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Development Models of Pedestrian Crossing Behavior on Midblock Segments Located on Dohuk City CBD Area

Dr. Abdulkhalik A.M.AL-Taei

Assistant Professor/Transportation Engineering, Mosul University/College of Engineering/Civil Dept.

ABSTRACT

In this study, ten pedestrian crossing spots located in Dohuk City CBD were selected to make analysis and evaluation to the behavior of the people crossing the main streets, and walking on sidewalks according to their genders. Data was collected using double video cameras fixed on selected points to observe pedestrian movements along crossings, and sidewalks, their interaction with drivers and vehicles conflicting them. Data compiled, was classified, and presented using Event Software to measure numbers of moving vehicles, people, vehicle gaps, space, pedestrian unit flow, speeds of both pedestrians, and vehicles passing the crossing lines on CBD midblock. Data was presented using Dohuk City GIS up-to-date map taken from the city Municipality Directorate. Data analysis was implemented using the Curve Fit 1.3, Minitab, and Excel 12 software. Different empirical models were chosen to study the different interactions and effects of human, geometric, and vehicular traffic parameters on the behavior of pedestrians crossing, and walking on crosswalks, and sidewalks respectively. Results show that, pedestrian flow with their speeds were parabolic in nature, while flow, speeds, and density with space were inversely correlated with considerably high correlation coefficient R, and low SSE. Females were usually moving faster than males when crossing on Dohuk City CBD segments. Pedestrian Density with flow varied with quadratic type model with low R, and high SSE values.

Key words: Pedestrian Crossing, Sidewalks, Gap and Lag, CBD Dohuk

INTRODUCTION

As population number is continuing to increase in all cities in Iraq, and especially in Kurdistan Region due to the recent development in the political and economic characteristics in the different cycles of the life. Immigration from the different cities of Iraq to the region increased too due to the settlement in the security condition in most parts of the region. Kurdistan Region is subjected to many trips from all around the countries around the region due to the commercial, educational, and business activities resulted in high accumulation of people in hotels, motels, and mega cities opened recently to receipt the increasing number of the people from outside the region. The population increase during the last thirteen years in Dohuk City, in both urban and rural locations of the city was very large. This ever-increasing number of population caused a lot of people to use the road spaces provided in the city and brought a big problem to the ever-increasing number of vehicles existed already in the different parts of the network.

The highway Capacity Manual-2000(HCM-2000)[1], and (HCM-2010)[2], versions, are both highly interested in detailing the Pedestrian Topic, in both concepts, and applications with some new addition to some of the concepts given in the old version. Some of the factors affecting walking speed are pedestrian density, gender, size of platoon, percentage of elderly population, handicapped pedestrian population, and child pedestrians. Typical pedestrian group is walking in 1.2m/sec. speed. Pedestrian space is the average area required for one pedestrian to move in appropriate speed on walking or queuing area measured in ped. /min./m.

Pedestrian traffic condition can be evaluated by using Level of Service (LOS) concept from LOS A up to LOS F. Pedestrian LOS at capacity (i.e., LOS E) is usually happened at average space values between (0.4-0.9) m^2/p. At this level space is restricting pedestrian from movement freely with the speed he/or/she is required.

Vallyon C. and Turners. (2011)[3] in their research paper focused on one of the key issues: namely, the delay experienced by pedestrians at traffic signals. Traffic signals are a common means of regulating this interaction and attempting to maintain or improve the safe and efficient use of the road network. The supplementary material also provides guidance on pedestrian level of service and acceptable delays. The research's pedestrian surveys confirmed the findings of international research, including the fact that after about (20–30) seconds of delay; pedestrian's level of frustration grows disproportionately to the actual delay itself, as evidenced by their disproportionate perceptions of delay.

Raguhram K. and Vedagiri P., (2013)[19] proposed that, the pedestrian crossing became one of the main issues in traffic engineering, especially in a highly congested urban area. Midblock are the major crossing hazardous locations from which pedestrian trying to cross with a speed depending on the pedestrian behavior. The main purpose of this study was to investigate the pedestrian crossing behavior at the uncontrolled midblock locations in India under mixed traffic condition. Pedestrian crossing behavior at uncontrolled midblock locations was modeled by the size of rolled gap occupied by vehicles passing the road section using the multiple linear regression technique.

Problem Development

A lot of trips are entering and exiting Dohuk City from the West and North West connections to Erbil, and Sulamania, producing more interaction with the people served by the roads and streets through which pedestrians are moving, crossing and transporting. As a consequence of a lack of comprehensive traffic safety countermeasures by the government and people's low awareness of traffic safety, the number of traffic accidents and fatalities had constantly increased over the last five years. Accident frequency is continuing to increase as it can be shown from the annual statistics of the Traffic Police Directorate in Dohuk City (5). Most of the accidents are happening within the boundary of the urban area where people and traffic are mostly moving. Car ownership increase trend during the last five years (2010-2015) show that more than 12 percent was the average growth rate increase in Dohuk City according to the Traffic Police Directorate in Dohuk City Annual Statistics (5).

Purpose of the Study

This study is proposed mainly to satisfy some of the points found needing more planning, or development from the pedestrian safety point of view, as those people are including large scale classes of people from males, and females. Most of them are students moving during the peak traffic demand periods to satisfy their job needs. In order to satisfy safety, the research should insist on the following points:

- Evaluation of the existing pedestrian crossing facilities used by CBD city residents;
- Driver behaviour related to pedestrians crossing at different parts of the Dohuk City inside CBD;
- Level of service of the crosswalks, sidewalks serving the ever-increasing numbers of pedestrians using the infrastructure of the city CBD computation;
- Type of CBD pedestrian crossings needed to be installed near those crossing locations like Zebra, Pelican, and other advanced types of pedestrian crossing;
- To build statistical modelling in order to predict CBD pedestrian-crossing phenomenon on the heavily pedestrianized crossing zones in both urban and sub-urban locations; and
- To correlate in some details CBD pedestrian crossing parameters with vehicular flow variables at mid-block segments.
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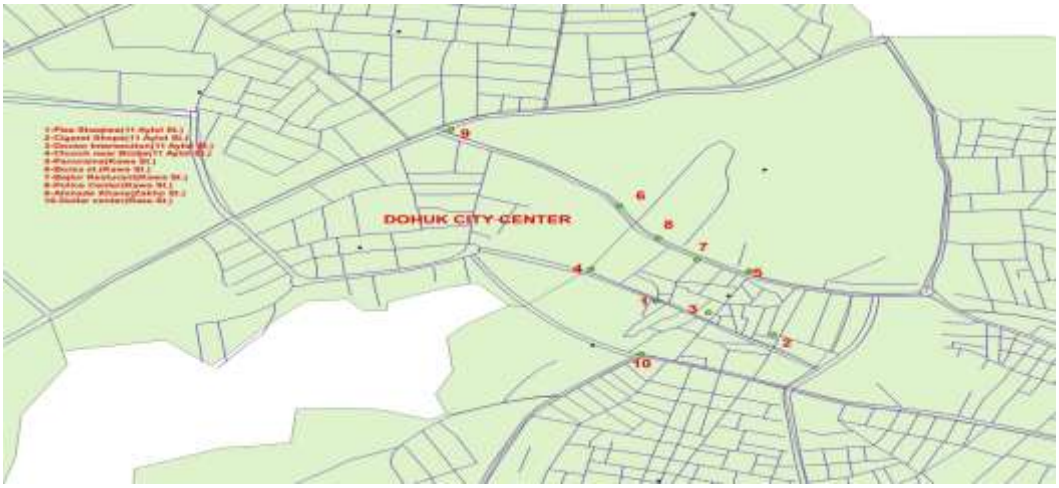
Method of the Study

The study methodology including how the pedestrian is going to cross roads of different classes from the midblock sections located in the Dohuk City infrastructure which have weak , or no control for pedestrian crossing .In the locations observed in this methodology , no pedestrian signs, marking , or signals are installed in order to control the safety, and security of the people of different ages, genders, and races are going to pass the roads randomly without any serious safety arrangements. . Figure (1), which a type of GIS Map for Dohuk City on which study this study was carried on. Methodology proposed in Figure (2) is to implement the different stages of this study including also the different traffic phenomena related to pedestrian (6).



• Location where Pedestrian Study Observations were taken

Figure (1): Dohuk City CBD Study Area with 10 Locations Used for Data Collection (6).

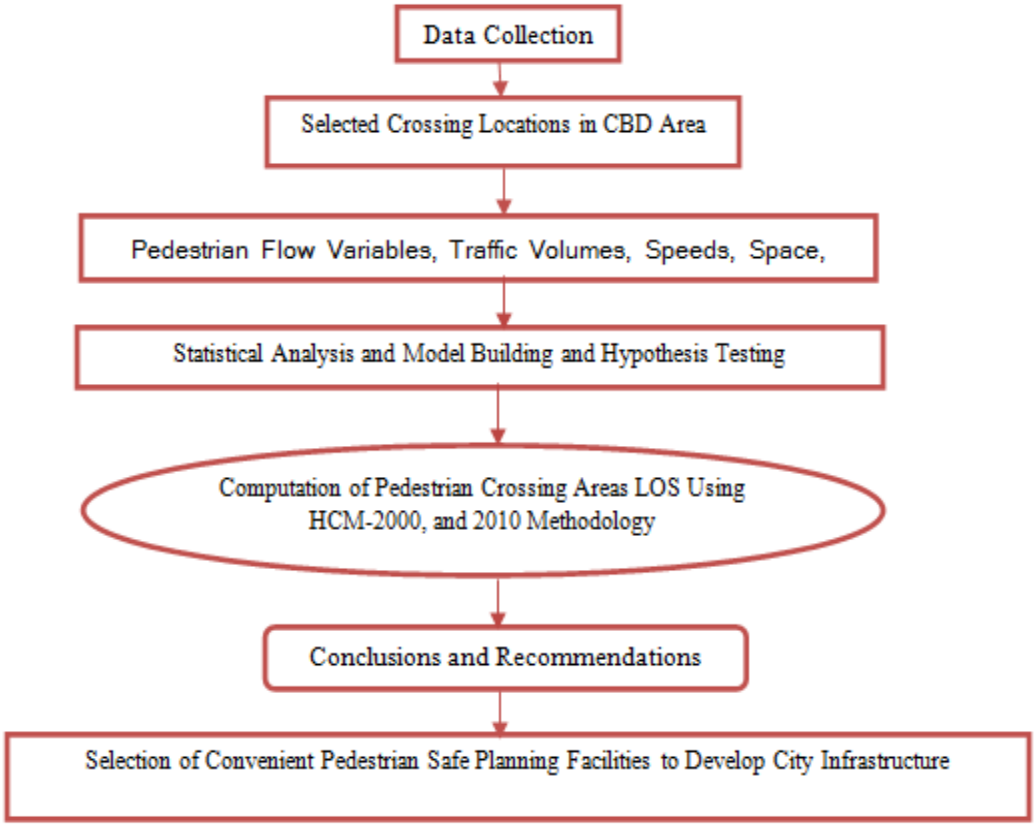


Figure (2): Research Methodology Work Flow Diagram

Traffic flow characteristics including traffic volume of vehicles in the main crossed road, vehicle speed, pedestrian speed, pedestrian flow, pedestrian density, and spaces were measured in this stage for both pedestrian movements inside CBD for both pedestrian crosswalks, and pedestrians walking on the sidewalk perpendicular to the crosswalk. The locations were observed with a two Video Cameras Type (Canon SX 210) installed on a vantage point of the nearest balcony of story building for two hours' period in order to observe in detail how the people of different genders and children passing and walking on both sidewalks and crosswalks are behaving respectively. Event Program Developed in Baghdad University was used to collect data from video photography (7). One of the CBD pedestrian crossings called Panorama Centre is shown in Plate (1):

Plate (1): Panorama Centre Commercial CBD Pedestrian Crosswalk

RESULTS ANALYSIS AND DISCUSSION

In this study, peak hourly vehicular and pedestrian flows were computed out of the two peak hours known in Dohuk City between (2:00-5:00) P.M. in order to know which is the peak hour where each one of both peaks are located. For this reason, video camera data was analysed for both flow types data collected from CBD observations.

Pedestrian Speed and Unit Flow Analysis on Crosswalks

In this type of analysis, the relationship between pedestrians flow and their speeds on the crosswalks in CBD area was computed by Curve Expert 1.3(1995)[8] statistical package to know how each one of them is affecting another. Figure (5) is showing the best fit model found among the sixteen trail models included in the package. In this analysis, pedestrian speed is found to increase as the flow increase up to an optimum value then decrease, in behaviour not looks like the well-known in vehicular traffic phenomenon. Capacity speed is going to happen at (67-70) pedestrian /m/min of unit flow. The best model found fitting this relationship was the Quadratic Fit, but with weak R=0.926, and high SSE=11.852 values as shown on the Figure. The shape of this model is:

$$Y=-1670.399+51.086X -0.366X^2 \ldots\ldots\ldots\ldots\ldots (1)$$

Where:

Y= Pedestrian speed on CBD crosswalks in m/min; and

X= Pedestrian unit flow on CBD crosswalks in ped. /m/min.

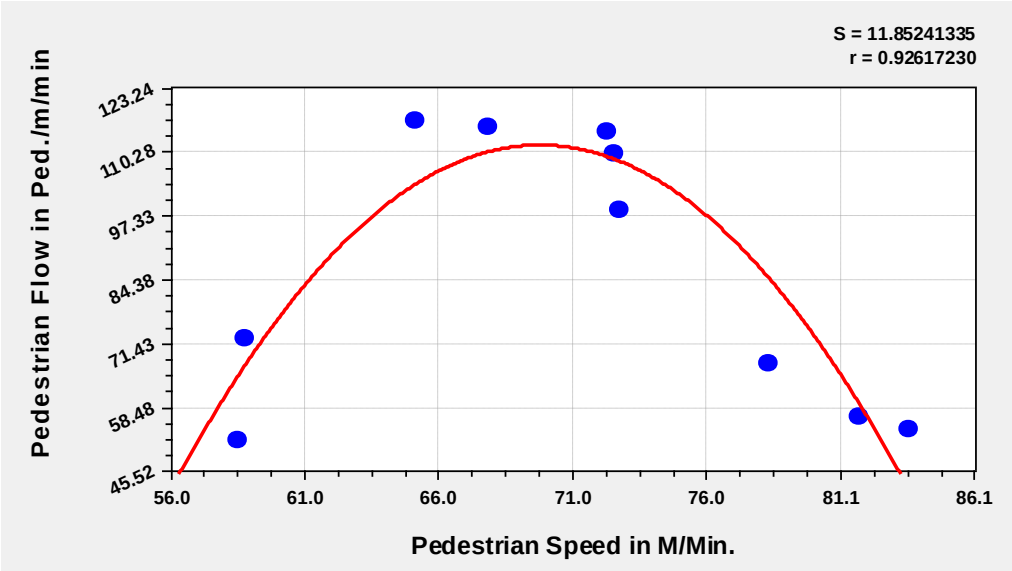


Figure (5): Effect of Pedestrian Flow on Pedestrian Speed in Midblock Crosswalks in Dohuk City CBD Area

Pedestrian Speed and Density Analysis on Crosswalks

Pedestrian density is the flow parameter that is usually computed from the ratio of the measured pedestrian unit flow divided by the measured speed of the pedestrian crossing the main road. To know how the density is affecting the pedestrian speed, data collected and scattered in Figure (6) is showing the best fit function between the two flow variables which is the Linear Model with a shape given as follows:

$$Y=110.781- 3.469X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where:

Y= Pedestrian speed on CBD crosswalks in m/min; and
X=Pedestrian density on CBD crosswalks in ped. /m^2.

This model is weakly representing the correlation between density and pedestrian speed in Dohuk City CBD crosswalks, as shown from the low R=0.815, and SSE=3.0 values on the Figure.

Pedestrian Unit Flow and Density Analysis on Crosswalks

Pedestrian unit flow and density relationship was predicted in Dohuk City CBD crosswalks by plotting the data observed from the Excel Tables collected from video filming. Figure (7) is showing the variation between pedestrian flow and their density on crosswalks. The best function best fitting the model of pedestrian flow and density is called the Exponential Association Model with a shape given below:

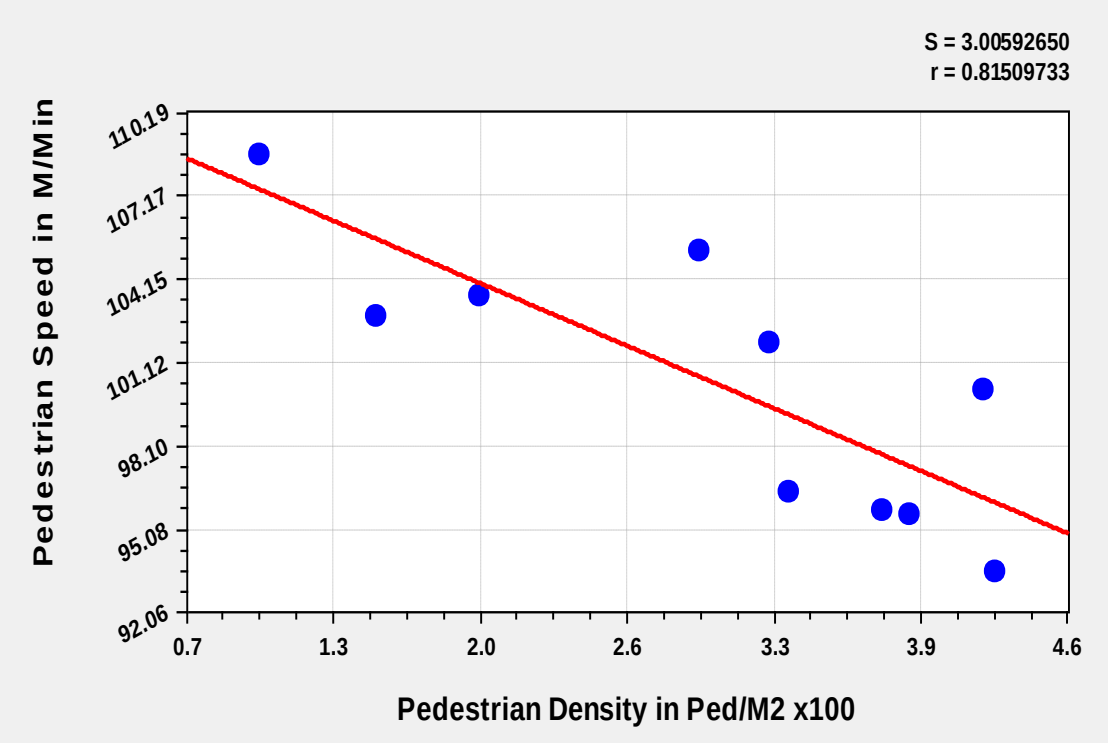


Figure (6): Effect of Pedestrian Density on the Pedestrian Speed on Midblock Crosswalks Located in Dohuk City CBD Area

$$Y=253.70749(1-e^{-0.33214x}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

Y=Pedestrian unit flow on CBD crosswalks in ped/min/m; and
X= Pedestrian density on CBD crosswalks in ped. /m^2.

Model fitted by the package is highly correlated both variables of pedestrian density, and flow on crosswalks in CBD with high R= 0.975, and low SSE=7.405 values shown on the Figure (7).

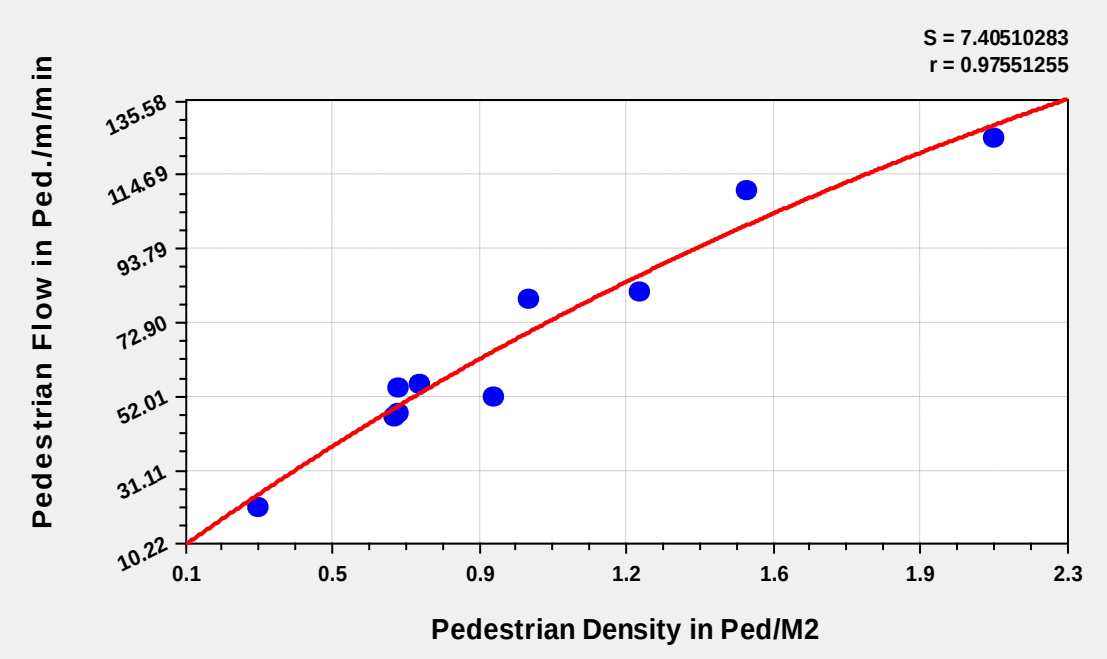


Figure (7) Effect of Pedestrian Density on Pedestrian Flow in Midblock Crosswalks in Dohuk City CBD Area

Shape of the function is looking like that found in vehicular traffic driving on roads. Reason of this high correlation that, density of pedestrians is increasing with the increasing unit pedestrian flow on crosswalks of Dohuk City CBD.

Pedestrian Unit Flow and Space Analysis on Crosswalks

To know the effect of the pedestrian space on the flow on the CBD crosswalks, the data measured from video filming was plotted by Curve Expert 1.3 (1995)[8] Package and shown in Figure (8). Figure shows that, unit pedestrian flow is decreasing with the increase in the spaces provided for the pedestrian to cross. Logarithmic Fit is the model best fitting the data collected. The shape of the model is given as follows:

$$Y=145.586-43.363\ln X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:
Y=Pedestrian unit flow in CBD crosswalks in ped. /min/m; and
X= Pedestrian space on CBD crosswalks in m^2/ped.

The function is correlating the two flow variables with an acceptable R=0.774, and SSE=21.317 values, shown on Figure (8), and found significant on 0.05 level. Residual analysis of SSE values is showing about the same total values of variations on both sides of the neutral axis. Depending upon unit pedestrian flow values and in comparison, with the HCM-(2010)[2] flow values, it can be concluded that most of the values observed during the peak hour demand were giving LOS E, and LOSF at the crosswalk CBD areas.

Pedestrian Speed and Space Analysis on Crosswalks

The relationship relating pedestrian space and speed on the CBD crosswalk was constructed by Curve Expert 1.3 (1995)[8] Package and drawing data with weak correlation R=0.521, and high SSE=7.358 values shown on Figure (9). The model best fitting the data in Figure (9) is called Reciprocal Model**.** This relationship shows that, when pedestrian space increases, then their speed will be decreases. The function shape is:

$$Y= (1/(3.105X+0.00933) \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where:
Y=Pedestrian speed on CBD crosswalks in m/min. and
X=Pedestrian density on CBD crosswalks in ped. /m^2.

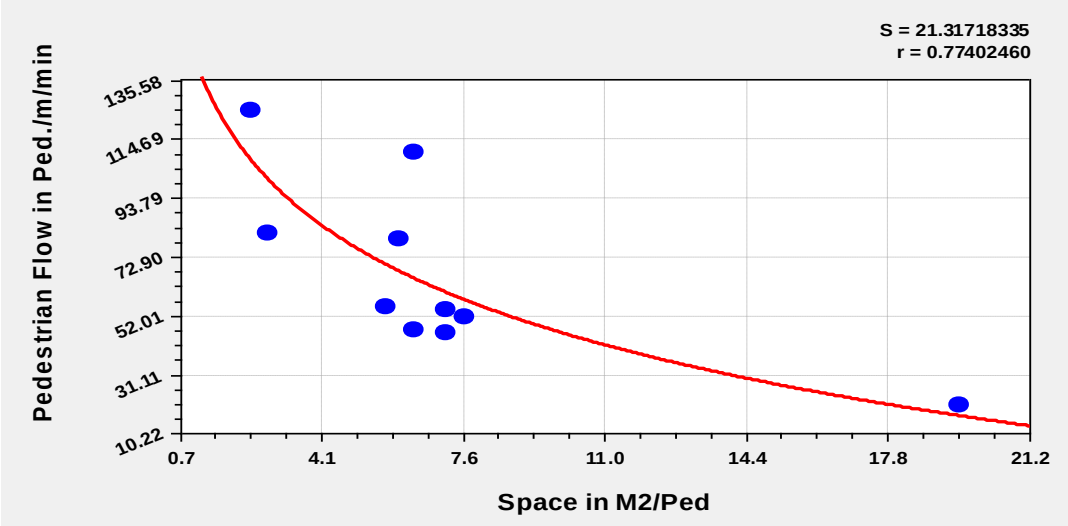


Figure (8): Effect of Pedestrian Space on the Pedestrian Flow in Crosswalks Located in Dohuk City CBD Area

Pedestrian Traffic Unit Flow and Speed Analysis on CBD Sidewalks

Relationship between pedestrian free walking speed and their number on the sidewalks on CBD area of the city was plotted in Figure (10), which demonstrates that, walking speed of pedestrian is increasing with the increase of the frequency. The form of the curve is very similar to that given by the HCM (2000)[1], and HCM (2010)[2] results, but with low R=0.675, and low SSE=0.089 values. The form of the model is called Exponential Association, with a function form as follows:

$$Y=1.0932(1-e^{-0.00117X}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where:
Y=Pedestrian free walking speed on CBD sidewalks in m/sec. and
X=Pedestrian Number using the CBD sidewalk.

Analysis of Pedestrian Traffic Unit Flow and Space on CBD Sidewalks

The effect of pedestrian space on flow is shown in Figure (11), which demonstrates that, flows usually going to decrease as spaces increase. The result is the same as that found on crosswalks located on CBD, and sub-urban flows. The model predicted is a type of Linear Model. The shape of the function is given below as:

$$Y= 116.7182 -17.1043X \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where:
Y= Pedestrian unit flow on CBD crosswalks in ped./m/min.and
X= Pedestrian space on suburban crosswalks in m^2/ped.

Correlation coefficient with low R=0.646, and high SSE=25.687 values were obtained from this analysis. Flow according to this shape function is going on with LOSA up to LOSD, which is unacceptable LOS in the CBD location according to HCM-(2010)[2] requirements.

Male Pedestrian Unit Flow and Speed on CBD

Pedestrians observed during the video camera filming using CBD crosswalks were usually composed of males, and females crossing from both sides of the crosswalk. to take opinion about their different behaviour during crossing, their peak hour volumes and walking speeds were correlated in Figure (12). The Figure is a type of Quadratic Model with relatively acceptable values of R=0.887, and high SSE=618.87 as shown on the Figure. The form of the model is as follows:

$$Y= -56127.201+116449.2X -54337.79X^2 \ldots\ldots\ldots\ldots (8)$$

Where:
Y=Pedestrian walking speed at CBD crosswalks in m/sec. and
X=Pedestrian peak hour volume in CBD crosswalks in ped. /hr.

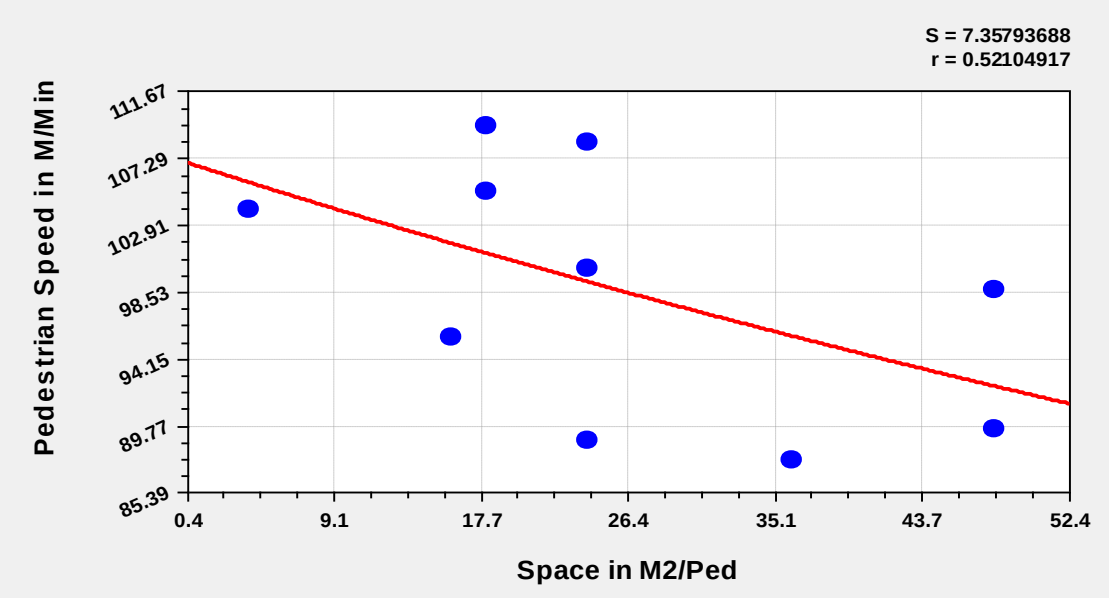


Figure (9): Effect of Pedestrian Space on the Pedestrian Speed on Midblock Crosswalks in Dohuk City CBD Area

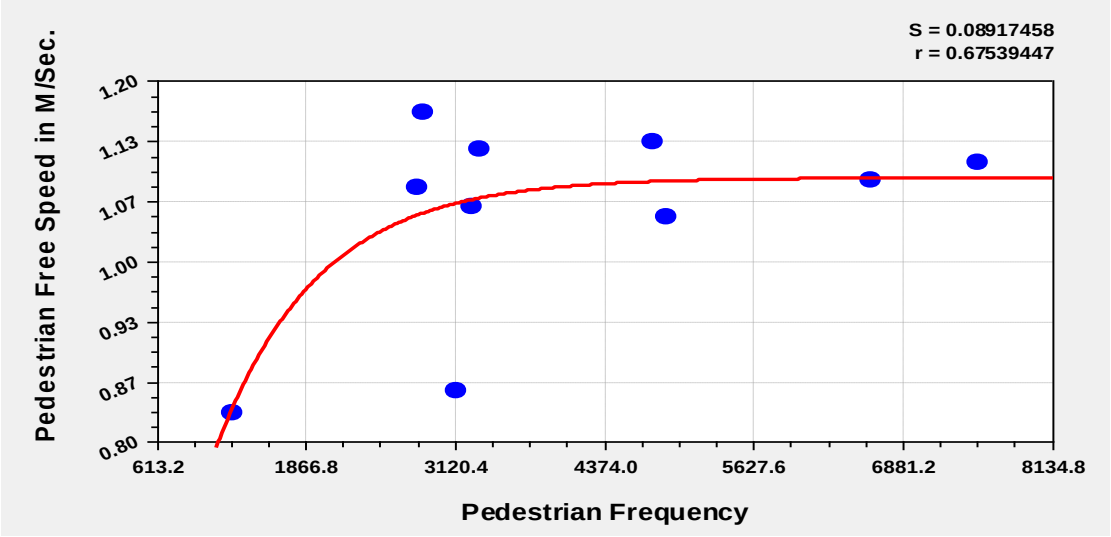


Figure (10): Effect of Pedestrian Frequency on the Pedestrian Free Speed on Midblock Sidewalks Located in Dohuk City CBD Area

Female Pedestrian Unit Flow and Speed on CBD

Females are usually walking in slower speed than males. For this purpose, female walking speed, and peak pedestrian peak hourly volume collected from the studied locations. Figure (13) is showing the predicted relationship between both variables. The Figure is demonstrating that, any increase of the peak pedestrian volume producing an increase in the female walking speed up to a certain peak value, then decreases with a peak value of 1.12m/sec at a peak pedestrian flow value of 5900 ped. /hr. The shape of the model derived by the Curve Expert 1.3 (1995)[8] is a type of Quadratic Model ***with*** a form as given below:

$$Y=-50189.169 +101407.72X -45766.689X^2 \ldots\ldots\ldots (9)$$

Where:
Y=Female pedestrian walking speed in CBD crosswalks in m/sec. and
X=Peak pedestrian hourly volume in CBD crosswalks in ped. /hr.

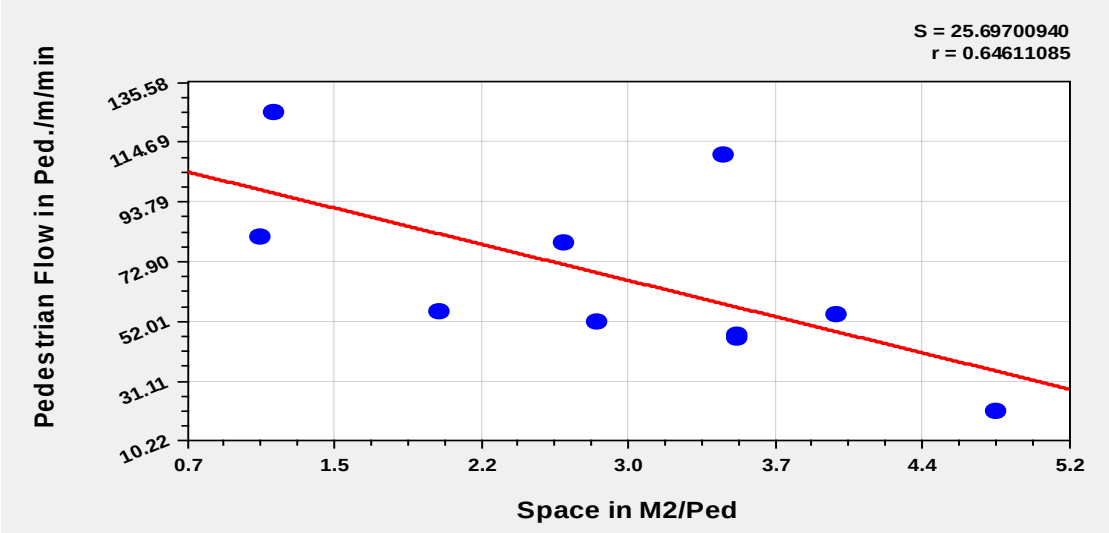


Figure (11): Effect of Pedestrian Space on Pedestrian Flow in Midblock Sidewalks in Dohuk City CBD Area

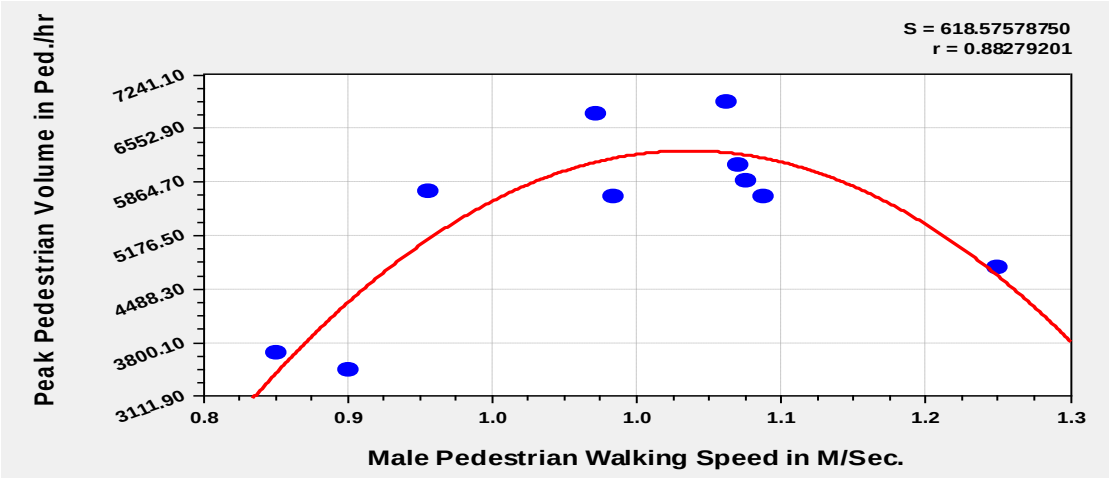


Figure (12): Effect of Pedestrian Peak Hour Volume on Male Pedestrian Walking Speed on Midblock Crosswalks Located in Dohuk City CBD Area

Power of the model is acceptable statistically looks like the trend given by the HCM-(2010)[2]. The LOS at the peak hour demand period with good R=0.727, and high SSE=819.347 was located at LOSB, or less, and for this case a serious safety management might be required in the CBD to improve the low LOS predicted.

CONCLUSIONS AND RECOMMENDATIONS

Pedestrian behavior in this study included several related items such as, their behavior on crosswalks, sidewalks, on CBD, where pedestrians are usually make their business, commercial, tourist, etc. activities. According to the size of data collected and the techniques used to analyze it, and decide what it is necessary to solve the pedestrian movement problem in Dohuk City urban areas. The following conclusions could be drawn out:

1- Pedestrian speed is defining the change in the unit flow of pedestrians weakly in a Quadratic Model with a weak R=0.926, and high SSE=11.852. Optimum speed is going to happen at (67-70) pedestrian /m/min of unit flow on CBD crosswalks;

2- Density and pedestrian speeds on crosswalks are related with a Linear Model with a acceptable R=0.815, and SSE=3.0 values. HCM-2000, and HCM-2010 are both supporting the shape of the speed-density trend resulted in this analysis;

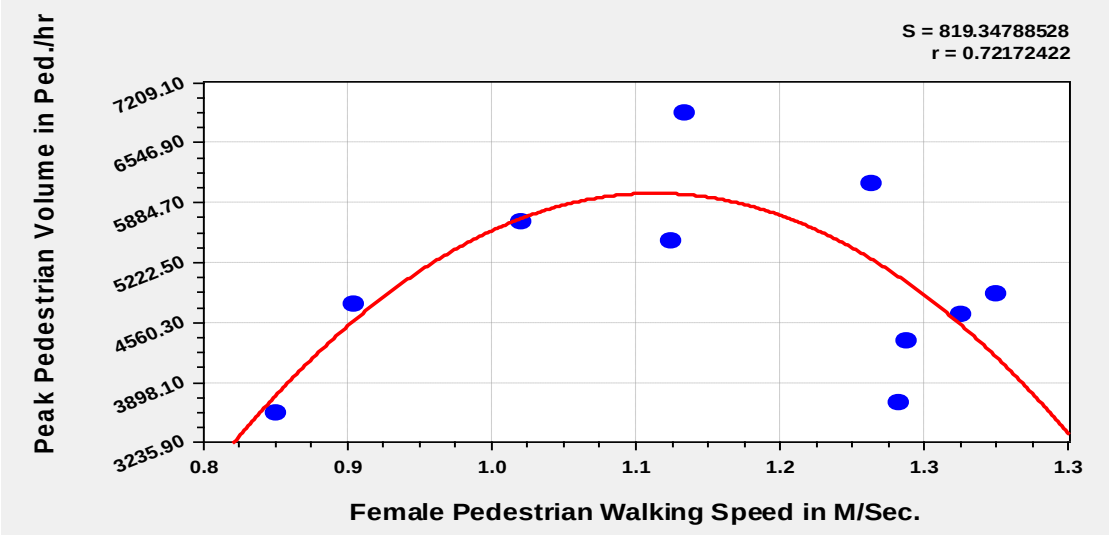


Figure (13): Effect of Peak Pedestrian Volume on Female Pedestrian Walking Speed on Midblock Crosswalks Located in Dohuk City CBD Area

3- Exponential Association Model is best representing the correlation of pedestrian unit flow, and density with high R= 0.975, and SSE=7.405 on CBD crosswalks. Both HCMs are giving a similar relationship obtained;
4- Pedestrian unit flow, and spaces are best related in a Logarithmic Fit with an acceptable R=0.774, and SSE=21.317 values. The shape of the function is similar to that given by both HCMs on Dohuk City CBD crosswalk locations.
5- Reciprocal Model is found best fitting the relationship between pedestrian speed, and their space on CBD crosswalks with weak with weak correlation R=0.521, and high SSE=7.358 values. Both HCMs are giving a similar shape to this fit between bot variables mentioned;
6- Pedestrian unit traffic flow and speed analysis on CBD sidewalks concludes that Exponential Association Model was the best fit of both variables with low R=0.675, and low SSE=0.089 values with LOSC, similar to HCM's shape curves.
7- Pedestrian traffic unit flow and space analysis on CBD sidewalks results concluded that, Linear Model is best fitting the relationship between both variables with low R=0.646, and high SSE=25.687 values. The model is weak and the change of unit flow isn't affected by pedestrian space on Dohuk City CBD area;
8- Male unit pedestrian flow and speed on CBD analysis show that, both variables are best correlated with 3rd Degree Polynomial Model and relatively acceptable value of R=0.887, and high SSE=618.87value. Comparison with the HCM's, LOS could be estimated to be LOSF up to LOSD, which are unacceptable LOS in the CBD area;
9- Female pedestrian unit flow and speed on CBD are found best correlated with good R=0.727, and high SSE=819.347 was located at LOSB in a Quadratic Model. Trend found is similar to that given by both HCMs, with LOSB which is acceptable in CBD area sidewalks.

This study is recommending a lot of changes necessary to be taken place to develop pedestrian movement safety in Dohuk City CBD such as pedestrian crossing automatic signs, zebra, and pelican crossing markings where they are justified, and need a further study for that by the Municipality of the city in corporation with Traffic Police Directorate and Building Architectural Planning Office. Some places where LOS is going to be LOSD to LODF needs overpass bridge structures to isolate pedestrians from the rapid hazardous traffic vehicles traveling with high speeds.

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