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Noor M. ASMAEL[1*], Mohanned Q. WAHEED[2]

ANALYSIS OF PEDESTRIAN CHARACTERISTICS CROSSING ALONG ROADS

Summary. Pedestrian crossing represents a substantial problem. In Iraq, there are no spaces marked specifically for pedestrians, which causes many conflicts between vehicles and pedestrians that lead to many accidents. The pedestrian death rate has increased recently due to the deficiency in adequate pedestrian infrastructure. However, to date, limited research has measured pedestrian behavior at crossing intersections in Iraq. There is a need to carry out in-depth studies to analyze crossing behavior to increase traffic efficiency and pedestrian crossing safety. Pedestrian crossing behavior is a serious issue to be addressed to provide adequate pedestrian facilities to enhance the pedestrian traffic environment. Road safety can be improved by locating crossing locations at the right locations and enforcing laws for pedestrian crossing. This study analyzes pedestrian crossing behavior in Baghdad City, Iraq, for four intersections at an unmarked crossing in the Central Business District (CBD) area. All required data were collected by video recording and a field questionnaire. Then, the data were extracted from video recordings and classified according to the selected variables. The period for observing the behavior was during the morning peak hours (November; time: 8:00 to 9:00 a.m.) for three days per week during normal conditions. This study examines pedestrian characteristics, vehicle/pedestrian flow characteristics, and traffic environment. Crossing patterns were followed for different gender and age groups. The finding reveals that the mean pedestrian speed is 1.33 m/sec. Also, males have a higher speed than females. The influences of age, gender, group size, and road width significantly affected pedestrian speed. The pedestrian speed decreased as pedestrian age increased. Gender and group size had significant effects on distinct crossing speeds. In addition, there is a weak significant correlation between pedestrian speed and selected variables. The study recommended specific marked places where a pedestrian must be located, and according to the pedestrian speed estimated in this study, a signal control for a pedestrian is recommended to be set up beside the street to organize the crossing with appropriate time for crossing safely.

1. INTRODUCTION

The pedestrian community is a key point in any transportation system. Pedestrian crossings located at intersections or major roads may be unsafe for many reasons, like speed, vehicle interaction, and vehicle numbers. Developed countries have arranged many strategies to improve mobility, but due to rapid urbanization and high population density in developing countries, pedestrian accidents have become a major safety issue recently. The number of accidents has increased due to the loss of obligation to traffic regulations and deficiencies in the legislative system, which represents an important factor in improving road safety [1]. Road traffic crashes happen due to the interaction between road users, vehicles, and road design [2]. Safety is important for road users, as unsafe crossing behavior reduces

[1] Mustansiriyah University, College of Engineering, Highway and Transportation Department; P.O. Box: 14022, Baghdad, Iraq; e-mail: noor_moutaz@uomustansiriyah.edu.iq; orcid.org/0000-0002-8871-7983
[2] University of Technology, Civil Engineering Department; P.O. Box: 19006, Baghdad, Iraq; e-mail: 40094@uotechnology.edu.iq; orcid.org/0000-0002-0200-5505
* Corresponding author. E-mail: noor_moutaz@uomustansiriyah.edu.iq

road safety [3]. Crossings are installed beside attraction sites like shopping areas with many road users, and rules govern the location of crossings to ensure safety [4]. Many variables, such as traffic conditions, environmental impacts, road conditions, and pedestrian characteristics, influence pedestrian behavior.

As problems have increased in recent years due to traffic congestion and air pollution, many cities worldwide have shown interest in using sustainable transportation relevant to non-motorized modes. Pedestrian movements in the urban environment represent an important subject. They are a key factor in planning, designing, establishing pedestrian facilities, and sustaining a healthy life. There is a need to realize how the existing facility accommodates pedestrians. The current analysis aided the understanding of the diagnosis factors that affect pedestrian safety at crosswalk intersections. The risky crossing is one of the important issues for pedestrian accidents. Therefore, roads must be designed to be safe and ensure traffic signal operation with appropriate time for crossing safely.

In Iraq, no local guidelines have been taken for designing pedestrian facilities, and no specific locations for pedestrians have been marked. Instead, foreign guidelines that are not adequate for the Iraq community are used. However, to date, no local research has measured pedestrian behavior at crossing intersections in CBD. All relevant local literature measures pedestrian speed on the sidewalk, which differs from crossing locations at intersections due to many conflicts. Due to the increasing pedestrian death rate, crossing at intersections represents an important subject that must be studied in-depth due to the many interactions between vehicles, pedestrians, and roads. Walking speed differs among countries because of the different physical characteristics of roads and pedestrians. The urban intersection includes many different movements that conflict with pedestrian crossing. This study aims to explore the influencing factors affecting walking speed, study crossing behavior, and find guidance for establishing pedestrian facilities. This study also aims to monitor human behavior at the crossing and to point out the interactions between driver maneuvers and pedestrian crossing. Statistical analysis is used as a tool to analyze pedestrian behavior, which represents a simple method. The research analysis was based on descriptive statistics to determine significant factors that affect pedestrian behavior. Hence, analyzing pedestrians' behavior has become urgently needed to increase road safety and provide adequate pedestrian facilities.

2. LITERATURE REVIEW

According to many works of literature, important factors that affect pedestrian speed are gender, age, weather, crossing distance, and terrain conditions [5-7]. Control measures and waiting time are the most important factors affecting pedestrian crossing [3]. Asaba and others stated that with more than a threshold of 21-28 s of waiting time, pedestrian patience was reduced and pedestrian violations increased when waiting was 40-45 s [8]. The decision for crossing-making depends on the desired waiting time [3]. Alver et al. [9] examined pedestrians' gap acceptance and the factors affecting it. They investigated midblock crossings in Izmir, Turkey. The data were gathered at peak hours and analyzed by image processing methods. The results showed that the 15th percentile of crossing speeds was 0.80 m/s, and critical gaps were between 4.1 and 6.2 s. Pawar and Patil [10] analyzed pedestrian decisions by studying gap acceptance at a mid-block crossing in India. Survey data based on video recording were observed for temporal and spatial gap acceptance, and 1,107 value gaps were extracted. A binary logit model was used for analysis, and six models were generated. From the results, for 50th percentile gaps, the values range between 4.1 and 4.8 s for temporal and between 67 and 79 m for spatial gaps. These values are lesser than the values for developed countries. Hu et al. [11] studied pedestrian safety in China. The data collected contained crash data from Changsha city, where six signalized intersections were examined. The study output shows a significant relation between pedestrian characteristics, severity level, and vehicle conflict. Fu, Miranda-Moreno, and Saunier [12] studied pedestrian safety at different types of crosswalk locations, and the relationship between vehicles and pedestrians was analyzed precisely at non-signalized intersections. A framework was developed for treating the interaction between pedestrian and vehicles that this approach used for road safety, pedestrian simulation, etc. The results showed that the interaction depends on vehicle deceleration rate and reaction time. Vuong [13] evaluated raised pedestrian crossings; the data collected at four locations on Ton Duc Thang Street have raised crossings.

The analysis was performed for four vehicle groups. For all vehicle groups running at 35.5 km/h or more, the results showed that raised crossings positively impact V85 speed. Forde and Daniel [14] analyzed walking speeds at two un-signalized midblock crosswalks. They investigated speed relation with age group, and the results show a significant difference between speeds for different age classes. Mukherjee and Mitra [15] analyzed pedestrian safety across 24 signalized intersections. Pedestrian fatalities vary depending on location in Kolkata, India. The pedestrian signal violation and its relationship with fatal crashes were investigated. The results indicate planning deficiencies, such as high vehicle-pedestrian interaction and long wait times. The findings were used to improve safety at signalized intersections. Shaaban et al. [16] investigated illegal crossing behavior in Al Doha, Qatar City. A six-lane divided arterial road was selected to observe the behavior. The findings show that illegal behavior was dominated by the male gender and waiting time increased as group size increased. Zhang et al. [17] investigated pedestrian behavior at an uncontrolled crossing in Wuhan, China. The findings show that risk increased significantly with an increase in the number of lanes and conflict area between vehicle and pedestrian. Pedestrian safety is also affected by traffic volume, age, gender, etc. Zhao et al. [18] investigated pedestrians and vehicles interaction at un signalized crosswalks, a microscopic flow model was used to explore the behavior. The findings show that waiting time is affected by a number of lanes. When the midblock crosswalk is more than 4, the signal control is suggested. Tezcan et al. [19] studied crossing behavior in Istanbul, Turkey. Midblock crosswalks were selected on location with three or two-lane streets. Multinomial logit models were used for modeling the crossing and platooning. The results showed that pedestrian behavior is controlled by traffic volume and accepted gaps, and the probability of platooning formation grows as the platoon size and traffic volume increase. Marisamynathan and Perumal [20] explored the crossing behavior at a signalized intersection in Mumbai. India. Three intersections with mixed traffic conditions were selected to study pedestrian-vehicular interaction, and the data were tested by statistical analysis. The findings showed that the crossing speed is 0.95 m/s for elderly pedestrians and 1.12 m/s for adults. Gender and group size of pedestrians are influencing factors that control pedestrian compliance behavior.

3. STUDY AREA

Baghdad is the capital city of Iraq, and its population increased to about 9 million. It has an increased motorization rate that threatens the lives of pedestrians to danger; therefore, pedestrian safety needs to be addressed. Four selected intersections managed by traffic police officers were selected to study the behavior. These intersections are located in the central business district (CBD) and are surrounded by major different activities. There are also many pedestrian movements in this area. The following issues need to be investigated to attain the goal of this study:

(1) Pedestrian characteristics data, which consist of pedestrian age and gender.
(2) Pedestrian crossing behavior data, which comprise waiting times at the signalized intersection and group size.
(3) Intersection environment data, which include vehicle flow, signal type, signal cycle, gap size, lane width, number of lanes, and so on.

4. DATA COLLECTION

The study area includes four intersections in Baghdad City:

1- Al-Saha Intersection

This intersection is located beside the Ministry of Health in the Bab Al-Muatham region (CBD). This intersection exhibits many conflicts between the movement of pedestrians and cars. Many public bus routes operate within the region. The area is also surrounded by hawkers. The intersection is accompanied by a heavy movement of pedestrians, as shown in Fig. 1 below.

2- Al-Sarafya Intersection

This intersection is located in the CBD area beside the Al-Sarafya Bridge and facilitates the movement of vehicles and pedestrians to the Karkh side. This intersection is accompanied by the medium movement of pedestrians in Baghdad, as shown in Fig. 1.

3- College of Art Intersection

This intersection is located in the CBD area before the Al-Sarafya intersection; educational sites are located beside this intersection, which is accompanied by heavy pedestrian movement, as shown in Fig. 1.

4- Al-Nakheel Mall Intersection

This intersection is located beside Al-Nakheel Mall on Palestine Street in Baghdad. Many Iraq ministries surround the area, and the medium movement of pedestrians accompanies this intersection.

Pedestrian behavior was observed along the intersection using a field survey with the aid of a camera to acquire real data. Behavior was observed during the morning peak hours (November; 8:00 to 9:00 a.m.) for three days per week during normal conditions (e.g., normal traffic flow and weather conditions). Depending on video recordings, the interactions between pedestrians and car drivers were investigated at the signalized intersection. The screenshots collected from the video recordings were used to obtain factors such as group size, pedestrian volumes, entry time to the crossing, and the time needed to walk the crosswalk. A questionnaire was administered among pedestrians to collect information about age. All people were surveyed by a questionnaire, and the data analysis considered only those who were recorded by the cameras at the same time.

a) Al-Saha Intersection

b) Al-Sarafya Intersection

c) College of Art Intersection

d) Al-Nakheel Mall Intersection

Fig. 1. Four selected intersections

5. RESULTS

A field survey was conducted to analyze the crossing maneuvers of pedestrians and car drivers at unmarked crossings. The following variables were considered to determine their effect on pedestrian

speed: vehicle speed (km/h), group size, gap size (sec), road width, and gender. Gap size was measured as the difference between the time of the car leaving the crossing and the next arriving car based on the cross-point location. After the data were collected, they were classified and organized to be ready for statistical analysis. Tab. 1 shows the descriptive statistics of the data.

Table 1

Descriptive statistics of the data

	Vehicle Speed (km/h)	*Group Size*	*Gap Size (sec)*	*Road Width*	*Pedestrian speed (m/sec)*
Mean	37.110	1.520	107.545	14.413	1.331
Standard Error	0.400	0.059	4.100	0.0618	0.035
Median	36	1	100	14.3	1.290
Standard Deviation	4.827	0.831	54.393	0.856	0.494
Sample Variance	23.3	0.69	2958.68	0.733	0.244
Kurtosis	0.364	1.746	-0.180	-1.395	0.430
Skewness	0.62	1.59	0.61	-0.04	0.65
Minimum	30	1	20	13	0.433
Maximum	50	4	280	15.7	3.08

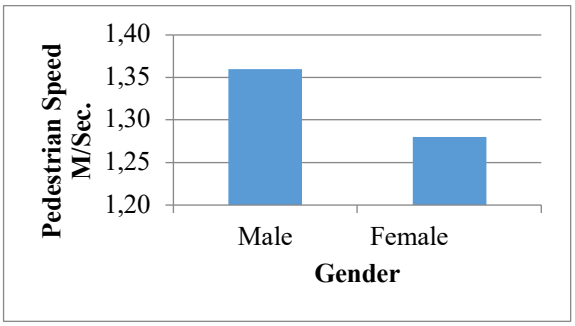
5.1. Inspection of pedestrian speed on the unmarked crosswalk

The selected pedestrian crossing locations were close to high-traffic generators in the city center. The conflicting situation within the intersection between car and pedestrian movement causes irregular crossing maneuvers for drivers and pedestrians at crossings. Before crossing the road, pedestrians stop at the curbside road and wait for acceptable gaps in the traffic flow. They reject or accept gaps depending on their characteristics, and older adults reject many gaps and accept longer gaps to cross the road, so they wait a long time at the curbside. The gap acceptance depends on the pedestrian's ability to cross the road. Fig. 2 shows the average pedestrian speed for different variables. Presently, the pedestrian speed of males is higher than that of females. The results agree with Sarsam and Abdulameer [21], who showed that as group size increases, pedestrian speed also increases. As the gap size increases, the pedestrian speed decreases. Moreover, as road width increases, pedestrian speed increases, and as age increases, pedestrian speed decreases.

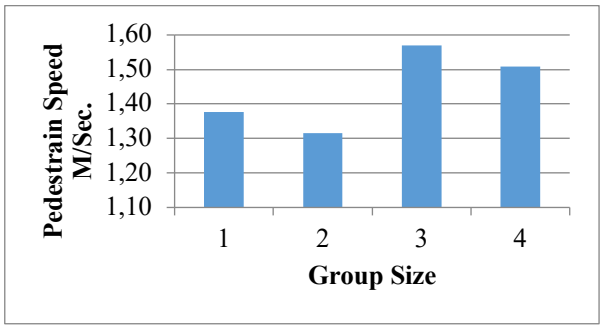
An ANOVA was performed to show if there is a difference in speed between males and females and to analyze the influence of gender on pedestrian speed. The output appears in Tab. 2, which indicates a significant difference between males and females. The difference in crossing speeds among gender groups was significant. The effect of group size on pedestrian speed was analyzed by the ANOVA. The output exhibited a significant difference between the speed of different groups, as the p-value of the test equaled 0.035. The effect of pedestrian age was also investigated, and the outputs showed a significant difference, with a p-value equal to 0.045. For the road width variable, there was also a significant difference, with a p-value equal to 0.01. Meanwhile, there was no significant difference in the effect of gap size on pedestrian speed.

5.2. Modeling Pedestrian Speed

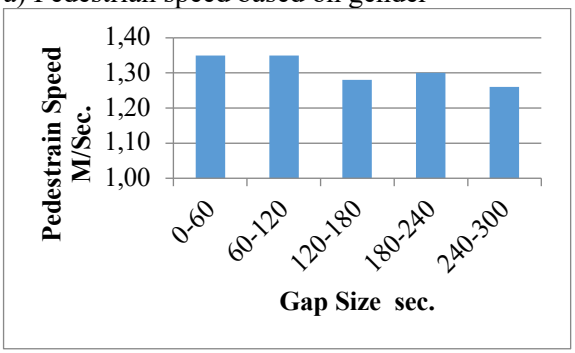
The collected data were checked for outliers using the Grubbs test. The results are shown in Tab. 3 below.



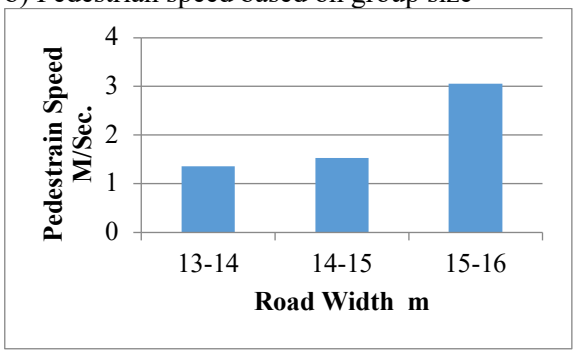
a) Pedestrian speed based on gender



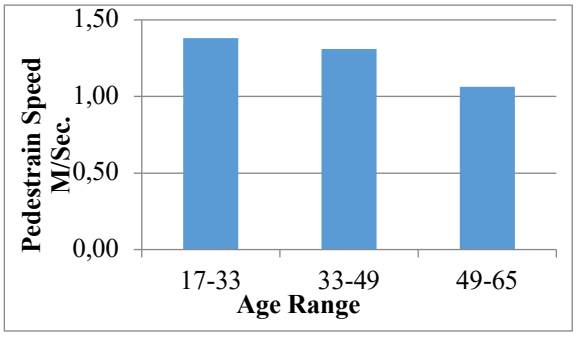
b) Pedestrian speed based on group size



c) Pedestrian speed based on gap size



d) Pedestrian speed based on road width



e) Pedestrian speed based on age

Fig. 2. Pedestrian speed values for different variables

Table 2

ANOVA

ANOVA: Single Factor						
Groups	*Count*	*Sum*	*Average*	*Variance*		
F	71	91.342	1.286	0.275		
M	71	105.799	1.490	0.213		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.471	1	1.471	6.012	0.015	3.908
Within Groups	34.271	140	0.244			
Total	35.743	141				

According to the interpretation of the test, the computed p-value is greater than the significance level (alpha=0.05), which indicates no outliers in the data. After that, the data were checked for normality using the Kolmogorov-Smirnov test, the results of which are shown in Tab. 4 below.

Table 3

Grubbs test output

Grubbs test / Two-tailed test					
	Vehicle speed (km/h)	Group Size	Gap Size	Road Width (m)	Pedestrian Speed (m/sec)
G (observed value)	2.652	2.802	3.132	1.697	3.548
G (critical value)	3.502	3.502	3.502	3.502	3.595
p-value (two-tailed)	1.000	0.651	0.209	1.000	0.060
alpha	0.05	0.05	0.05	0.05	0.05

Table 4

Kolmogorov-Smirnov test results

Kolmogorov-Smirnov test					
	Vehicle Speed	Group Size	Gap Size	Road Width (m)	Pedestrian Speed (m/sec)
D	0.143	0.373	0.109	0.184	0.081
p-value (two-tailed)	0.005	0.000	0.062	0.000	0.283
alpha	0.050	0.050	0.050	0.050	0.050

As the computed p-value exceeds the significance level (alpha=0.05), one cannot reject the null hypothesis H0. According to the explanation above, none of the variables, except gap size and pedestrian speed, follow a normal distribution. Fig. 3 shows the scatter plots of various variables selected in this study and their relation to pedestrian speed.

The Pearson correlation matrix for the dependent variable (pedestrian speed) and independent variables, which include (group size, gap size, road width, and vehicle speed) is studied at a significance level of 0.05, as shown in Tab. 5 below, which shows a negative relationship between vehicle speed and gap size with pedestrian speed. This means that pedestrian speed increased as vehicle speed decreased, and pedestrian speed decreased as gap size increased.

Fig. 4 shows the histogram of pedestrian speed. According to the statistics test, a pedestrian speed model cannot be built using regression analysis due to the non-normal distribution of variables. In addition, a weak relation between gap size and vehicle speed is shown.

6. DISCUSSION

Due to an increase in pedestrian accidents that happen on roads, there is a need for an in-depth study to investigate pedestrian behavior. Intersections with unmarked crossings decrease pedestrian safety and increase interactions with vehicle drivers. The current study investigated pedestrian perceptions and behavior along with four sites in the CBD area in Iraq. Videos and questionnaire surveys on the vehicle-pedestrian interaction were considered to analyze the behavior. The influences of selected variables on pedestrian speed were investigated using a correlation test. The analysis shows that pedestrians' characteristics represent important predictors of pedestrians' behavior. Results from different analyses point out that crossing speed is affected by gender, age, group size, and road width, which agrees with the results of [22]. The pedestrian speed decreased as pedestrian age increased, which agrees with the results of [23, 24]. The difference in crossing speeds among gender and group size is significant. The

average pedestrian crossing equals 1.49 for males and 1.28 for females, showing that males have a higher crossing speed than females, which agrees with the results of Khudhair and Alsadik [25]. There is a significant relationship between pedestrian speed and length of crossing, which agrees with the results of [23]. In addition, there is a weak statistical relationship between pedestrian speed and selected variables in this study. However, there is a need to further investigate other sites beyond the CBD area. The results show that the average pedestrian speed for the Iraq community is 1.33 m/sec, which is slightly lower than the results for the Palestine area conducted by Hassouna [24] and agrees with the results of the Jordan area conducted by Tarawneh (2001). According to the HCM Manual, 2010 [26], pedestrians walk with a median speed of 1.5 m/sec, which differs from the value speed in local conditions. Pedestrian speed in the Arab world is slower than in the USA, UK, or Canada due to their culture, facility type, and side friction Banerjee et al.[27]. The findings show that the speed of approaching vehicles during crossing varies between (30-50 km/h), which increases the probability of danger at the intersection, leading to fatalities. The gap size and pedestrian speed follow a normal distribution, and the gap size increases as the pedestrian speed decreases. An inadequate pedestrian facility leads to many pedestrian-vehicular crashes. Therefore, crosswalks should be located along intersections and well connected with the sidewalk. The outcomes are useful for planners and engineers to develop a better pedestrian facility and accurate pedestrian simulation.

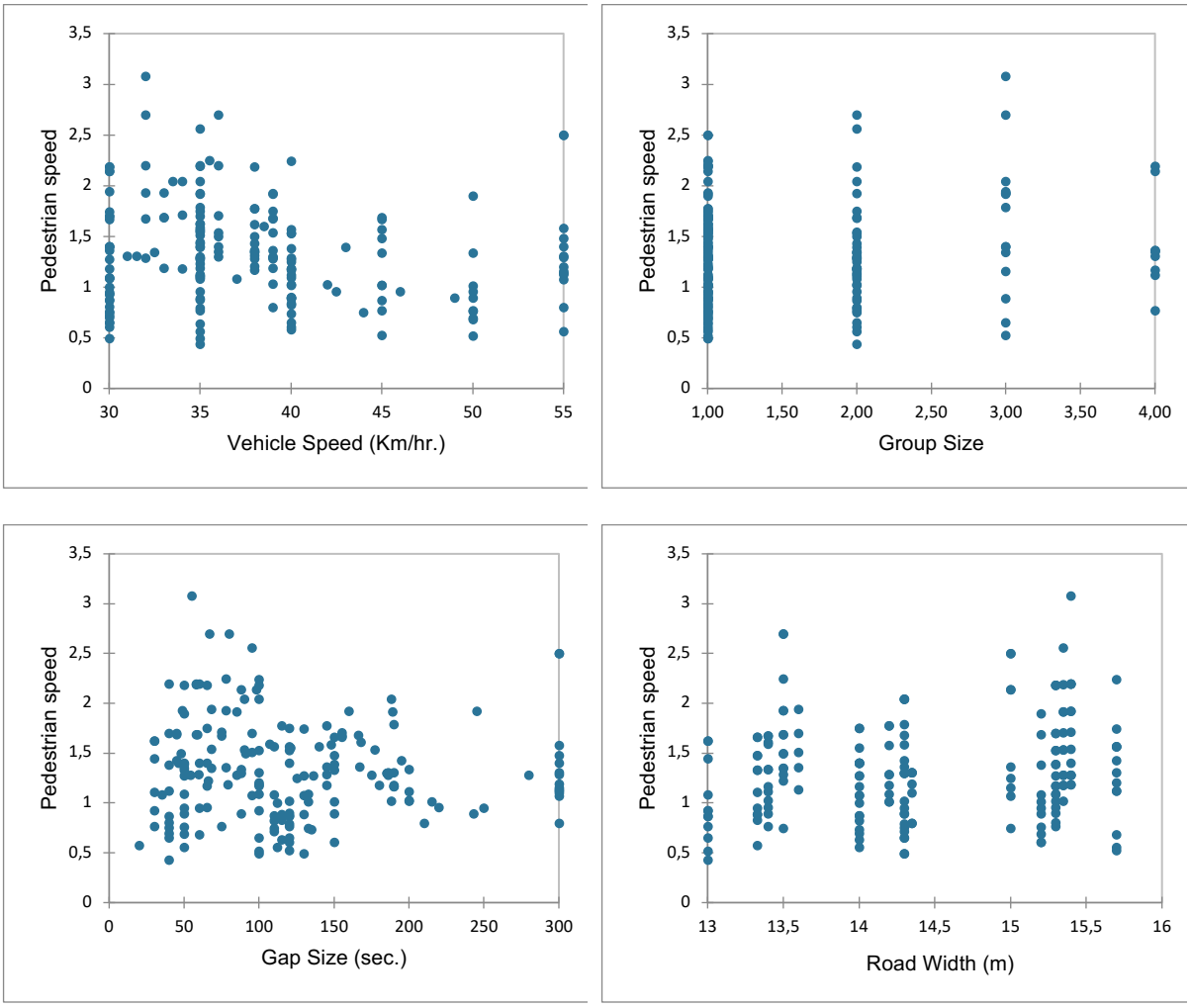


Fig. 3. Scatter plot of data

Table 5

Pearson Correlation Matrix

Correlation matrix (Pearson):					
Variables	Vehicle Speed (km/h)	Group Size	Gap Size (sec)	Road Width (m)	Pedestrian Speed m/sec
Vehicle Speed Km/hr.	1	0.069	0.271	-0.039	-0.227
Group Size	0.069	1	0.123	-0.001	0.158
Gap Size (sec)	0.219	0.084	1	0.008	-0.084
Road Width (m)	-0.039	-0.001	0.008	1	0.162
Pedestrian speed	-0.227	0.158	-0.084	0.162	1
p-values (Pearson):					
Variables	Vehicle Speed Km/hr.	Group Size	Gap Size (sec)	Road Width (m)	Pedestrian Speed
Vehicle Speed Km/hr.	0	0.361	0.000	0.607	0.002
Group Size	0.361	0	0.104	0.990	0.035
Gap Size (sec)	0.000	0.265	0	0.579	0.268
Road Width (m)	0.607	0.990	0.579	0	0.031
Pedestrian speed	0.002	0.035	0.268	0.031	0

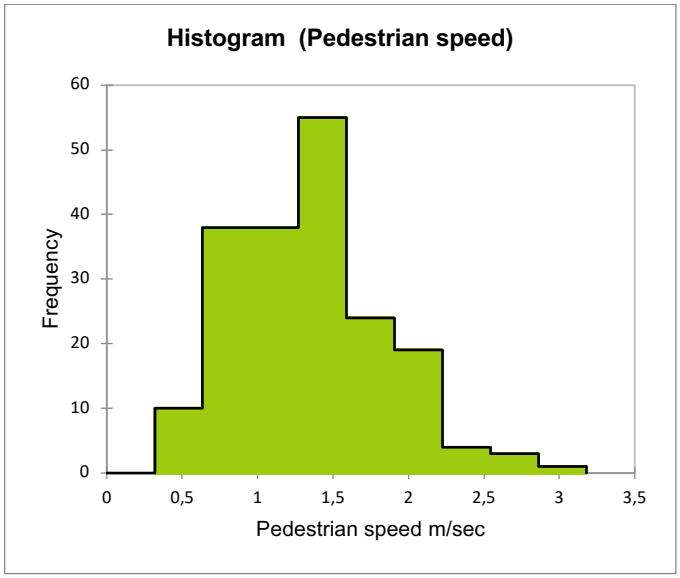


Fig. 4. Pedestrian Speed Histogram

Description of the study's limitations

The following points represent some limitations that are not taken into account in this research, and there is a need to study them:

1- This study is limited to intersections inside the CBD area; it is preferable to take intersections outside the CBD area to estimate pedestrian speed and compare the speed between these two areas.
2- Factors considering waiting time for pedestrians need to be studied.

3- The movement of disabled persons needs to be studied.
4- Measures are needed to analyze the level of service for pedestrian facilities.
5- Interaction between pedestrian and bus service can be analyzed using the DEA approach to evaluate pedestrian facility effectiveness [28,29].

7. CONCLUSIONS

Four intersections have been studied: the Al-Saha intersection, the Al-Sarafya intersection, the Al-Nakheel Mall intersection, and the College of Art intersection. For all intersections, correlations have been studied among pedestrian speed, vehicle speed, gender, size of pedestrians, gap size, and road width.

From the results, the following conclusions are drawn:

1- The average pedestrian speed is 1.33 m/sec for the Iraq community;
2- Male speed is higher than female speed;
3- As pedestrian groups increased, pedestrian speed increased;
4- Gap size increased as the pedestrian speed decreased;
5- Pedestrian speed increased when the road width increased;
6- There is a weak correlation between pedestrian speed and other factors considered in this study.

8. RECOMMENDATIONS

Pedestrian crossing represents a substantial problem. In Iraq, there are no spaces marked specifically for pedestrians, which causes many conflicts between vehicles and pedestrians that lead to many accidents. Different recommendations are suggested:

- Specific pedestrian crossing road markings for a pedestrian must be located. According to the pedestrian speed estimated in this study, a signal control for pedestrians is recommended to be set up beside the street to organize the crossing with appropriate time for crossing safely.
- Strict laws should be made that make drivers stop at pedestrian crossings.
- In some countries, there is an asphalt pad that makes the car slow down when crossing near a pedestrian crossing, and it is important to apply this.
- A pedestrian bridge with a curved shape should be made to reduce walking distances. Alternatively, pedestrian bridges with elevators should be made to increase comfort to the users at places containing substantial pedestrian movement crossing (e.g., colleges, and markets).

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