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PEDESTRIAN MIDBLOCK CROSSING SAFETY DEVELOPMENT MODELING IN DOHUK CITY ROAD NETWORK

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ABSTRACT: Pedestrians are vulnerable users walking on foot, having no or little protection-usually provided by police officers-when trying to cross from a midblock section in urban areas. A lot of conflicts and sometimes real pedestrian crashes probably took place in some locations in Dohuk City midblock crosswalks. For this purpose, and to have a comprehensive idea about the safety situation in this city, and what are the main safety countermeasures needed at some hazardous pedestrian crossing locations, this study was proposed. Data were collected from twenty crosswalk locations in central business district (CBD), and suburban areas related to pedestrian movement using two video camera photography to collect data. Data were compiled and presented to measure pedestrian speeds, space, unit flow, crossroad width, etc., meanwhile, vehicular traffic data related to crossing volume, speed…etc. were presented too. Safety and security data related to conflicts of pedestrians with cross vehicles and some actual crash data were obtained from the qualified offices controlling traffic in the city. The Exponential Model was found as best-fitting conflict rates and pedestrian spaces with high R^2 in both urban and suburban areas. Meanwhile, the Quadratic Model was found to best fitting conflict rates and pedestrian speeds with R^2 values of 0.764, and 0.818 in both urban and suburban areas respectively. Conflict rates are found as best correlating the real crash frequency with a high R^2 value of 0.924 in suburban areas. Conflict rates in both CBD and suburban areas are going to be decreased as the pedestrian provided space, speed, crossed road width, and 85th percentile vehicular speed, but increased with the amount of waiting time experienced by pedestrians at crosswalk edge with R^2 values of 0.84, and 0.90 for CBD and suburban crosswalks respectively.

Keywords: Conflicts; Crash; Midblock crossing; Pedestrian; Sidewalks.

نمذجة تطوير السلامة لعبور السابلة على شبكة الطرق في مدينة دهوك

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الملخص: السابلة او المشاة هم مستخدمي الطريق غير المحصنين والذين يسيرون في الطريق على الأقدام ، ولا يتمتعون بأي حماية عند محاولة العبور على ضفتي الطريق في المناطق الحضرية للمدينة حيث تفتقر اغلبها الى الحماية التي يتم توفيرها من قبل مسؤلي المرور في بعض الاحيان. يحدث الكثير من التعارض وأحياناً حوادث حقيقية في بعض مواقع عبور السابلة في مدينة دهوك. ولأخذ مفهوم كامل حول وضع السلامة في هذه المدينة وماهي التدابير اللازمة في بعض مواقع عبور المشاة الخطرة, تم جمع أنواع مختلفة من البيانات من 20 موقع لعبور السابلة من مناطق في مركز المدينة وضواحيها باستخدام التصوير بكاميرتي فيديو. تم تجميع بيانات السابلة كالسرعة، والفضاء، وتدفق الجريان، ... إلخ، وفي الوقت نفسه تم جمع بيانات تخص المركبات منها حركة مرورها وسرعتها ... إلخ. تم الحصول على بيانات السلامة المرورية المتعلقة بالحوادث الفعلية من المكاتب المؤهلة التي تتحكم في حركة المرور في المدينة. تم تثبيت بعض البيانات الأخرى المتعلقة بعرض الشوارع واللازمة لفهم أسباب القصور في سلامة السابلة في مدينة دهوك ثم حللت جميع هذه البيانات من خلال إجراء تحليل احصائي لربط المتغيرات المختلفة للحصول على نماذج تجريبية تصف الموقف في المواقع المحددة. النتائج التي تم الحصول عليها تعتبر التعارض فعال في وصف الحوادث وكذلك معدلات التعارض تعتمد على سرعة السابلة وعرض موقع العبور.

الكلمات المفتاحية: التعارض؛ اصطدام؛ معبر الوسط؛ سابلة؛ المماشي.

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1. INTRODUCTION

Traffic safety is known as a critical social and a huge economic matter in Kurdistan Region-Iraq. The rapid economic growth has produced increased motorization, particularly in urban areas. In parallel, the improvements in the infrastructure have enhanced high traffic mobility and speed. As a result of a lack of comprehensive pedestrian traffic safety countermeasures by the government and people's low sensibility of traffic safety, the proportion of traffic crashes and fatalities had constantly increased over the last five years. These impacts involve tragic loss in effort, time, money, and human lives. Moreover, they create growing feelings of a great lack of safety in all facilities of human lives.

NCHRP, 2008, defined traffic conflicts as an event involving two or more road users, in which one user performs some typical or unusual activity such as a direction or speed that places other users in jeopardy or crash unless an evasive manoeuvre is undertaken.

Hemasiri, and Edirisinghe, 2010 conducted a study in Sri-Lanka at pedestrian crossings as most of the drivers in the country don't follow the rule of "Give way to pedestrians". Three main types of field data were collected: video survey, observer measurements, and drivers' interview. Six different Zebra crossings located within the limits of the Kandy-Peradeniya-Gelioya road segment were selected for field surveys. The behaviour of drivers with pedestrians was summarized in this study to use as a guideline to improve pedestrian safety.

Hussein and Neham, 2008, investigated three "T", and, four "cross" legs signalized intersections in Iraqi Capital, Baghdad, to study the traffic conflicts as a surrogate to traffic crashes. They considered shapes of conflicts mostly took place at signalized intersections. Conflicts were correlated to approach spot speed, stopped vehicles near signals control, delay time, and some other traffic geometric parameters of the intersection approach such as lane width, median width, and length of the auxiliary lanes constructed near left-turn movement. The study concluded that conflicts are mostly correlated linearly to stopped delay time with R^2=0.978, meanwhile, an exponential model described the relationship between conflict rate and traffic volume with R^2 from 0.77 to 0.94 acceptable on 90% significance level. Multiple regression analysis showed that conflict rates increased with increasing approach spot speed, but reduced with increasing lane width, median width, and availability of auxiliary lanes.

Diogenes and Lindau, 2010, evaluated the pedestrian safety and analogy of midblock crossing with the highest number of pedestrian crashes in Porto Alegre city, Brazil. Twenty-one crosswalks were chosen for evaluation. Results show that pedestrian crash hazard was affected by a combination of interacting hazard factors, such as the presence of bus stops, number of lanes, road width, and the volume of vehicles and pedestrians.

Zhang *et al.*, 2019, investigated the behaviour and safety of pedestrian crossing at midblock crosswalks. For this goal, twelve midblock crosswalks located in Wuhan, China were chosen to gather data through field investigation. Descriptive statistics were applied to resolve pedestrian crossing attitudes and the allocation of pedestrian-vehicle conflicts. Three models for pedestrian-vehicle conflicts analysis were found to measure the influence of various factors on pedestrian safety. Also, it was pointed out that pedestrian behavioural properties such as rolling gap mode, crossing with others would obviously increase the potential of pedestrian-vehicle conflicts.

1.1 Pedestrian Safety Problem

Pedestrian safety problem in Dohuk City is merely related to the sprawl in both population, and vehicles, especially in the last five years. Terrorist attacks to wide lands around the Kurdistan Region in Mosul, Anbar, and Kirkuk cities caused the migration of a lot of people to the region congesting both roads, and crosswalks due to the unusual movement of both people and vehicles in Dohuk City road network. Figure 1 is showing the trend of car ownership in Dohuk City between the period 2002 up to 2014. The average number of growths in car ownership was increased by 12 per cent between 2010 and 2014 periods (Accident Data Files, 2015). Vehicle-pedestrian conflicts increased as it seems clear from the crash statistics compiled by the Directorate of Traffic Police in Dohuk City Crash Files.

1.2 Study Purpose

To reveal some of the tragedy related to the safety of the pedestrians, or the unprotected users walking on foot, the following goals are planned:

- To prepare a database related to pedestrian safety in Dohuk City for future research or development.
- To collect crash data related to pedestrians and where mostly the problem is probably going to accumulate.
- Nature of traffic conflicts produced between vehicles and crossing people, especially at peak service hours;
- To correlate pedestrian crashes with conflict rates on midblock pedestrian crossing zones;
- To correlate conflict rates with other pedestrian crossing parameters, and some road geometric parameters.

2. RESEARCH METHODOLOGY

To execute the main goals of this study, a certain area was selected including all the urban, and suburban areas

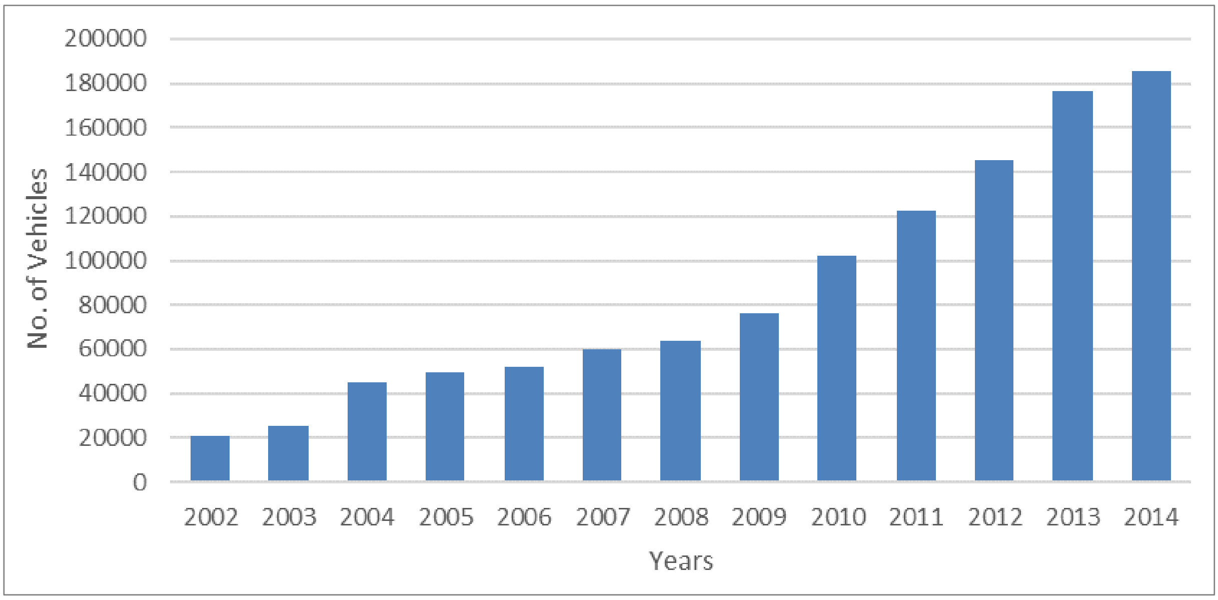

Figure 1. Number of vehicles owned by the people in Duhok City during the period (2002-2014), (Accident Data Files, 2015).

of Dohuk City. Figure 2 shows the selected areas, which is a type of GIS Map taken from the City (Golden Guide, 2010). Figure 3 shows the flow chart of the proposed methodology, which contains the main types of data collected. Traffic conflicts is an event that can be observed showing the interaction of vehicle against pedestrians while crossing the road. Conflicts used by Glauz and Migletz, 1980, as surrogates for the prediction of crashes at some hazardous locations are selected to study pedestrian crossing behaviour.

Using the conflict data collection form used by Glauz and Migletz, 1980, thousands of conflict data were observed between vehicles and pedestrians in both CBD and suburban crossing locations selected for analysis in this study. In this form, conflicts are classified into major conflicts (M.C.), and secondary conflicts (S.C.), Major conflicts are those related to turning or through movement contacts with pedestrians represented by some dangerous action or longhorn. Meanwhile, minor conflicts are represented by brake light during pedestrian crossing as a parameter to draw out some conclusions. Conflict rates per 1000 vehicles were computed for this correlation using the following equation given by Glauz and Migletz, 1980:

$$\text{Conflict Rate}/1000\ \text{Vehicle} = (\text{NCO}/\text{TVO}) \times 10 \qquad (1)$$

where:
NCO: Number of conflicts observed during three hours of study; and
TVO: Total number of vehicles counted during the same period of time in thousands.

Conflict rates during the period of observing pedestrians were recorded in order to take an opinion about the critical situations. Pedestrians were usually subjected to driver frustrations when passing the road in the existence of mechanized traffic. Crash data was compiled from crash data files from the Directorate of Traffic Control in Dohuk City, 2015, through the period (2009-2014) which is the up-to-date provided crash data to represent the safety behaviour of pedestrians crossing from different midblock locations. Crash data were provided only for suburban area pedestrian crossing locations meanwhile; CBD area crashes were not registered. Location selected on both areas within Dohuk City in this study is midblock segments not near to any congested signalized or unsignalised intersection, and those candidates as dangerous by police officers. Other data related to pedestrian flow parameters such as unit flows, speeds, spaces, etc., were collected from video filming and manually transferred into computer files. The huge volume of the compiled data was analyzed using SPSS Program version 24, 2017, and Microsoft Excel Package.

Figure 4 shows two locations one of them in CBD and the other in suburban Dohuk City area where data cameras had been fitted on illumination poles or at some vantage points for photography.

3. ANALYSIS OF RESULTS AND DISCUSSIONS

In order to start the stage of results analysis and discussions, the twenty locations were investigated, ten of them are in the CBD area and the other ten is in suburban areas. To start the data analysis in this study, peak hour demands between (8:30-10:30 A.M.), and (5:30-7:30 P.M.) were selected as peak morning and evening periods for both vehicles and pedestrians and limited exactly in order to concentrate data collection and analysis.

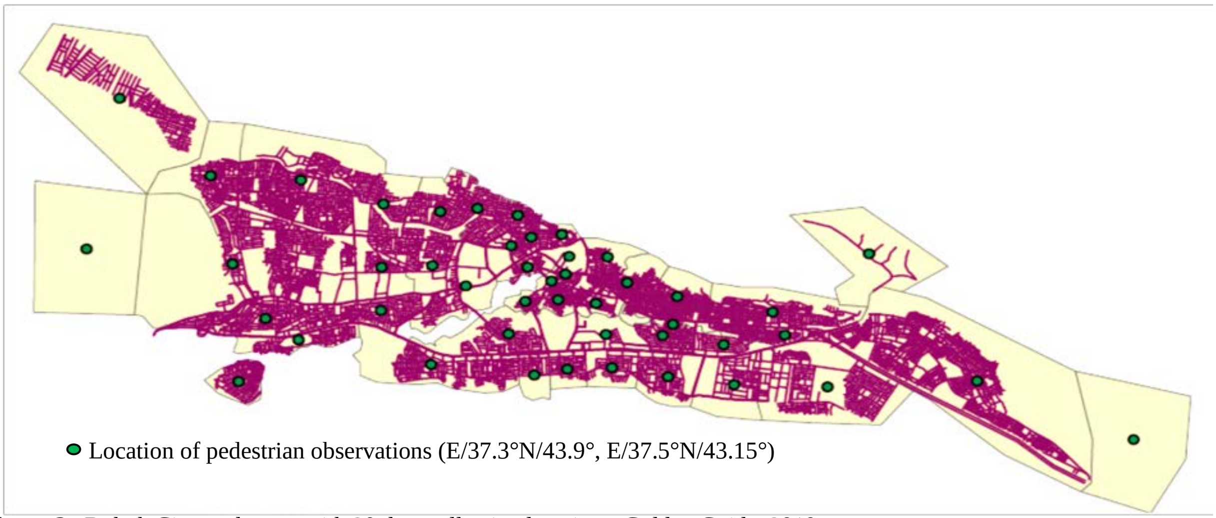

Figure 2. Dohuk City study area with 20 data collection locations, Golden Guide, 2010.

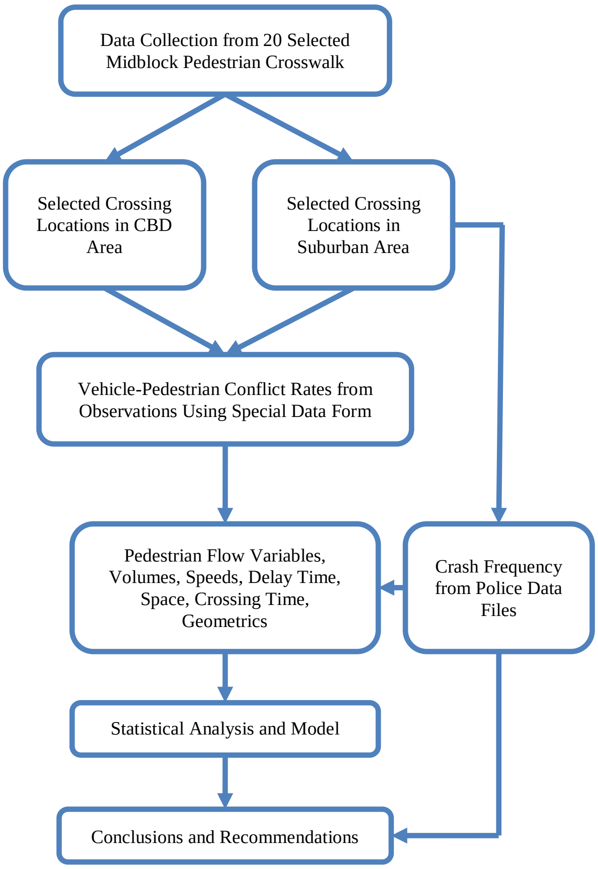

Figure 3. Research methodology workflow diagram.

Figure 4. Two photos showing two of the pedestrian crosswalks in both CBD and suburban areas: **(A)** Panorama Centre Commercial. CBD pedestrian crosswalk. **(B)** Shelan Hospital (Qazi Mohammad St.). commercial suburban pedestrian crosswalk.

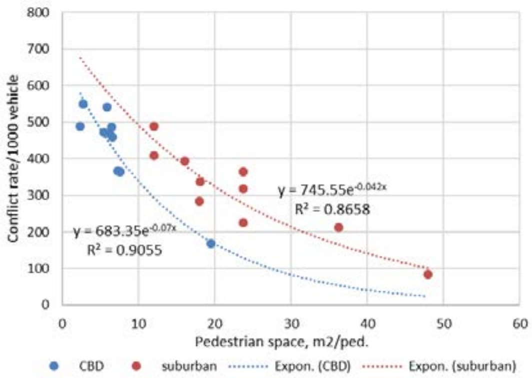

Figure 5. Effect of pedestrian space on the conflict rate in midblock crosswalks in Dohuk City CBD and suburban areas.

3.1 *Pedestrian Conflict and Pedestrian Space at CBD and Suburban Crossing Locations*

Pedestrian conflicts (i.e., both major and secondary conflicts) were computed in rates per 1000 vehicles from Eqn. (1) and correlated with pedestrian provided space in m^2/pedestrian (m^2/ped.) which is the number of pedestrians occupying an area of one square meter at the crosswalk during the crossing process stated by the HCM, 2010. The space variable was counted automatically from an area of one square meter using photoshop and Excel sheet limited with photo zoom picture by picture. Figure (5) shows the variation of conflict rates with space. A relationship is described by Exponential Models with a good correlation of determination coefficients R^2 of 0.906 and 0.866 for both CBD and suburban locations, respectively. Equations (2) and (3) reflect the fact that as pedestrian move closer, conflicts with the adjacent vehicles will increase. The form of the models derived are as follows:

$$Y_1 = 683.35e^{-0.07x} \qquad (2)$$

$$Y_2 = 745.55e^{-0.042x} \qquad (3)$$

where:
Y_1: Conflict rate/1000 vehicles in Dohuk City CBD crosswalks;
Y_2: Conflict rate/1000 vehicles in Dohuk City suburban crosswalks; and
X: Pedestrian space in m^2/ped.

Correlations between conflict rate and pedestrian space were implemented using the above statistical analysis by both simple and multiple regression to show the effect of the independent on the dependent variable and what shapes of empirical models are correlating them.

3.2 *Pedestrian Conflict and Pedestrian Speed at CBD and Suburban Crossing Locations*

Conflict rates and pedestrian speed variations on the crosswalks located in both CBD and suburban areas are shown in Fig. 6. Coefficients of correlation R^2 are 0.764 and 0.818 for CBD and suburban crosswalks respectively. The best models are 2nd Degree Polynomial Models with the following mathematical forms:

$$Y_1 = 770.9X^2 + 2332X - 1259 \qquad (4)$$

$$Y_2 = -4044.7X^2 + 12492X - 9136.2 \qquad (5)$$

where:
Y_1: Conflict rate/1000 vehicles for CBD crosswalks;
Y_2: Conflict rate/1000 vehicles for suburban crosswalks; and
X: Pedestrian speed, m/s.

Figure 6 shows that at an optimum conflict rate of about 500 conflicts/1000 vehicles, the pedestrian speed is around 1.55 m/sec. Both trends are going to increase with the increase of pedestrian speed up to the above-mentioned number of conflict rate and then goes down to reduce. The conflict rate decreases for suburban after a certain speed, since the number of pedestrians in the suburban is low with higher walking speed.

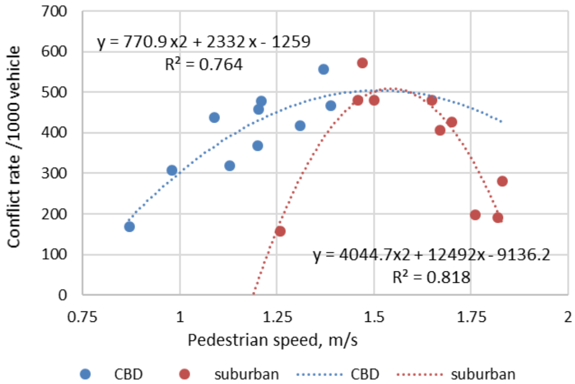

Figure 6. Effect of conflict rate on pedestrian speed on midblock crossing sections in Dohuk City CBD and suburban areas.

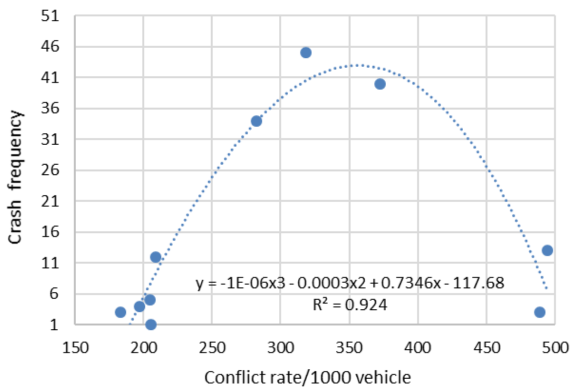

Figure 7. Pedestrian crash frequency and conflict rates correlation on midblock crossings located in Dohuk City suburban area.

3.3 Pedestrian Traffic Crash Frequency and Conflict Rate Correlations

In order to detect how much traffic conflicts, represent the chance of traffic crashes to occur on pedestrian crosswalks, crash data and conflict rates are correlated in this study to know the empirical relationship combining them. The analysis was implemented for suburban locations only using a step-wise form of the SPSS program; as the CBD investigated locations did not have enough crash data to perform the analysis required.

Crash frequency and conflict rates data in a suburban area was plotted to find if there is any correlation with the conflict rates at suburban crosswalks. Figure 7 shows the predicted model obtained, which indicates that crashes increase as conflict rate increases on suburban crosswalks, up to a peak value of 43 crash at 365 conflicts rate/1000 vehicles, then decrease as conflict rates increase as drivers are going to be more sensitive and awake to drive obeying traffic rules and ordinances. This correlation is describing an empirical crash field data registered by police officers and conflicts from photography filming with manual data counting. In this crosswalk a special Zebra type is needed, in addition to an automatic push-button pedestrian crossing signal installation will be very useful to survive people's life, especially school students and elderly people. Some of the cross midblock locations investigated in this study are more than 10 meters wide, and some pedestrians are not so fast to cross, in this case, an overpass is required as a safe structure to provide more safety and security to some weak type pedestrians. The mathematical model is a 3rd Degree Polynomial with R^2 of 0.924 as follows:

$$Y = -1E - 06X^3 - 0.0003X^2 + 0.7346X - 117.6 \qquad (6)$$

where:
Y: Crash frequency of pedestrians on suburban crosswalks, and
X: Conflict rate of pedestrians on suburban crosswalks in conflicts/1000 vehicles.

This result is supporting many other results found elsewhere, that crashes could be represented or replaced by conflict rates in other safety research or safety supporting projects such as those implemented by Khalik, 1997.

3.4 Analysis of conflict rates with pedestrians and other traffic and geometric characteristics of the crossing locations

Pedestrians are usually coming to crosswalks to pass safely as soon as possible with minimum delay time and without interaction with the passing vehicles. This condition is highly affecting the behaviour of the pedestrian, which may lose his/her patience to cross without care. In this study, conflict rates are correlated with five main factors to know how they affect pedestrian safety in both CBD and suburban areas. The main factors selected for step-wise correlation analysis with pedestrian conflict rates (as a dependent variable) are provided pedestrian spaces, the pedestrian speed at a crossing, road width which is the total approach width from curb to curb distance without considering median width as a geometric variable, 85th percentile vehicular traffic speed, and pedestrian waiting time. The analysis is performed for both CBD and suburban crosswalk locations included in this study. The analysis was performed using the SPSS program. The model variable introduced are described as below:

- Y_1 Conflict rate in conflicts/1000 vehicles on CBD crosswalks;
- Y_2 Conflict rate in conflicts/1000 vehicles on suburban crosswalks;
- X_1 Pedestrian space measured in m^2/ped;
- X_2 Pedestrian speed at crosswalks in m/sec;
- X_3 Total width of a crossed road in (m);
- X_4 85th percentile vehicular traffic speed on main crossed road in km/h; and
- X_5 Pedestrian waiting time on road curbstone in sec/ped.

3.4.1 Pedestrian conflict rate modelling in Dohuk City CBD area crosswalk

Step-wise regression analysis correlating conflict rates on CBD crosswalk, and other variables listed above is shown below:

$$Y_1 = 813.958 - 4.871X_1 - 22.251X_2 - 17.344X_3 - 12.318X_4 + 45.766X_5 \qquad (7)$$

From the above model, it is shown that some of the variables are going to decrease conflict rates, meanwhile, only one is going to increase it. Pedestrian space, and speed, is going to decrease it, and the same effect seems for road width, and vehicle speed too, but pedestrian waiting time on curbstone on CBD is going to increase them. Collinearity table which shows the interaction among the five independent variables, X_1, X_2, X_3, X_4, and X_5 is shown in Table 1.

Analysis of variance ANOVA is shown in Table 2 for the predicted model.

The derived model produced multiple correlation coefficient for the total model of R^2= 0.84. VIF is best showing that collinearity is very weak as its value is less than 5.0, and the P-value of 0.838% is less than 5% required insignificance level (Anderson, 2008). In Table 2, the F-calculated value is more than the standardized value of F at 5% insignificance level of 3.84, this means that regression coefficients are the best-fitted values as the null hypothesis will be rejected. The partial correlation matrix shows no collinearity among the five independent variables, and proof model validity as it is shown in Table 3. Figure 8 shows the uniform

Table 1: Collinearity matrix of independent variables X_1, X_2, X_3, X_4, and X_5 for step-wise regression analysis of conflict rates on Dohuk City CBD crosswalks.

Predictor	Coefficients	Standard Deviation	Student t-value	Probability of Insignificant	Variable Inflation Factor (VIF)
Constant	813.958	976.666	0.833	0.451	-
X_1	-4.871	7.386	-0.659	0.546	2.667
X_2	-22.251	405.281	-0.055	0.959	2.153
X_3	-17.344	24.569	-0.706	0.519	1.193
X_4	-12.318	10.757	-1.145	0.316	2.558
X_5	45.766	41.532	1.102	0.332	3.349

Table 2: Analysis of variance of variables included in the regression analysis of Y_1, X_1, X_2, X_3, X_4, and X_5 of conflict rates on Dohuk City CBD crosswalks.

Source of Variation	D.F.	SS	MS	F	P
Regression	5	141363.85	28272.77	4.12	0.00838
Error	4	27449.28	6862.32		
Total	9	168813.13			

Table 3: Partial correlation matrix of the step-wise regression of Y_1, on the other variables X_1, X_2, X_3, X_4, and X_5 of conflict rates on Dohuk City CBD crosswalks.

Variables	Y_1	X_1	X_2	X_3	X_4	X_5
Y_1	1.00					
X_1	-0.20	1.00				
X_2	-0.117	-0.416	1.00			
X_3	-0.110	-0.017	-0.007	1.00		
X_4	-0.233	-0.307	-0.395	-0.022	1.00	
X_5	0.241	0.474	-0.685	0.221	0.439	1.00

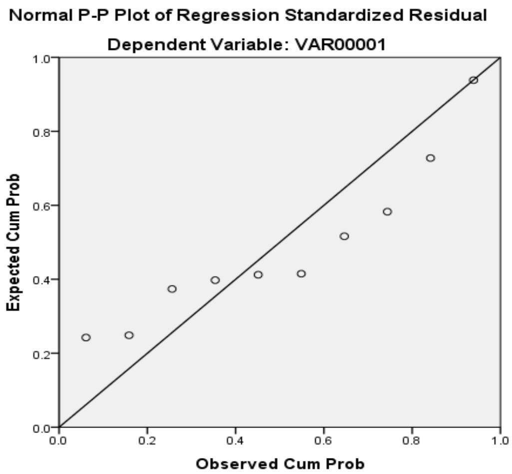

Figure 8. Expected and observed regression validation of conflict rates around normal probability diagonal line on Dohuk City CBD midblock crosswalks.

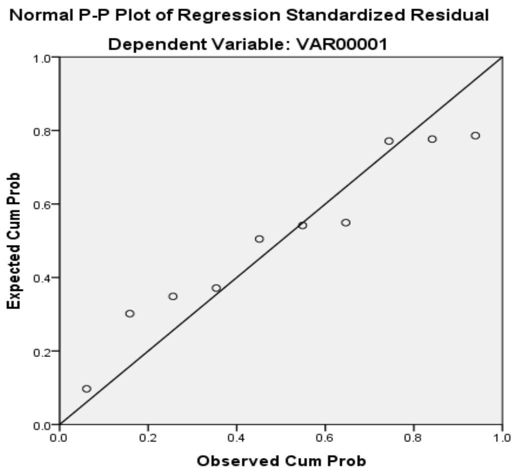

Figure 9. Expected and observed regression validation of conflict rates around normal probability diagonal line on Dohuk City suburban midblock crosswalks.

Table 5: Analysis of variance of variables included in the regression analysis of Y_1, X_1, X_2, X_3, X_4, and X_5 for conflict rates on Dohuk City suburban crosswalks.

Source of Variation	D.F.	SS	MS	F	P
Regression	5	150203.28	30040.656	7.3	0.0048
Error	4	16460.632	4115.158		
Total	9	166663.912			

Table 6: Partial correlation matrix among Y_2, and other variables X_1, X_2, X_3, X_4, and X_5 for conflict rates on Dohuk City suburban crosswalks.

	Y2	X1	X2	X3	X4	X5
Y2	1.00					
X1	-0.550	1.00				
X2	-0.450	0.295	1.00			
X3	-0.182	-0.151	0.589	1.00		
X4	-0.233	-0.159	0.282	0.065	1.00	
X5	0.013	0.252	0.262	0.522	0.217	1.00

distribution of SSE values around the diagonal of the normal probability plot around the zero value of the SSE, which represents the model validation as plotted using the SPSS programme.

3.4.2 Pedestrian conflict rate modelling in Dohuk City suburban crosswalk

Step-wise regression analysis correlating conflict rates on Dohuk suburban crosswalk and other same variables listed above is shown in the model represented in eqn. 8 as below:

$$Y_2 = 698.479 - 3.815X_1 - 301.984X_2 - 12.829X_3 - 0.966X_4 + 1.016X_5 \quad (8)$$

From the model, it is shown that some of the variables are going to increase conflict rates, meanwhile, others are going to decrease it. Pedestrian space, pedestrian speed, total road width, and 85th percentile vehicle speed is decreasing conflict rates but, pedestrian waiting time on the curbstone of Dohuk City suburban area is increasing it. The collinearity table representing the interaction among the five independent variables X_1, X_2, X_3, X_4, and X_5 is shown in Table 4.

Figure 9 shows the uniform distribution of SSE values around the diagonal of the normal probability plot around the zero value of the SSE, which represents the model validation criteria as plotted using the SPSS program.

4. CONCLUSION

According to the size of data collected and the techniques used to analyze it and decide what is necessary to solve the pedestrian safety problem in Dohuk City in both CBD and suburban crosswalks. The following conclusions could be drawn out:

- Vehicle conflicts and pedestrian space are related in Exponential Models with R^2=0.906 and R^2=0.866 in CBD and suburban crosswalks respectively.
- Vehicle conflicts and pedestrian speed are related in Quadratic Polynomial Models with R^2=0.764 and R^2=0.818 in CBD and suburban crosswalks respectively. The optimum value was 500 conflicts /1000 vehicles at pedestrian speeds of 1.55 m/s.
- Crash and conflict rates correlations in the suburban area show a Cubic Polynomial Model with a high coefficient of multiple determination R^2 of 0.924. The function is best fitted with a peak crash frequency at 365 conflict rates per 1000 vehicles at an optimum crash frequency of 43. The model concludes that in suburban area crosswalks conflict rates could be considered as a surrogate to crash frequency in describing the safety condition in Dohuk City suburban area.
- Conflict rate per 1000 vehicles happened in Dohuk City CBD and suburban crosswalks decrease with pedestrian provided space, speed, crossed road total approach width, and 85th percentile vehicular speed, but increases with the amount of waiting time experienced by a pedestrian at crosswalk edge with R^2 values of 0.84 and 0.90 for CBD and suburban crosswalks respectively.

A lot of changes are found necessary to be recommended to develop pedestrian movement safety in Dohuk City in both CBD and suburban crosswalks, such as pedestrian crossing automatic signs, zebra, and pelican crossing markings where they are justified in order to reduce or eliminate conflicts, and/or crash occurrence near or at crosswalks and make crossing easier for pedestrians. Formal analysis obtained a lot of results that recommend some locations need overpass bridge structures to isolate pedestrians from the rapid hazardous traffic vehicles travelling with high speeds and, this selection is needing more study by decision-makers to put down the type of each solution needed.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest as regards this article.

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