.in another two un-signalized intersections , terms crossing is identical for all pedestrians during peak traffic and there was no possibility of passing the resolution, because in un-signalized intersections there is no specific and safe time for pedestrians crossing. Then by using the frequency distribution tables and the cumulative frequency distribution tables that was formed for all withdrawals, frequency distribution diagrams and the cumulative frequency distribution diagrams (figures 1 to 3) were plotted. The purpose of this work is determination the average speed indicators and 15<sup>th</sup> percentile speed and etc. according to the tables 3 to5.

Due to the frequency distribution curves (figures1 to 3) and tables 3 to 5.the most average speed values and 15<sup>th</sup> percentile speed in all pass cases and in both signalized and un signalized intersections is for men and however groups of pedestrians in all condition crossed through intersections with lower speed and the lowest values of average speed and 15<sup>th</sup> percentile speed is for them.

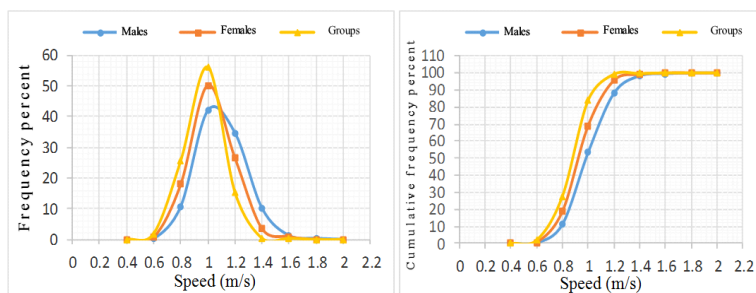
In passing through the signalized intersections with conflicted crossing of vehicles. Men pass with average speed and 15<sup>th</sup> percentile respectively 1/09 and 0/83 m/s, women pass with average speed and 15<sup>th</sup> percentile respectively 1/03 to 0/87 m/s and group of pedestrians pass with average speed and 15<sup>th</sup> percentile respectively 0/97 and 0/74 m/s.

In passing through the un-signalized intersections by affecting conflicted crossing of vehicles, men pass with average speed and 15<sup>th</sup> percentile respectively 1/13 and 0/84, women with average speed and 15<sup>th</sup> percentile

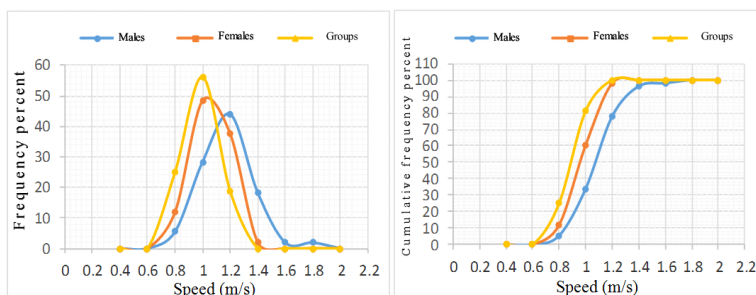
respectively 1/04 and 0/80 m/s and groups of pedestrians with average speed and 15<sup>th</sup> percentile respectively 0/99 and 0/76 m/s.



**Fig. 1:** Frequency and cumulative frequency distribution curves of the un-conflicted crossing of pedestrians at signalized intersections.



**Fig. 2:** Frequency and cumulative frequency distribution curves of the conflicted crossing of pedestrians at signalized intersections.



**Fig. 3:** Frequency and cumulative frequency distribution curves of the conflicted crossing of pedestrians at un-signalized intersections.

**Table 3:** The results of the study at signalized intersections in condition of un-conflicted crossing.

Categories	People Number	Speed Average	S.D. (m/sec)	mode	V <sub>15</sub>	Avarage	The most Speed	The Least Speed
Male	1380	1/29	0/181	1/25	1/03	1/29	2/22	0/53
Female	861	1/19	0/155	1/25	0/94	1/20	1/67	0/75
Group Movements	833	1/11	0/132	1/11	0/88	1/11	1/67	0/91

**Table 4:** The results of the study at signalized intersections in condition of conflicted crossing.

Categories	People Number	Speed Average	S.D. (m/sec)	mode	V <sub>15</sub>	Avarage	The most Speed	The Least Speed
Male	944	1/09	0/180	1/00	0/83	1/08	2/22	0/41
Female	581	1/03	0/151	1/00	0/78	1/01	1/54	0/64
Group Movements	514	0/97	0/136	1/00	0/74	0/95	1/54	0/62

Analyze and compare the results:

Analyze the results the effect of age on the transmission speed of the pedestrians in all intersections:

In table 6, the effect of age on the transmission speed of the pedestrians in all intersections was evaluated and to eliminate the effect of weight, the speed of equiponderant pedestrians were compared with each other to do this review. First by using Kolmogorov-Smirnov test, normality of data was evaluated. After determining the speed of the data distribution is normal, by using ANOVA statistical test and Spearman correlation to see the rate of correlation was used. Then to determine the cause of the difference according to tables 7 and 8 Gabriel post hoc test was used.

**Table 5:** The results of the study at un-signalized intersections in condition of conflicted crossing.

Categories	People Number	Speed Average	S.D. (m/sec)	mode	V <sub>15</sub>	Average	The most Speed	The Least Speed
Male	192	1/13	0/198	1/12	0/84	1/12	1/82	0/70
Female	158	1/04	0/129	1/12	0/80	1/05	1/33	0/67
Group Movements	162	0/99	0/109	0/94	0/76	0/98	1/25	0/80

**Table 6:** The analysis between speed and age of the Pedestrian with the same Weight.

Gender	Age Group	Weight group	People Number	Speed Average (m/s)	S.D. (m/sec)	Evaluation Results ANOVA upper 95% Certainty	Cohesion Test Result and Spearman Cohesion
male	Teen young middle-aged elderly	thin	40	1/33	0/199	P-Value =0/003 F=4/808 major difference	P-Value =0/028 R= -0/173 major difference
			83	1/36	0/172		
			17	1/30	0/128		
			22	1/20	0/181		
	Teen young middle-aged elderly	normal	133	1/31	0/197	P-Value < 0/0001 F= 29/753 major difference	P-Value < 0/0001 R= -0/208 major difference
			519	1/33	0/157		
			257	1/28	0/148		
	Teen young middle-aged elderly	fat	152	1/18	0/233	P-Value =0/123 F=1/957 major difference	P-Value =0/064 R=-0/169 minor difference
			12	1/21	0/181		
Female	Teen young middle-aged elderly	Thin	62	1/24	0/183	P-Value =0/123 F=1/957 major difference	P-Value =0/064 R=-0/169 minor difference
			50	1/18	0/148		
			33	1/17	0/139		
			18	0/97	0/122		
	Teen young middle-aged elderly	Normal	6	1/31	0/132	P-Value < 0/0001 F= 13/393 major difference	P-Value < 0/0001 R=-0/541 major difference
			59	1/27	0/150		
			19	1/13	0/133		
	Teen young middle-aged elderly	Fat	18	0/97	0/122	P-Value < 0/0001 F=43/903 major difference	P-Value < 0/0001 R=-0/337 major difference
			6	1/36	0/137		
	Teen young middle-aged elderly	Normal	407	1/20	0/138	P-Value < 0/0001 F=43/903 major difference	P-Value < 0/0001 R=-0/337 major difference
			161	1/14	0/132		
			30	0/94	0/093		
Teen young middle-aged elderly	Fat	-	-	-	P-Value < 0/0001 F=19/454 major difference	P-Value < 0/0001 R=-0/348 major difference	
		51	1/12	165/0			
		102	1/09	129/0			
Teen young middle-aged elderly	Fat	23	0/91	137/0	P-Value < 0/0001 F=19/454 major difference	P-Value < 0/0001 R=-0/348 major difference	
		23	0/91	137/0			

As seen in table 6, the speed of crossing all the pedestrians in all intersections were compared with statistical tests. The results showed that the effect of age on the speed of pedestrians that effects of aging in men is different from women and the weight factor is effective in reducing the rate of people speed. According to the results listed in table 6, observed that the average speed for men in slim and normal weight categories, with 95% certainty have a significant difference. However in obese weight group, the speed difference between ages is not statistically significant.

To determine the cause of the difference, Gabriel post hoc test was used. As a result of this test is shown in table 7, cause of men difference crossing speed in slim weight categories is older age group that has a significant difference with teenager and young group. Speed of teenager, young and middle-aged age group have no statistically significant difference in crossing the intersections. Middle-aged and older people have no statistically significant speed, too. Thus from these results it seems that teenager and young pedestrians in slim weight categories pass with same speed and the speed of middle-aged pedestrians is between these two groups and older group. Also in the normal weight group apart from a young age have a statistically significant difference with each other and young group have a statistically significant difference with older pedestrians.

The results in table 6, women average speed in all weight groups with 95% have significant difference. The table 8, the results of Gabriel post hoc test show for women in slim weight group, the speed of teenager and young groups by a factor close to 1, (P=0/970) is very similar and difference speed of teenager and young groups

are due to middle-aged and older age groups. Also in normal weight group, there is a statistically significant difference with the large difference between all groups and for women in obese weight group, difference speed of all age groups is from older woman.

**Table 7:** The evaluation result for all group connection analysis (male).

Gender	Weight Group	Age Group Comparison		P-Value	Cohesion Test Result and Spearman Cohesion	
male	thin	teen	young	0/976	Major difference with group ( elderly) Gabriel	
			middle-aged	0/993		
		young	teen	0/976		
			middle-aged	0/789		
	normal	middle-aged	elderly	0/001	Major difference with group ( elderly) Gabriel	
			young	0/325		
		elderly	teen	0/993		
			young	0/789		
	fat	thin	teen	middle-aged	0/025	Major difference with teen and young Group Gabriel
				elderly	0/325	
			young	teen	0/001	
				middle-aged	0/325	
		normal	teen	young	0/537	Major difference with group ( elderly Games-Howell
				middle-aged	0/656	
			young	elderly	<0/0001	
				teen	<0/0001	
fat	middle-aged	young	0/537	Major difference with middle-age and elderly Group Games-Howell		
		elderly	<0/0001			
	elderly	teen	0/565			
		young	<0/0001			
fat	normal	teen	elderly	<0/0001	Major difference with Young and Elderly Group. Games-Howell	
			young	<0/0001		
		elderly	teen	<0/0001		
			young	<0/0001		
	fat	teen	middle-aged	0/991	Major Difference with all Groups Games-Howell	
			elderly	0/944		
		young	middle-aged	0/993		
			elderly	0/944		
fat	middle-aged	young	0/991	No Major difference with Groups Gabriel		
		elderly	0/326			
	elderly	teen	0/171			
		middle-aged	0/171			

*Compare the results:*

The figure 4. maximum crossing speed values 15<sup>th</sup> percentile in all pass cases (un-conflicted crossing and conflicted crossing of vehicles) in both signalized and un-signalized intersections is for men and however groups of pedestrian in all condition cross with the lower speed through intersections and the lowest values of 15<sup>th</sup> percentile speed is related to them. Also crossing pedestrian speed in un-conflicted crossing condition is more than crossing time with conflicted of vehicles in both case signalized and un-signalized intersection. the impact of conflicted of vehicles is different in signalized and un signalized intersections. so that crossing 15<sup>th</sup> percentile pedestrian speed in un-signalized intersection, in compared to pedestrians crossing the signalized intersections in condition with the impact of conflicted of vehicles is a little more.

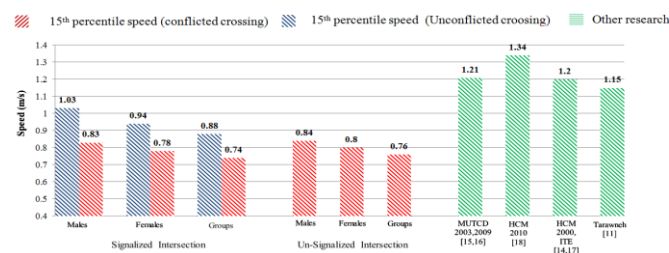
Also the figure 4, to compared 15<sup>th</sup> percentile pedestrian speed in this article with other studies mentioned in the review of the literature, viewed that the speed of pedestrians in rasht city in all crossing condition (un-conflicted crossing and conflicted crossing of vehicles) is much less than other research.

In terms of crossing pedestrians with conflicted of vehicles in both types signalized and un-signalized intersectins. 2601 people were crossed. the results of table 9 show, in signalized intersections in condition of crossing with conflicted of vehicles, men, women and group of pedestrian 15<sup>th</sup> percentile speed was respectively 19/4, 17/0 and 15/9% less than 15<sup>th</sup> percentile speed in un-conflicted crossing. also in un-signalized

intersections in condition of crossing with conflicted of vehicles, men, women and group of pedestrians 15<sup>th</sup> percentile speed was slaked respectively 18/4, 14/9 and 13/6% into condition of un-conflicted crossing.

**Table 8:** The evaluation result for all group connection analysis (female).

Gender	Weight Group	Age Group Comparison		P-Value	Cohesion Test Result and Spearman Cohesion
male	thin	teen	young middle-aged elderly	0/970 0/050 <0/0001	Major Differences in Middle-aged and Elderly Groups Gabriel
		young	teen middle-aged elderly	0/970 0/004 <0/0001	Major Differences in Middle-aged and Elderly Groups Gabriel
		middle-aged	teen young elderly	0/050 0/004 0/063	Major differences in Teen and Young Groups Gabriel
		elderly	teen young middle-aged	<0/0001 <0/0001 0/063	Major differences in Teen and Young Groups Gabriel
	normal	teen	young middle-aged elderly	0/002 <0/0001 <0/0001	Major Differences in all Groups Gabriel
		young	teen middle-aged elderly	0/002 <0/0001 <0/0001	Major Differences in all Groups Gabriel
		middle-aged	teen young elderly	<0/0001 <0/0001 <0/0001	Major Differences in all Groups Gabriel
		elderly	teen young middle-aged	<0/0001 <0/0001 <0/0001	Major Differences in all Groups Gabriel
	fat	young	teen middle-aged elderly	0/423 <0/0001	Major differences in elderly Groups Gabriel
		middle-aged	teen young elderly	0/423 <0/0001	Major differences in elderly Groups Gabriel
		elderly	teen young middle-aged	<0/0001 <0/0001	Major Differences in all Groups Gabriel



**Fig. 4:** Compare the 15<sup>th</sup> percentile crossing speed of pedestrians taken in this paper and other research.

**Table 9:** The Comparison of conflicted and un-conflicted crossing.

Type of intersection	Categories	Reduction of un-conflicted
Signalized	Male	19/4%
	Female	17/0%
	Group movement	15/9%
Un-signalized	Male	18/4%
	Female	14/9%
	Group movement	13/6%

**Conclusion:**

In this article by survey crossing speed of pedestrian in two signalized and un-signalized intersections affected by conflicting of vehicles was found:

-Through crossing of signalized intersections with impact of conflicting of vehicles, men cross with average speed and 15<sup>th</sup> percentile respectively 1/09 and 0/83 m/s, women cross with average speed and 15<sup>th</sup> percentile respectively 1/03 and 0/78 m/s and group of pedestrians with average speed and 15<sup>th</sup> percentile respectively 0/97 and 0/74 m/s .

-Through crossing of un-signalized intersections with impact of conflicting of vehicles, men cross with average speed and 15<sup>th</sup> percentile respectively 1/13 and 0/84, women with average speed and 15<sup>th</sup> percentile respectively 1/04 and 0/80 m/s and group of pedestrians with average speed and 15<sup>th</sup> percentile respectively 0/99 and 0/76 m/s.

-In signalized intersection in terms of conflicting crossing of vehicles, men, women and group of pedestrian 15<sup>th</sup> percentile slake respectively 19/4, 17/0 and 15/9% to 15<sup>th</sup> percentile speed in un-conflicted crossing terms.

-In un-signalized intersections in terms of conflicting crossing of vehicles, men, women and group of pedestrians 15<sup>th</sup> percentile slake respectively 18/4, 14/9, 13/6% into 15<sup>th</sup> percentile speed in un-conflicted crossing terms.

-In the slim and normal weight group, difference crossing speed of men, with 95% certainty is statistically significant in all age groups. Nevertheless in obese weight group, difference speed between ages is not statistically significant.

-In all weight groups, difference crossing speed of women, with 95% certainty is statistically significant in all age groups.

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