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Gap Analysis and Delay Development Modeling on Pedestrian Midblock Crossing in Dohuk City Road Network

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SYNOPSIS

In this study, 20 midblock crosswalk midblock locations are selected within the infrastructure of Dohuk City road network in a detailed GIS map. Video filming using double cameras installed on selected vantage points were used to make video photography on the vehicles, and pedestrians moving on the scene. Event program was used to collect a lot of data about gap periods between successive vehicles encountering pedestrians willing to cross from the intended cross locations in Dohuk City CBD and suburban selected areas. Number of pedestrians crossing, their speeds, crossing time, and delay time at road curbstone from both directions of cross were registered. Scanned data related to delay time, gap size, percentage accepted and rejected gaps were correlated with each other, and some other geometric and traffic characteristics of the system in order to take an opinion about size of gaps, and lags of vehicular traffic were pedestrian is promoting to cross. Analysis show that, gap size convenient for most of pedestrians to cross is (3.0-3.5) sec., which is acceptable by HCM-2010, to install signals on the intended locations where pedestrians usually used to cross where no control signal, or sign are existed. Delay time experienced by pedestrians was found to increase with both speed of crossing vehicles, and road width on CBD area, while on suburban crosswalks, traffic volume, and the other two mentioned parameters were found effective, but with low R^2, and high SSE values within a multiple linear regression models.

Key words: Pedestrian Crossing, CBD, Gap and Lag, Suburban, Dohuk City.

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. Kurdistan Region is subjected to many trips from all 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. 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.

Vallyon C. and Turners S., (2011)[1], 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. Observation studies showed that, in Auckland and Wellington, pedestrian delays were substantially longer than 30 seconds.

Raguhram K. and Vedagiri P., (2013)[2] 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. Gap acceptance, rejection was developed depending on the discrete choice theory. A certain 4 lane arterial segment in Hyderabad, India was selected for gap data collection. Accepted, and rejected 4198 gap collected during this study. The study concluded that, pedestrian behavior characteristics like the rolling gap, driver yielding behavior and frequency of attempt plays an important role in pedestrian uncontrolled road crossing.

PROBLEM DEVELOPMENT

Due to this multidirectional unplanned expansion of the people, and traffic vehicles, and the huge expansion in different cycles of life, human and vehicular interaction became unreasonable, unacceptable and produced a problem in safety and security especially in Dohuk City. This city is close to Turkey, Syria, and other parts of Iraq, and increased the trip attraction to the different facilities in this city, and more complicated the problem from North, West, and South directions. 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. 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. Accident frequency is continuing to increase as it could be shown from the annual statistics of the Directorate of Traffic in Dohuk City (3). Most of the accidents are happening within the boundary of the urban area where people and traffic are mostly moving and interacting each other with a shortage in the traffic control devices, especially for pedestrians on the midblock crossing segments.

Study Purpose

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 young people moving during the peak traffic demand periods to satisfy their job needs. In order to solve a part of the problem, the following purposes could be justified in this study:

- To measure the amount of delay time due to waiting in sec./pedestrian usually experienced in both directions of crossing the road from curb to curb, which is the measure of patience to pedestrians;
- Correlation of the measured delay time in both CBD and suburban crosswalks with other pedestrian flow and road geometric parameters, and how it should be controlled;
- Pedestrian delay time might be introduced in the economic analysis, and compromise for designing a more comprehensive crossing schemes for each location;
- Determination of lag period in both CBD and suburban crosswalks as an approach to install a convenient pedestrian sign, or signals to regulate crossing safely;
- To model the gap between successive vehicles acceptance, and rejection phenomenon by pedestrians crossing between these crossing vehicles, and the size of the problem might be encountered;
- To propose the kind of pedestrian crossing marking that might be designed on each crosswalk, in order to provide safety, and security to the people crossing day, and night; and
- Where to install the overpasses, were pedestrian crossing medians are no more useful, and safe.

METHOD OF THE STUDY

Twenty crosswalks located on both CBD, and suburban areas of Dohuk City were observed in this methodology ,where 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), is showing the study area which is a type of GIS Map for Dohuk City road network on which this study was carried on taken from GIS Centre(4). Methodology proposed in Figure (2) is to implement the different stages of this study including also the different traffic phenomena related to pedestrian. 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 (1984)[5]. Data compiled was scanned and presented using the Excel Word Version 12(2010)[6].

● Locations where Data Collected and the Two Cameras Installed

Figure (1): Dohuk City GIS Road Network Map Showing 20 Urban Locations (4).

Pedestrian Waiting Time (Delay) at Crosswalk Study

Pedestrian is usually trying to observe the oncoming traffic vehicles from right and left. For this reason, he/or/she might try to wait until he can pass safely. The waiting time is a good parameter representing the response and reaction of the pedestrian to the different stimuli encountering him during this operation of passing. In this study, the waiting time or sometimes called pedestrian delay time was measured from the video filming of the site accumulated for both directions of passing (i.e., the right, and left) using the Event Program by observing a group of pedestrians and counting their number and their time lapse to count the total waiting time and prepare it for more analysis.

Data Collection

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Selected 20 Crossing Locations in Dohuk City Road Network Urban

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Pedestrian Flow Variables, Traffic Volumes, Delay Time, Speeds, Gap Size, Geometrics

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Statistical Analysis and Model Building and Hypothesis Testing

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Gap, and Lag Analysis and Multiple Regression Correlations

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Selection of Convenient Pedestrian Selection of Convenient Pedestrian Safe Planning Facilities to Develop the Suburban City

↓

Conclusions and Recommendations

Figure (2): Research Methodology Work Flow Diagram

Data of Gap Size Related to Pedestrians Crossing Opportunities

Gap in traffic engineering theory is usually defined as the " length of time period measured between each successive pair of vehicles travelling in the same direction of flow in a specific road section, or intersection approach" (2009)[7]. This gap period may be convenient to the pedestrian according to his human capabilities to pass the crosswalk with or without certain traffic control such as a sign, or signal. Other types of pedestrians including children, females, old people, and handicapped couldn't be able to accept a certain period of gap, then he/or/she will decide to reject it as soon as possible to still standing up until a more convenient gap will come to pass safely.

Analysis of Pedestrian Delay Time and other Traffic and Geometric Characteristics of the Crossing Locations.

Pedestrians are usually coming to crosswalks in order to cross as soon as possible with minimum delay time, and he/or/she is unwilling to stay a lot of time near the road. This condition is highly affecting the behaviour of the pedestrian, and may loss his/or/her patience to cross without care. In this discussion, average pedestrian waiting time computed from video filming in sec./ped. is correlated with three main factors to know how much they are affecting the waiting time of the pedestrian, especially in CBD area. The main factors selected for step-wise correlation with pedestrian waiting time are, peak hourly traffic flow, vehicles speed in the road stream, and road width on both locations included in this study. The analysis is executed for both cases in CBD and sub-urban locations included within this study. The model variable is described as below:

Y=Average pedestrian waiting time considered as dependent variable;
X_1= A 10 minutes' vehicular hourly volume in traffic stream;
X_2=85th Percentile speed measured during the period of waiting time observation from the accumulated distribution of speeds; and
X_3=Main crossed street width measured in meters at each spot.

Pedestrian Delay Time Modelling in Dohuk City Crosswalk CBD Area

Analysis of the data collected in CBD crosswalks is resulting in the above three variable, the following step-wise linear regression model:

$$Y = -0.163+0.131\,X_2 + 0.228X_3 \quad \ldots\ldots\ldots\ldots (1)$$

Collinearity table which showing the interaction among the two independent variables, X_2, and X_3, is shown in Table (1):

Table (1): Collinearity Matrix of Independent Variables X_2, and X_3

Predictor	Coefficients	Standard Deviation	Student t Value	Probability of Insignificant	Variable Inflation Factor(VIF)
Constant	- 0.163	6.587	0.025	0.981	-
X_2	0.131	0.097	1.351	0.219	1.0
X_3	0.228	0.326	0.701	0.506	1.0

Analysis of variance ANOVA is shown in Table (2) for the confidence, or not for the predicted model.

Table (2): ANOVA Table of Analysis of Variance of Variables Included in the Analysis Y, X2, and X_3

Source of Variation	D.F.	SS	MS	F	P
Regression	2	17.456	8.782	1.138	0.373
Error	7	53.694	7.671		
Total	9	71.150			

the non-uniform distribution of SSE values around the diagonal of the Normal Probability Plot around the zero value of the SSE, which represent the model validation as plotted from the **SPSS Version 20 Package (2014)**[9].

Pedestrian Delay Time Modelling in Crosswalk Sub-urban Area

On sub-urban area crosswalks in Dohuk City investigated in this study, the pedestrian waiting, or lost time near curbstone from both directions of crossing is correlated with the

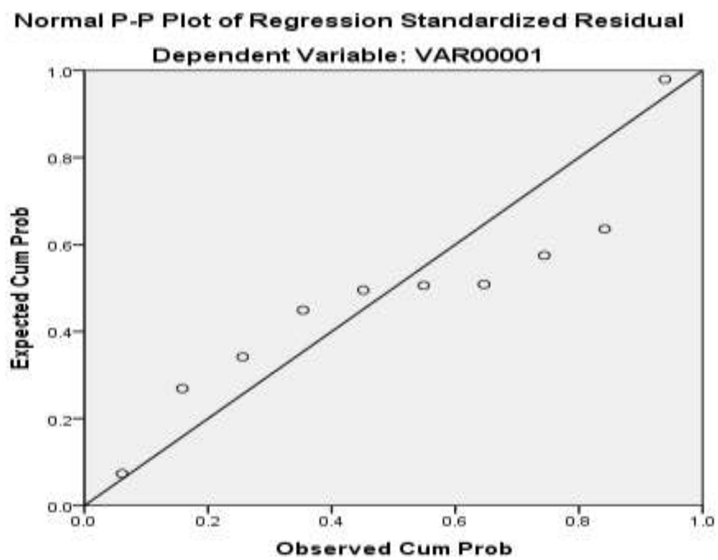

Figure (3): Normal Probability Plot of Residuals around Diagonal Matrix of Data on Delay Time Values on Midblock Crosswalks Located in Dohuk City CBD Area

other traffic, and geometric parameters described above as X_1, X_2, and X_3, this correlation is necessary to study the effect of each of the three parameters on the waiting, and crossing behavior of the pedestrians. The data collected from the video filming of these ten locations are plotted using the analysis tool. Results generated out of this analysis are listed as a three variables step-wise regression model as follows:

$$Y = -2.5 + 0.0122 X_1 + 0.0084 X_2 + 0.503 X_3 \quad \ldots\ldots\ldots\ldots (2)$$

The derived relationship is showing that, pedestrian waiting time is going to increase with the increase of the vehicle flow in the main Street, vehicles speed, and street width. Table (4) is showing the Collinearity results among the three variables, and VIF parameter of good result as its values for the three variables are less than 5(1997)[8]. Table (5) is indicating to the ANOVA table for the analysis of variance of the data introduced in this analysis. The model power representing these three variables is R^2 of 0.556, and SSE of 5.764 in values with F calculated value less than the standardized value of F for a 5% significance level of 27.91, **Minitab Version 11 Package (1992)[10] this** means that regression coefficients are weak in value. Figure (3) shows the non-uniform distribution of residual values around the standard diagonal of the normal probability plot due to some the weakness of fitting of the model.

Table (3): Collinearity Matrix of Independent Variables X_1, X_2, and X_3

Predictor	Coefficients	Standard Deviations	Student t Value	Acceptance Probability	VIF
Constant	-2.54	11.90	-0.21	0.838	
X_1	0.012189	0.006638	1.84	0.116	1.3
X_2	0.00839	0.09678	0.09	0.934	1.1
X_3	0.5030	0.4951	1.02	0.349	1.2

Analysis of Gap-Acceptance on CBD Crosswalks

Table (4) is showing a sketch or regression model drawn by Curve Expert 1.3 Package (1995)[11]to understand the type of the relationship developed between the gap size, and percentage of the vehicular

Table (4): ANOVA Table of Analysis of Variance of Variables Included in the Analysis Y, X1, X2, and X_3

Source of Variation	Degrees of Freedom	Sum Squares	Mean Squares	F Statistic	Probability of Acceptance
Due to Regression	3	249.47	83.16	2.50	0.156
Due to Error	6	199.33	33.22		
Total	9	448.79			

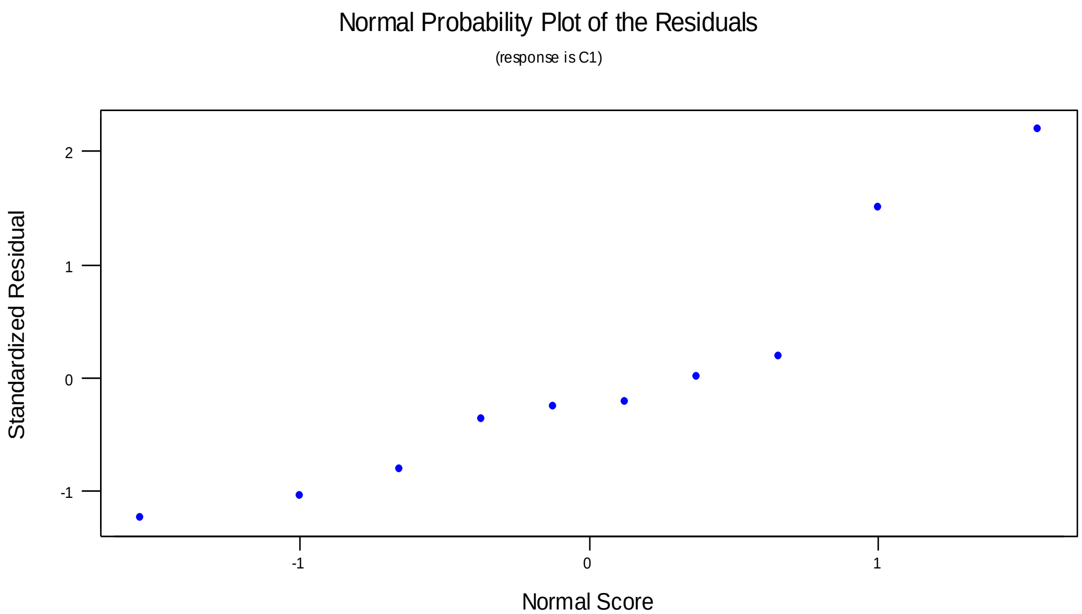

Figure (4): Normal Probability Plot of Residuals around Diagonal Matrix of Data of Delay Time Values on Midblock Crosswalks Located in Dohuk City Sub-urban Area

gaps accepted by pedestrians. The model is type of Vapour Pressure Model between the percentage of accepted gap by passing pedestrians, and the size of the gap measured by the slow-motion technique form video filming. The peak percentage of the percentage of pedestrians accepting the gap of (3.0-3.5) sec. in size, which is similar to the value of the gap period used for the design of un-signalized intersection given by HCM (2000)[12], and HCM (2010)[13]. This behavior is mainly due to that, after (3.0-3.5) sec. gap, all pedestrians will pass and nobody stay near the curbstone, then pedestrian flow will be dissipated and acceptance vanishes. The shape of the predicted function is as follows:

$$Y= e^{11.6174 - (10.90/X) - 4.34 \ln X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where:
Y=Percentage of pedestrians accepting a certain size of gap, and
X=Size of gap period measured by slow motion technique in sec.

Predicted model was obtained with very high value of correlation coefficient R=0.995, and very low SSE=0.967 values to reflect its power of representing the relationship statistically.

Analysis of Gap-Rejection on CBD Crosswalks

Some of the pedestrians couldn't pass directly as thee time period between successive vehicles aren't enough to complete the cross. Percentage of this type of pedestrians rejecting the gap provided and waiting for another longer one is demonstrated in Figure (6), which is showing that, percentage of pedestrians rejecting a certain gap is reducing up to a gap size of (3.0-3.5) sec. then start to increase again. This behaviour is coming due to that, after 3.0sec.gap, all the pedestrians stopped on the curb stone will pass, then no body stay waiting to cross. The type of the function is a 3rd Degree Polynomial Model with a high R=0.914, and

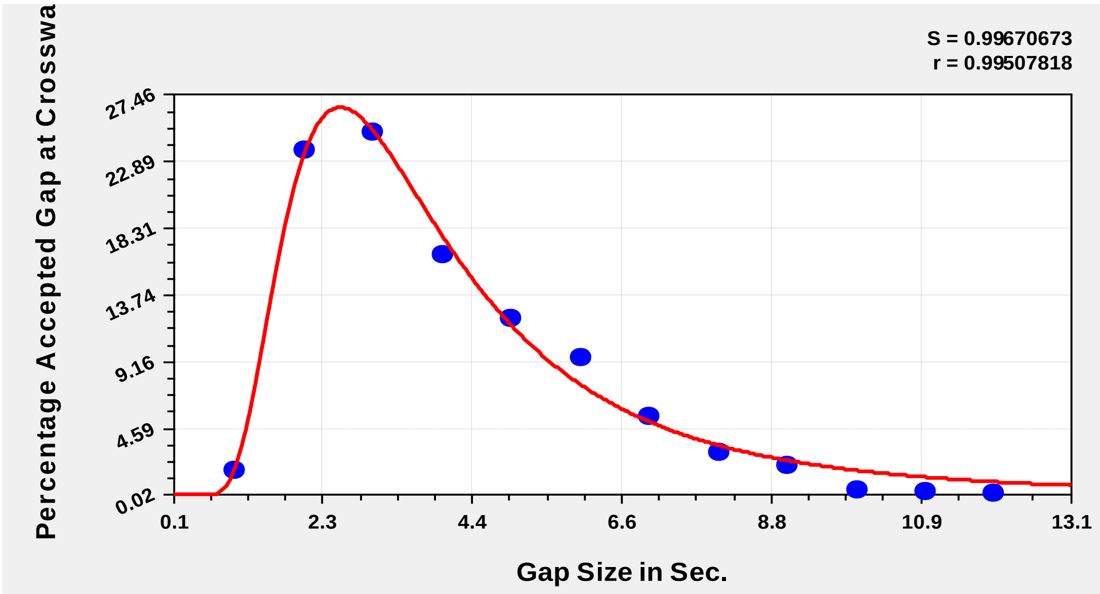

Figure (5): Percentage Accepted Gap Distribution on Midblock Crosswalks in Dohuk City CBD Area

Very low amount of SSE=0.0268 values. The shape of the function predicted is as follows:
$Y=1.0878-0.1649X+0.0368X^2-0.00293X^3$…………(4)
Where:
Y=Percentage of pedestrians rejecting a certain size of gap, and
X=Size of gap period measured in sec.

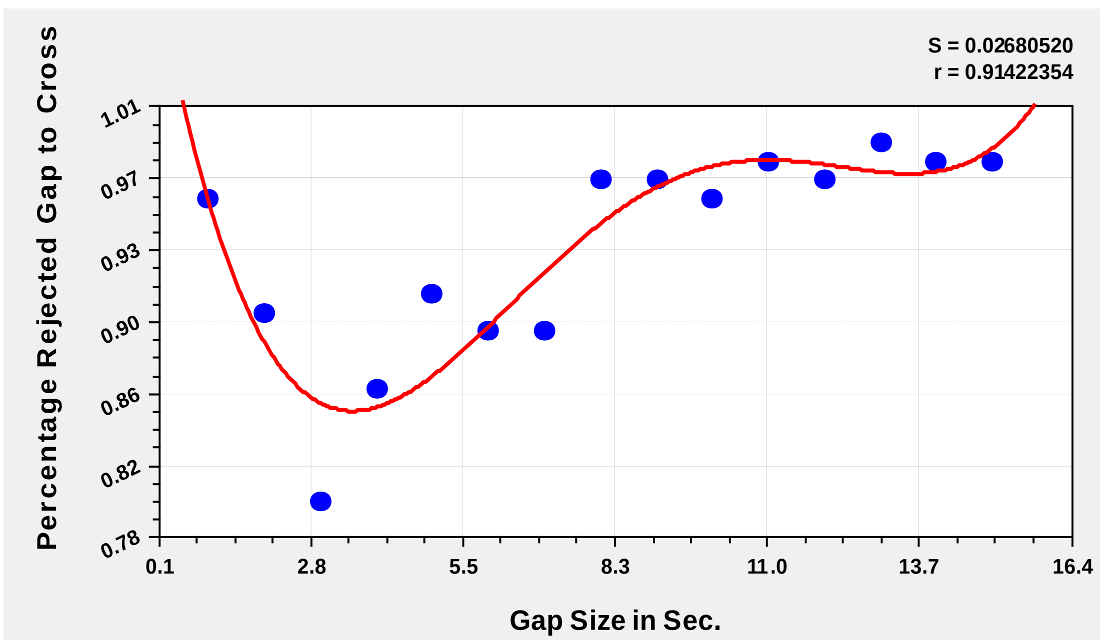

Figure (6): Percentage Rejected Gap Distribution on Midblock Crossing Sections in Dohuk City CBD Area

The gap size of (3.0-3.5) sec. found from the analysis is concluding that, pedestrians were rejecting any gap less than this value, while they accept to pass when a gap of this size of gap or more is provided. From the analysis of both accumulated percentage of accepted and rejected gaps on CBD crosswalks shown in Figure (7), it is shown that critical gap size on which both percentages of people accepting, and rejecting each gap size are 50 percent (i.e., lag size). In the Figure, lag size obtained is (3.0-3.5) sec., which consists with the results concluded in the above paragraph.

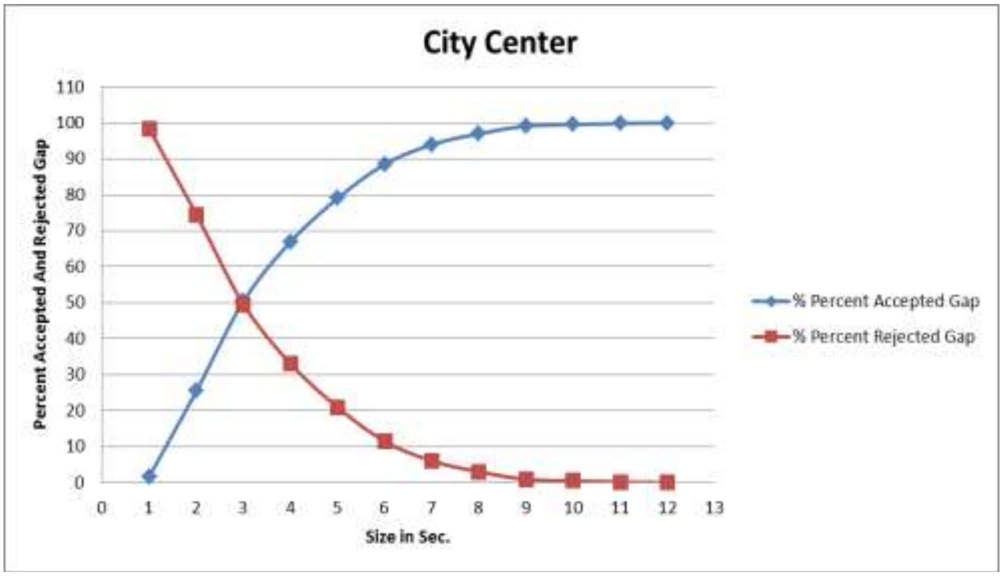

Figure (7): Accumulated Accepted, and/ or Rejected Gap on Midblock Crosswalks Located in Dohuk City CBD Area

Analysis of Gap -Acceptance on Sub-urban Crosswalks

In order to understand the type of distribution between the size of gap found between vehicles, and the percentage of pedestrians crossing during them, Figure (8) was drawn by Curve Expert 1.3 Package (1995)[11] sub-urban area by video filming. The model fitted and given below is a 3rd Degree Polynomial Model using the data collected from the investigated locations located in the Dohuk City. From the Figure, it is shown that pedestrians accepting gaps up to a gap size of (3.0-3.5) sec., then their percentage decline as gap size increases. In sub-urban areas like the CBD about the same gap size is obtained from the analysis of percentage accepted gap. HCM (2010)[13] is recommending this gap size for the design of un-signalized, or four-leg controlled intersections. The shape of the predicted function is as follows:

$Y= -0.1262 +0.2183X – 0.0547X^2- 0.005X^3$ ……………. (5)

Where:
Y=Percentage of pedestrians accepting a certain size of gap, and
X=Size of gap period measured by slow motion technique in sec.

The predicted model was obtained with very high value of correlation coefficient R=0.993, and very low SSE=0.00763 values to reflect its high correlation power.

Analysis of Gap- Rejection on Sub-urban Crosswalks

Pedestrians are usually enforced to reject even long gaps on CBD crosswalks, but in sub-urban crosswalks, this behavior might be different. To make analysis for this phenomenon, data was collected from the ten sub-urban crosswalks and drawn by the Curve Expert 1.3 Package (1995)[11] in order to obtain a certain correlation between them, as shown in Figure (9), which is a type of 3rd Degree Polynomial Model which shows that, pedestrians in sub-urban area are usually able to reject gaps smaller than (3.0-3.5) sec., and accepting the gaps more than this value. The form of the relationship predicted is as follows:

$Y=1.1262 -02183X +0.0547X^2 +0.005X^3$ ……………..… . (6)

Where:
Y=Percentage of pedestrians rejecting a certain gap located in sub-urban area; and
X=Size of gap period in sub-urban area measured by slow motion technique in sec.

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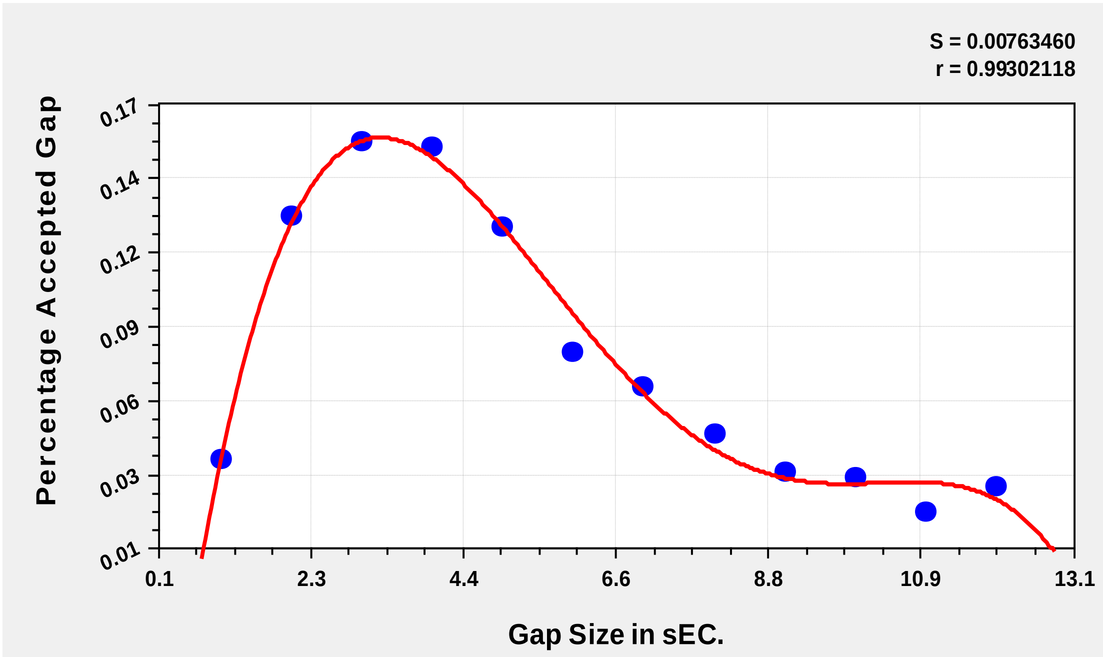
Relationship in Figure (9) was obtained with high correlation Coefficient R^2= 0.993, and very low value of SSE=0.00764, indicating the strong representation of model including the above two variables.



Figure(8): Percentage Accepted Gap Distribution on Midblock Crossing Sections in Dohuk City Sub-urban Area

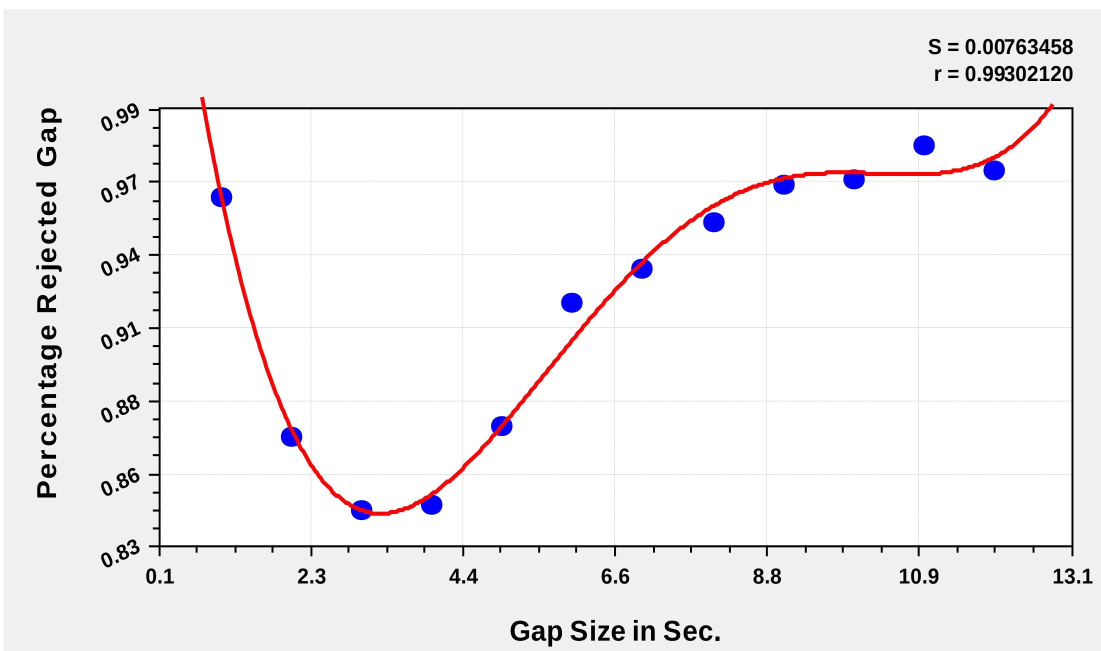


Figure (9): Percentage Rejected Gap Distribution with Gap Size on Midblock Crossing Sections in Dohuk City Sub-urban Area

From both values of accumulated accepted and rejected percentages of gaps and gap size drawn in Figure (10), it is shown that the critical gap size, or lag is (3.0-3.5) sec. This result is agreed with the result obtained above. La g size obtained shows that, 50 percent of people are accepting the gap size, while the other 50 percent are willing to reject it.

CONCLUSIONS AND RECOMMENDATIONS

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:

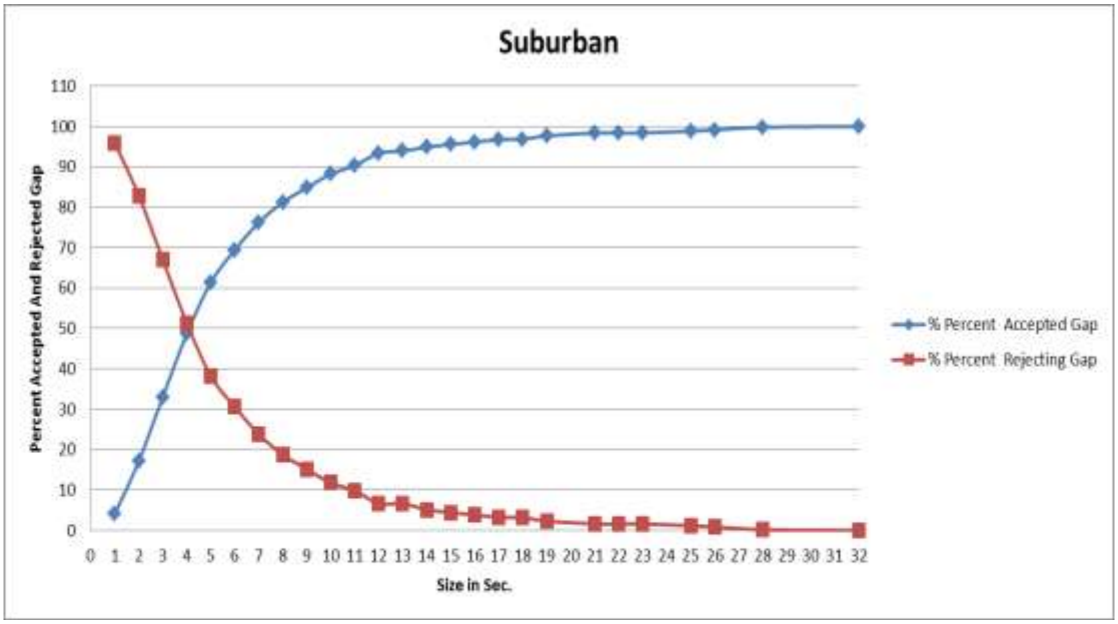


Figure (10): Accumulated Accepted, and/or Rejected Gap on Midblock Crosswalks Located in Dohuk City Sub-urban Area

1- Pedestrian waiting time modelling (i.e., pedestrian delay time) in CBD area is correlated using step-wise multiple regression analysis with vehicular flow, and vehicles speed on the crossed road, and road width. The model derived from empirical analysis is showing direct dependency of pedestrian waiting time on the on the last two variables only with no effect to the first one with low R^2 =0.245, and high SSE=2.76958 values. The model is giving a reasonable value of VIF, but smaller value of F statistic than standard F value at 0.05 significance level;
2- Pedestrian waiting time modelling in sub-urban area with the same three variables mentioned in point 35 is resulted in multiple three variable model all of them are positively increasing with waiting time value. The model resulted in R^2=0.556, and high SSE=5.764 values. The model is giving a reasonable value of VIF, but smaller value of F statistic than standard F value on 0.05 significance level;
3- Analysis of percentage gap acceptance between vehicles by pedestrians and gap size on CBD road crosswalks are both related with the Vapour Pressure Model, with high R=0.995, and low SSE=0.996. The relationship indicating high correlation between both variables. The peak percentage of the percentage of pedestrians accepting the gap occurred at (3.0-3.5) sec.in size, which is similar to the value of the gap period used for the design of un-signalized intersection given by both HCM's;
4- Analysis of gap rejection on CBD crosswalks shows that both variables are correlated with the 3rd Degree Polynomial Model with high R=0.914, and low SSE=0.0258 values. Analysis results show that, percentage of pedestrians rejecting a certain gap is reducing up to a gap size of (3.0-3.5) sec;
5- From the interaction of both results of acceptance and rejection at CBD crosswalks of Dohuk City, and at a gap size of (3.0-3.5) sec., critical lag is happened which assist the results obtained before;
6- Analysis of gap acceptance on sub-urban crosswalks resulted in a correlation of both variables in the form of 3rd Degree Polynomial Model with a very high R=0.993, and very low SSE=0.0076 values. It means that a high power of correlation is presented between both variables. Pedestrians accepting gaps up to a gap size of (3.0-3.5) sec. is found;
7- Analysis of gap rejection on sub-urban crosswalks and correlated with gap size in a mathematical relationship in the form of 3rd Degree Polynomial Model given with high R=0.993, and very low SSE=0.00763 values. Both variables are strongly correlated in this curve. which shows that, pedestrians in sub-urban area are usually able to reject the gaps smaller than (3.0-3.5) sec; and
8- On suburban crosswalks interaction of both accepted and rejected percentages of gaps with their size is resulting in a lag size of (3.0-3.5) sec. and similar to that found in CBD analysis.

A lot of changes necessary to be recommended to develop pedestrian movement safety in Dohuk City both CBD and suburban crosswalks, such as pedestrian crossing automatic signs, zebra, and pelican crossing markings where they are justified in order to regulate gap size and make crossing easier for pedestrians. Formal analysis obtained a lot of results that recommends some places need overpass bridge structures to isolate pedestrians from the rapid hazardous traffic vehicles travelling with high speeds.

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