An Impact of Traffic Characteristics on Crash Frequency

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Abstract. With the development of roads, modes of transportation were also developed, and increasing numbers of those modes and routes were needed. This increase brought into focus many problems of the highway system. One of the most important concerns in the highway networks is road safety, which requires various studies to be carried out to reduce crash causalities. One of the factors that affect road safety is the traffic characteristics. This includes average daily traffic, operating speed, traffic density, and heavy vehicles percentage. This study focused on the effect of average daily traffic and heavy vehicles percentage on crash frequency. The old Baghdad – Baquba rural road, a two-lane, two-way road, was chosen for this study. This study used two sets of data (traffic characteristics and crash data). Generalized linear regression models were utilized to develop a model that reflects the effect of the average daily traffic and heavy vehicles percentage on crash frequency. The results showed a positive correlation between average daily traffic and crash frequency and between heavy vehicles percentage and crash frequency.

Keywords: Road safety; traffic characteristics; crash frequency.

1. INTRODUCTION

With the development of roads, modes of transportation were also developed, and increasing numbers of those modes and routes were needed. This increase brought into focus many problems of the highway system. One of the important concerns in highway networks is road safety, which requires various studies to be carried out to reduce accident causalities [1]. Therefore, global organizations have studied this issue, and global warnings have been declared due to the increase in the global rate of road fatalities. The negative social and economic consequences of road accidents have highlighted this issue; therefore, the reduction of the rate of road fatalities and the promotion of safe road networks are included in the targets of the sustainability development goals (SDG 2030) set by the United Nations [2-8].

In Iraq, road fatalities have increased within the last four [9-12]. Studies have investigated the risk factors [13]; road user behavior, road factors, and vehicle factors are the most contributing factors [2,14,15]. Some of these studies focused on the roadway factor, such as the geometric design elements and pavement surface conditions [16-19]. One of the factors that affect road safety is the traffic characteristics. This includes factors such as average daily traffic, traffic density, operating speed, and heavy vehicles percentage [20]. Al-Taeie [21] studied the role of the gap and lag length at un-signalized intersections on the fatalities frequency. This study focused on the traffic characteristics: average daily traffic (ADT) and heavy vehicles percentage (HVP).

1.1 The Effect of Traffic Characteristics on Road Safety

Many studies have investigated the relationship between traffic characteristics (average daily traffic and heavy vehicles percentage) and crash frequency. One of the most common factors affecting crash frequency is the average daily traffic (ADT) or as represented in data availability Annual Average Daily Traffic (AADT). This factor is normally available in traffic characteristics databases built from data collected manually or mechanically. It is a major concern for researchers to investigate the relationship between average daily traffic and frequency or crash rate. Some studies revealed that an increase in average daily traffic could lead to an increase in crash frequency; the more vehicles on the road, the more conflicts occur between the vehicles. In contrast, some studies indicated that less crash frequency correlated with increased average daily traffic due to lower speeds [22].

The heavy vehicles percentage is another factor that could affect the crash frequency on road networks. Many studies investigated the effect of heavy vehicles percentage on crash numbers [23-25]. The findings of these studies indicated that the increase in heavy vehicles percentage could lead to an increase in crash numbers. However, the percentage of this increase is related to the road type. For example, a higher rate of heavy vehicles could lead to higher crash frequency on two-lane two-way roads more than on other types of roads [26].

1.2 Generalized Linear Models

One of the important issues in road safety analysis is the modeling of crash data. The Generalised Linear models have been utilized in considering road safety issues. Regression models like Poisson, Poisson Gamma, and Poisson Inverse Gaussian are considered to analyze the effect of the environmental, traffic, and geometric characteristics on the crash frequency and rate [27]. Previous studies tried to develop crash frequency prediction models that could be classified into two groups. The first group utilized conventional univariate regression models such as Poisson, Poisson Gamma, and Zero-Inflated models. The second group

considered more specified models such as Generalised Additive Models, Markov switching models, and random parameters models. First, simple linear regression models were used to develop crash frequency models assuming that the crash counts data follow the normal distribution. However, studies revealed that Poisson regression is more fitting the crash data. Although the Poisson regression models were used to describe crash data for many years, researchers have indicated the issue of over-dispersion using these models. Therefore, to overcome this issue, Poisson Gamma regression models, which consider the over-dispersion in accident data, have been considered an alternative to Poisson regression models [28]. For this study, the Poisson Gamma regression model was supposed to develop the crash frequency model using The R Project for Statistical Computing.

The aim of this study is to develop a safety performance function that reflects the effect of some of the traffic characteristics on crash frequency for the Old Baghdad–Baquba rural road. Therefore, the generalized linear regression models were used to develop a statistical model, using The R Project for Statistical Computing, which may reflect the effect of average daily traffic and heavy vehicles percentage on crash frequency. This model could provide a smooth facility for practitioners to understand the impact of traffic characteristics on road safety for rural roads in the Iraqi level terrain.

2. DATA DESCRIPTION AND METHODOLOGY

The main objective of this study is to investigate the relationship between crash frequency (the number of crashes that happen on a road segment for a specific period, such as a year) as the dependent variable and the effect of the traffic characteristics (average daily traffic and heavy vehicles percentage) as the independent variables. Based on that, the needed data and the study area are identified. Then, the above techniques will be selected to develop the required model. Two sets of data were used in this study. The first dataset provided the crash data, and the second data set provided the count data for the average daily traffic and heavy vehicles percentage.

The selected road for this study is the Old Baghdad-Baquba Road which connects a main city (Diyala) in Iraq to Baghdad (the capital). The total length of the road is 70 km. For the purpose of this study, the road was divided into segments of a fixed length of 1 km. Traffic characteristics data and crash count data were needed to build the proposed model. The first dataset (crash data) was collected from two data sets from the Traffic Departments in Baghdad and Diyala provinces for three years (2016-2019). These datasets were examined to check data quality and omit errors in the data entry process, like missed entries or wrong values. Then, the two datasets were merged into one crash dataset. The second dataset needed for this study is the traffic characteristics dataset. Traffic volumes were collected for eight hours per 10 weekdays, from 7:00 am to 3:00 pm. The selected road has been used highly by a high percentage of heavy vehicles, which converted to an equivalent number of passenger cars to find the ADT.

The Generalised Linear Models were used to develop the crash frequency model for the Old Baghdad-Baquba Road, depending on the traffic characteristics. Before building the model, it was necessary to check for collinearity between the independent variables (average daily traffic and heavy vehicles percentage). Collinearity is a possible linear relationship between the independent variables, which causes inaccurate estimates because of high standard errors that could affect the significance of the model [29].

To check for the possible collinearity between the independent variables in this study, the Variance Inflation Factor (VIF) method was used. The Variance Inflation Factor is a test that indicates collinearity. The maximum acceptable value of the Variance Inflation Factor is 5. This has been applied to check for collinearity in this study. The Generalised Linear Model (Poisson Gamma) was used to analyze the crash data and to develop the safety performance function using the two datasets (traffic characteristics and crash data). Table 1 shows the descriptive statistics for the collected data. Safely Performance Functions (SPF) are prediction models that associate crash frequency (as the dependent variable) to the traffic and geometric factors as a full SPF or as a simple SPF that considers the effect of a traffic factor such as the average daily traffic, which is the common form used in the literature [30].

Table 1: Descriptive statistics for crash frequency and traffic conditions.

Var	Min	Max	Mean	S.D.
Crash frequency	0	32	0.38	1.29
LnADT	6.29	9.39	7.17	0.51
HVP	3	19	4.60	2.72

3. RESULTS AND DISCUSSION

Collinearity analysis was performed using the Variance Inflation Factor to check if there is any correlation between the independent variables (average daily traffic and heavy vehicles percentage). If the VIF between the two independent variables is more than 5, then one of them should be excluded from the analysis. The results showed that the collinearity inductor (VIF value) is within the acceptable limitations. After checking that the collinearity was within the acceptable limits, it was decided to consider all the independent variables (average daily traffic and heavy vehicles percentage) to build the prediction model for the Old Baghdad-Baquba Road using the Generalised Linear Models (Poisson Gamma) as shown in Table 2.

Table 2: Statistical parameters for generalised linear model (Poisson Gamma) for old Baghdad-Baquba Road.

Var	Coefficients	S.E.	z	Probability
Intercept	-6.12	2.74e-01	-19.31	<2e-15
LnADT	0.82	6.25e-01	35.14	<2e-14
HVP	0.17	3.50e-01	16.49	0.000327

The results showed that average daily traffic is a significant factor at a confidence level of 95%, and there is a positive correlation between the average daily traffic (ADT) and the crash frequency. The results also showed that the heavy vehicles percentage affects the crash frequency significantly at a confidence level of 95%, and there is a positive association between the heavy vehicles percentage and the crash frequency. The reason behind that could be that the higher the number of heavy vehicles, the higher the number of overtaking maneuvers. That could lead to higher numbers of head-on and run-off road crashes. This could be noticed in two-lane two-way roads, as in the studied road.

Figure 1 shows the residuals versus the fitted values. It can be seen that data points variate around the estimated regression line in almost a constant way. It suggests that the data points bounce randomly around the estimated regression line. This indicates that the relationship between the predictors (traffic characteristics and heavy vehicles percentage) and the response (crash frequency) follows the Poisson Gamma distribution, as it was assumed in the analysis approach utilized in this study [31]. Figure 2 shows the Q-Q normal plot. This plot is considered a visual check for the normality of the data. It is a graphical tool to check the assumption that the data follow a specific distribution, such as normal or exponential distribution. It is based on comparing the assumed distribution's quantiles to the normal distribution's quantiles. It can be seen that the dataset formed a skewed line. This indicates that the crash counts data follows the Poisson Gamma distribution as assumed in the analysis [31].

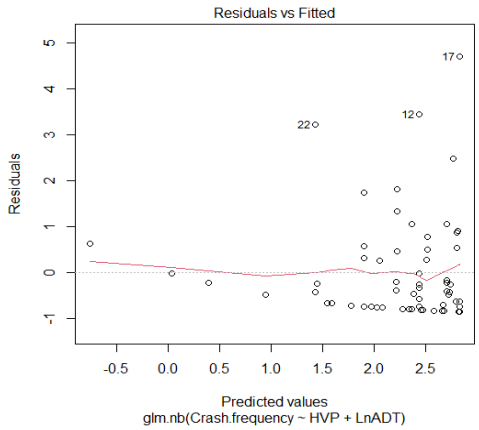

Figure 1: Residuals versus fitted values of the regression analysis for the developed model.

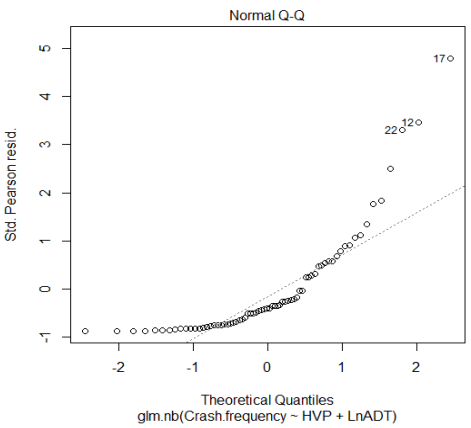

Figure 2: Q-Q Normal plot of the regression analysis for the developed model.

4. CONCLUSIONS

This study aimed to develop a safety performance function reflecting the effect of the traffic characteristics (average daily traffic and heavy vehicles percentage) for estimating the crash frequency for Old Baghdad - Baquba road in Iraq. It was indicated, by previous studies, that the Generalised Linear Model (Poisson Gamma) is an effective regression analysis approach for modeling crash data. Therefore, it was assumed that the crash counts data follow the Poisson Gamma distribution, and this was confirmed later in the study. Before developing the model using the above approach, it was necessary to carry out a collinearity test for the predictors. The Variance Inflation Factor test was used for this purpose. The results showed that there is an acceptable collinearity between the independent variables. The collected data were used to develop the model using The R Project for Statistical Computing. The results of the developed safety performance function showed that the crash frequency is significantly and positively correlated to the average daily traffic parameter. The results also, showed that there is a significant positive correlation between the crash frequency and the heavy vehicles percentage that may cause the need for more passing manoeuvres related to more crash.

This study focused on one rural road. It recommended developing safety performance functions for other roads or road networks to enable a comparison process for the findings of this study in the same or similar jurisdictions. This study utilized the Generalised Linear Models (Poisson Gamma) as the regression analysis approach for developing the proposed model. It is recommended to use other techniques approved by researchers, such as Gaussian regression, to be compared to the technique selected in this study.

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