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Evaluation the effect of some traffic characteristics on the safety performance of intersections.

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ABSTRACT

Traffic accidents and traffic delay have a negative impact on the mobility traffic flow due to their huge costs on the transport system. Thus one of the main primary aims for transport policy makers are reducing the negative effect of traffic accidents and traffic delay on the road network. In this study, fixed and random parameters Tobit models have been developed to model the accident rates from 20 intersections in Al-Karakh district in Baghdad City, Iraq. The safety significant of logarithm of annual average daily traffic, the percentage of heavy vehicles and the delay time for both major and minor directions for each intersection on the accident rates were evaluated. The main finding of this study shows that delay has an important effect on traffic accident rates of intersections. Regarding to the effect of other factors on traffic accident rates, the result of the model shows that the logarithm of annual average daily flow, the percentage of heavy vehicles for both major and minor directions of the intersection are positively associated with more accident rates.

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1. Introduction

1.1 Background

The majority of transportation engineers consider that intersections are the most hazard location in the road network due to the conflict between traffic streams in all directions; thus, many accidents occur in these hazard locations. This safety problem has been supported by number of accidents that occur in the intersection around the world. For instant, the percentage of overall accidents occurred in the boundary zone of the intersections is about 43% in the United State of America and 40 % in Norway (Lord et al., 2005) (Elvik and Vaa, 2004). More than 30% of accidents occurred in the intersections in Singapore road networks from 1992 – 2002 (Tay and Rifaat, 2007). In Canada more than 30% and 40% were registered as fatal persons and injuries persons due to the accidents that occurred in the intersections (Barua et al., 2010). In Australia, the percentage of intersection accidents from total accidents in 2010 in the State of New South Wales was 54% (RTA, 2010).

A much debated questions are whether the delay has a considerable effect on traffic accident rates, especially, on the intersections. However, to date

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there has been little studies about the relationship between delay and traffic accident rates. Traffic accidents and delay in the intersections are two significant factors that effect on the road users of the network. In terms of economic perspective increasing of travel time due to increasing the delay in each approach of the intersection has a significant effect on the traffic capacity and safety level of the intersection. There is a controversy issue about the relationship between the traffic accidents and traffic delay. Some researcher claimed that there is an inverse relationship between delay and traffic accident rates. They hypothesis that in the intersection approach with less delay time leads to a high average speed of traffic flow, therefore the chance of accidents will be high . On the other hand, some researcher claimed that increasing delay time will increase the conflict between the vehicles and increase the traffic accidents (Wang et al., 2009). Thus, it's important to evaluate the relationship between the traffic accidents and traffic delay which can lead to apply some policies to reduce both traffic accidents and delay in the intersections. However, there is a gap in the knowledge about the relationship between traffic accidents and delay in the intersections using statistical approach, thus this study introduces a more robust statistical approach to evaluate the effect of delay on traffic accidents at intersections.

1.2 Aim of the study

The main aim of this study is to evaluate the impact of traffic characteristics for selected intersections on traffic accident rates using statistical approach (Tobit model) this model has been considered to find the relationship between the dependent variable (accident rates) and the independent variables (traffic characteristics). Tobit model has been used because there is right censoring in accident rates data that has been used in this study.

The aim of the study can be achieved through this objective:

- Evaluate the effect of traffic flow on major direction (Ln AADF $_{\text{major direction}}$), traffic flow on minor direction (Ln AADF $_{\text{minor direction}}$), heavy vehicles parentage on major direction (%Hv $_{\text{major direction}}$), hevy vehicles on minor direction (%Hv $_{\text{minor direction}}$) delay on major direction (D $_{\text{major direction}}$) and delay on minor direction (D $_{\text{minor direction}}$) on accident rates.

2- Methodology

2.1 Data

Twenty intersections in Al-Karakh district in Baghdad City, Iraq are used as a case of study in this study. Accidents data was obtained from the Ministry of Planning and from the municipality of Baghdad city.

2.1.1 Accidents data

The accident data are collected for ten years, from 2008 to 2018 for 20 selected intersections in Al-Karakh district. These data are collected by the police and included all type accidents. The data are obtained from the departments of traffic in Al-Karakh district in Baghdad City, Iraq. In this study, the total accident rates that occur in each approach of the intersections are analysed as the dependent variable, the dependent variable is computed as follows:

$$Accident\ rate_i = \frac{\sum_{yr=1}^{n} Accidents_{yr,i}}{\left[\sum_{yr=1}^{n} AADF_{yr,i} * L_i * 365\right]/100000000} \qquad (1)$$

Where Accident rate denotes accident numbers for every 100 million vehicles on each intersection, *i*, yr denotes the year (from 1 to *n*), $Accidents_{yr,i}$ denotes accident numbers per year yr (year from 1 to *n*) on intersection *i*, $AADF_{yr,i}$ denotes the average annual daily flow in year yr on intersection *i*, and L_i denotes the length of intersection *i* in kilometres, the length of intersection was selected to be any roadway segments across intersection and any roadway segments that located within 50m from the intersection boundary in all directions.

2.1.1 Traffic characteristics data

Traffic characteristics data such as Ln AADF $_{\text{major direction}}$, Ln AADF $_{\text{minor direction}}$, %Hv $_{\text{major direction}}$ and %Hv $_{\text{minor direction}}$ are obtained by counting theses traffic characteristics at the each approach in the selected intersections from (6:00 am up to 11:00 pm) during the workdays of the week. While the D $_{\text{major direction}}$, and D $_{\text{minor direction}}$ each approach are calculated using Highway Capacity Software (HCS 2010).

Table 1: Summary statistics of accident rates, Ln AADF $_{major\ direction}$, Ln AADF $_{minor\ direction}$, %Hv $_{major\ direction}$ and %Hv $_{minor\ direction}$, D $_{major\ direction}$ and D $_{minor\ direction}$

Parameters	Min	Max	Mean	S.D.
Accident rates	0	12411	105.13	34.19
Ln AADF $_{major\ direction}$	7.11	14.98	8.83	1.07
Ln AADF $_{minor\ direction}$	6.05	12.54	7.39	1.06
%HV $_{major\ direction}$	3	31	12.42	4.02
%HV $_{minor\ direction}$	2	27	9.22	1.33
Delay $_{major\ direction}$	15	79	48.92	2.07
Delay $_{minor\ direction}$	8	62	39.98	3.29

2.2 Data analysis

The dependent variable in this study is the accident rate in each approach in the selected intersections. The heterogeneous effects for each independent variable will be evaluated; a random Tobit model will be used in this study. The main idea in the random Tobit model, some or all independent variables will be considered as random or fixed parameters. The random parameters are assumed to vary across all observations and assumed to follow the normal distribution with mean equal to 0 and variation equal to 1. However, the fixed parameters are assumed to be fixed across all observations. The coefficients and elasticity effect of each independent variable in the random Tobit model will be estimated using N-Logit version5 which is a statistical software that founded by William Greene (Greene, 2007).

The Tobit model was developed by Tobin (1958). It is a model where the dependent variable is either right- or left-censored. Specifically, it involves the notion of left-censored denotes data that is censored at a low threshold while right-censored denotes data censored at a high threshold. With respect to accident data, the data is left-censored with clustering at zero bases. This is performed with the realization that it is impossible to observe accident frequencies on all or a few intersections during the time of observation. Thus, the construction of the Tobit model is performed as follows:

$$Y_i^* = \beta X_i + \varepsilon_i,\ i=1,2,3,\ldots\ldots\ldots,N$$
$$Y_i = Y_i^* \ \ if \ \ Y_i^* > 0$$
$$Y_i = 0 \ \ if \ \ Y_i^* \leq 0 \qquad (2)$$

Where, N denotes the number of observations, Yi denotes the dependent variable (traffic accident rates), β denotes the vector of estimate parameters, Xi denotes for the independent variables (D $_{major\ direction}$, D $_{minor\ direction}$, Ln AADF $_{major\ direction}$, Ln AADF $_{minor\ direction}$, %Hv $_{major\ direction}$ and %Hv $_{minor\ direction}$) and εi denotes to the error term with mean (μ) equal to 0 and variance σ^2 equal to 1. Specifically, there is an index that is both stochastic and implicit (dormant variable) that is denoted as Y_i^* and is only observed in examples where the Yi value exceeds zero. Therefore, the Tobit model's likelihood positive and aforementioned zero observations is as follows (Greene, 2003):

$$\log LL = \prod_0 \left[1 - \boldsymbol{\Phi}\left(\frac{\beta X}{\sigma}\right)\right] \prod_1 \sigma^{-1}\, \phi \left[\frac{(Y_i - \beta X)}{\sigma}\right] \qquad (3)$$

In Equation (3), $\boldsymbol{\Phi}$ denotes the standard normal distribution function, and ϕ denotes the standard normal density function, and this corresponds to a description of the Tobit in the traditional sense (fixed parameter). Nevertheless, a challenge in the model involves accounting for heterogeneity (factors that are not observed and could differ across observations). In order to ensure that heterogeneity is accounted for by using a random parameter, a simulated maximum likelihood estimation procedure was developed by (Greene, 2003). Estimable parameters that are permitted for random parameters are as follows:

$$\beta_i = \beta + \varphi_i,\ i= 1,2,3,\ldots., N \qquad (4)$$

Where φi denotes a term that is randomly distributed (Poisson regression model: $\lambda i \mid \varphi i = exp$ (βXi) and Negative Binomial regression model: $\lambda i \mid \varphi i = exp$ (βXi + εi)). Thus, the log-likelihood is re-expressed as follows:

$$LL = \sum_{\forall_i} \ln \int_{\varphi_i} g(\varphi_i)\, P(n_i/\varphi_i) d\varphi_i \qquad (5)$$

Specifically, $g(\varphi_i)$ denotes the probability density function of φi. The estimation of the random parameters is performed by using a maximum likelihood-based on a simulation that uses Halton draws (Bhat, 2003)

The elasticity effect is performed to evaluate the effect of parameters on the change of the accident rates in all intersections. Approximately, elasticity is considered to denote the percentage change in the mean accident rates owing to a 10% change within the independent variables. Elasticity effect is computed as follows:

$$E_{X_{ik}}^{\lambda_i} = \frac{\partial \lambda_i}{\lambda_i} * \frac{X_{ik}}{\partial X_{ik}} \quad (6)$$

Equation (6) refers to the elasticity of the accident rate based on the kth independent variable for observation i.

3- Results and discussion

3.1 Model Evaluation

Table 2 shows the overall log-likelihood at convergence for fixed and random parameters Tobit model, chi square value, degree of freedom and the confident level for the accident rates for all intersections. Based on the log-likelihood at convergence the random parameters Tobit model fit the data statistically better than fixed parameters Tobit model

3.2 Model results

Tables 3 and 4 show the estimated parameters for the fixed and random parameters Tobit models for accident rates of 20 selected intersections.The average elasticity effects, which is presented in Figure 1 pro-vide additional insights with regard to what occurs with accident rates at all intersections

Table 2. Overall log-likelihoods for fixed and random parameters Tobit models

Model	Log-L at (β) for Fixed parameters model	Log-L at (β) for Random parameters model	Chi-square	Degree of freedom	% confident
Fixed	**-1296.445**	**-1289.622**	**13.65**	**6**	**97**
Random	**-829.738**	**-824.040**	**11.39**	**4**	**99**

Table 3. Fixed parameters Tobit model for accdent rate

Parameters	Constant	Ln AADF major di-rec-tion	Ln AADF minor direc-tion	%Hv major di-rection	%Hv minor di-rection	D major direction	D minor direction
Coefficient	**-64.32**	**29.59**	**21.07**	**1.98**	**0.94**	**1.99**	**1.31**
T	**-5.66**	**11.46**	**7.99**	**10.44**	**3.01**	**3.08**	**5.11**

Table 4. Random parameters Tobit model for accident rates

Parameters	Coefficient	T
Constant	-73.95	- 6.15
Ln AADF	31.11	13.18
Std.	-	-
Ln AADF $_{minor\ direction}$	23.27	9.27
Std.	-	-
%Hv $_{major\ direction}$	1.71	7.22
Std.	5.89	6.09
%Hv $_{minor\ direction}$	1.03	3.62
Std.	9.11	11.42
delay $_{major\ direction}$	1.61	11.03
Std.	1.27	5.12
delay $_{minor\ direction}$	0.87	4.66
Std.	1.25	7.08

The results, as shown in Table 4, point out that the parameter of logarithm annual average daily flow for the major direction (Ln AADF $_{major\ direction}$) as found to be positive and fixed parameter, this indicates that increasing Ln AADF $_{major}$ was associated with increase accident rates for all intersections. The average elasticity effects of Ln AADF $_{major}$, presents explain the change in the total accident rates for all intersections. The accident rates on average increased by 34.5% due to 10% increasing in Ln AADF $_{major}$. In a similar context, intersections with higher Ln AADF $_{minor\ direction}$ have higher accident rate, the parameter for Ln AADF $_{minor}$ resulted as fixed parameter in the model. According to Figure 1, the elasticity effects a 10% increasing in Ln AADF $_{minor}$ led to increase accident rates by 19.3%. These results support the idea that increasing both Ln AADF $_{major\ direction}$ and Ln AADF $_{minor\ direction}$ at intersections leads to increase the prospective conflicts among vehicles (Milton and Mannering, 1998), therefore; it increases the likelihood of accidents occurrence. These findings are consistent with a wide range of previous studies (Abdel-Aty and Haleem, 2011; Das and Abdel-Aty, 2011)

As shown in Table 4, a positive correlation was found between %Hv major direction and accident rates. The %Hv major direction resulted in a normally distributed random parameter with a mean of 1.71 and a standard deviation of 5.89. This distributional parameter implies that the increase in %Hv major direction increased the accidents rates for 61% of intersections and decreased the accidents rates for the other 39% intersections. In the same path, the result of random parameters Tobit model shows that the %Hv minor direction was significantly increase the accident rates. The %Hv minor direction resulted in a normally distributed random parameter with a mean of 1.03 and a standard deviation of 9.11. This distributional parameter implies that the increase in %Hv minor direction increased the accidents rates for 54% of intersections and decreased the accidents rates for the other 46% intersections. As shown in Figure 1, the elasticity effects of the percentage of heavy vehicles on accident rates a 10% increasing in both %Hv major direction and %Hv minor direction lead to increase accident rates by 15.3% and 7.2%, respectively.

Both %Hv major direction and %Hv minor direction are observed to be positively associated with accident rates. This result may be explained by the fact that increasing heavy vehicles percentage, effects other driver behavior, increasing lane changing and overtaking (Dong et al., 2015).

Regarding to the result of random parameters Tobit model presented in in Table 4. It is found that intersection with higher D major direction in general result in higher accident rates. For the random parameters Tobit model, the D major direction resulted as random parameter is normally distribution with mean equal to 1.61 and standard deviation equal to 1.72. These distribution parameters indicated that 82% of the distribution was less than zero, whereas 18% of the distribution was greater than zero. This implies that in the majority of intersections increasing D major direction increase accident rates. The elasticity effects show the effect of D major direction on the accident rates, a 10% increase in D major direction leads to increase the accident rates by22.4% (see Figure 1). The D minor direction parameter was found to be statistically significant and positively correlated with accident rates for all intersections. The D minor direction was resulted as random parameter, with a mean of 0.87 and a standard deviation of 1.25. The parameter distribution indicated that for 75% of intersections, increasing D minor direction increased accident rates. However, for 25% of intersections, increasing D minor direction decreased accident rates. Referring to the elasticity effects, a 10% increase in delay minor direction was expected to increase accident rates by 19.3% (see Figure 1). The average elasticity effects, which is presented in Figure 1 provide additional insights with regard to what occurs with accident rates at all intersections.

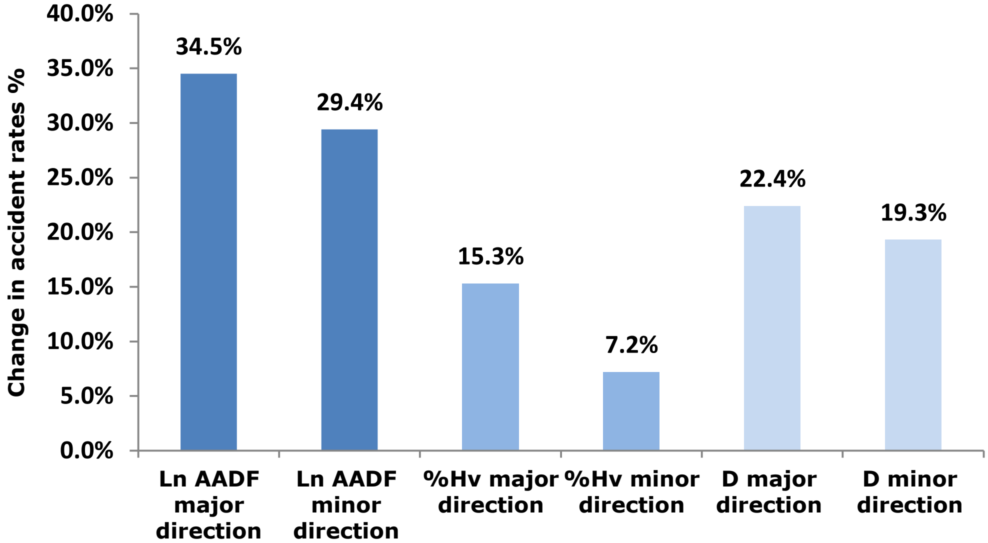

Figure 1 Elasticity effect of random parameters Tobit models for accident rates

Table 5. Impact of independent variables on traffic accident rates for all intersections

Parameters	Paramter effect	Random or Fixed parameter	Positive effect (%)
Ln AADF $_{\text{major direction}}$	↑	Fixed	100
Ln AADF $_{\text{minor direction}}$	↑	Fixed	100
%Hv $_{\text{major direction}}$	↑	Random	61
%Hv $_{\text{minor direction}}$	↑	Random	54
delay $_{\text{major direction}}$	↑	Random	82
delay $_{\text{minor direction}}$	↑	Random	75

4- Conclusion

This study shows an analysis of fixed and random parameter Tobit models for traffic accident rates occurred at 20 intersections in Al-Karakh district in Baghdad City, Iraq. The aim of this study is to observe the effect of intersection delay on the rate of accidents. Ten years (2008 – 2018) of traffic accident rates, Ln AADF major direction, Ln AADF minor direction, %Hv major direction and %Hv minor direction, D major direction and D minor direction are used to developed fixed and random parameter Tobit models.

This study has identified that both Ln AADF major direction and Ln AADF minor direction have posi tively fixed effect on traffic accident rates. The result of random parameters Tobilt model presented that both %Hv major direction and %Hv minor direction resulted as random parameters and increased the accident rates for more than half of the intersections. The D major direction and D minor direction are mostly significant the rate of accidents at all intersections. Intersections with higher delay in both directions positively associated with rate accidents for the majority of intersections.

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