

TOTAL CRASHES RATES MODELING USING THE RANDOM PARAMETERS TOBIT MODEL (RPTM)

SALAH SABBAR THAMEEL¹, ZAYD A. AL-OBAIDI^{2*}, AHMED ABDUL KADHIM MOHSIN³

Abstract: This study examined the total accidents along the road directly as a continuous variable and explored the use of an additional technique according to Tobit regression. Unlike Previous studies, that have dealt with accident frequency; the current study shows the total accident rates directly as a continuous variable. The random and fixed parameters of Tobit model were evaluated to carry out an exhaustive study of the traffic features like percentage of heavy vehicles(%HV), Free Flow Speed (FFS) and logarithm of Annual Average Daily Flow (AADF) that influence the total accident rates. Data on total accident rates and traffic characteristics were gathered from 2016–2020 along Al- Fallujah – Al-Qaim rural road in Al-Anbar province, Iraq. This road has been segmented into 345 homogenous roadway segments. The obtained results show that the (RPTM) was able to find a better statistical compatibility also and offer comprehensive insights into the traffic characteristics that contribute to total accident rates than the fixed parameters Tobit model. Based on the random parameters model, also the results exhibit an increase in the traffic characteristics under study, namely the logarithm of average flow, the (%HV), and (FFS). consequently, contributed to the rise in the total accident rates.

INTRODUCTION

In the last few decades, many numbers of studies have been conducted to determine the determinants that influence the accident frequency over specific time periods on roadway segments. These studies have been carried out in an effort to learn more about how accidents occur. These investigations have made use of count data models such as those based on the Poisson distribution and the negative binomial distribution, random effects, and random parameters models [11, 12]. The substantial body of previously published studies provided a significant quantity of knowledge about understanding of the factors that effecting on accident frequency. However, another approach was developed to study the influence of factors on accidents occurred. This approach that is being taken in this scenario is to consider the number of accidents that occur for every 100 million kilometers traveled by vehicles (VKT). Rather than using the number of accidents in roadway segments. Accident rates can offer a unit metric of the safety along the roadway sections. This relative safety can be accomplished by limiting the consequence of accident exposure, and accident rates are easier to grasp than accident rates per period of time. It would appear that the accident rates may be modeled as a continuous variable using the statistics. When it comes to modeling, it is best to make use of a variable as opposed to a non-negative integer number.

¹ University of Anbar, Ramadi, Iraq. Email: ahmadsala2016@uoanbar.edu.iq

² University of Anbar, Ramadi Iraq. Email: eng.zayd132@uoanbar.edu.iq

³ University of Altinbas, Istanbul, Turkey. Email: ahaho81@gmail.com

*Correspondence: eng.zayd132@uoanbar.edu.iq

Keywords: Accident Rates, Random Parameters, Tobit Model, Traffic Characteristics, Civil Engineering.

count-data models to ascertain the frequency of accidents. In the meanwhile, accident rates can be equal to 0 because there were no reports of accidents being received or because there were no incidents to begin with. During the time period that was the focus of this investigation, it was seen in a few of the portions. In order to represent this non-negative continuous variable, the typical standard ordinary differential equation is utilized as the modeling tool. A skewed outcome is almost certainly going to be created by utilizing the regression method of least squares. estimates of the parameters and judgments based on statistical analysis The crash rates should be approached as though they were filtered on the left direction (censored at 0), and the Tobit model technique should be applied in order to find a solution to this problem. This is a sensible way to find a solution to this issue. The vast bulk of the research that is now accessible attempted to predict crash rates, and the majority of those estimates were based on Tobit models. the early studies to investigate crash rates employing Tobit regression was carried out by Anastasopoulos and colleagues [1]. This study is widely regarded as an innovative, ground-breaking study (2008). As part of their investigation into the collision rates that were observed on Indiana's interstate routes, they presented a Tobit model and demonstrated the usefulness of Tobit regression as a potential tool for safety analysis. They also illustrated the potential of Tobit regression as a useful tool. Tobit model became a popular method for analyzing accident rates for two-lane country roads after conducting Anastasopoulos, et al. [1] study [6], work zones [3], and signalized junctions [9].

LITERATURE REVIEW

According to modeling statistics, numbers of accidents per each vehicle miles traveled is considered as continue variable compared with the integer number which it is non- negative. The using of crashes and injuries per vehicle miles traveled give us good indexes for road safety, therefore many studies by using Tobit modeling, such as in 1995 Talley use the Tobit modeling for calculate the accidents cause passengers vessel damaged cost [18]. In fact, every year the quantity of deaths and injuries due to road accidents increase which effect on health and economy, as example In Malaysia, the number of deaths and injuries are increasing each year, also in 2008 the percentage of accidents which includes injuries increased by 2.7% and the percentage of road deaths increased by 3.9% during one year [16]. There are different factors effects on road accidents such as speed which consider the most important factor in road accident which includes injuries and fatalities, therefore there are large numbers of studies and researches reported a big relationship between traffic factors with fatalities [10, 19].

These factors including the speed, traffic flow, heavy vehicle etc. The studies and research are affected by the speed of vehicles and AADT. The second factor which effect on road accident are heavy vehicles because it has a big complex systems due to a failures caused by vehicle characteristics such as large trailer outward movement, wheel braking, braking distance, and lack of acceleration while driving. Actually the percentage of heavy vehicles does not only affect accident rates, but it also affects air pollution due to the shortness of the chimney as comparing with private cars [21].

In 1995, Fancher and Campbell presented a study on the size and weight of heavy vehicles, such as multiple axles and the length of the vehicle, and confirmed that there is a significant impact on the number of accidents, such as deaths and injuries [5], but in Iraq, according to the Central Statistical Organization

considered the Traffic accidents is one of the reasons of death [2], therefore the speeds can be defined as vehicles are traveling in high speed as compared with the other vehicles which traveling with limit speed.

For most drivers in world ,as example in Poland country and US larger than 50% of drivers are driving more than the limit speed [14], because of high percentage mentioned above , the number of fatalities reached 31% in Poland and 27% in US [13, 15], so the driving with high speed lead to increasing in distance of braking, reduce the sight distance and reduce the reaction time to make decisions and finally increase the probability of accident [4]. According to the International Transport Forum (ITF), the increase of speed lead to increase the percentage of accident [8]. in iraq exactly in Anbar provance they imported 174,000 cars in 2003 which lead to increase the number of accident rates according to the ministry of planning [20]. in fact there are other factors which affects on accident rates such as geometric design of road as example the under layres (subbase layre) which should be the compaction test not less than 96%. [22].

METHOD

The regression model Tobit was developed by Tobin in 1958, the model characterized by its ability to handle the dependent variable which can be either right- or left-censored. However, the left-censored data has a low threshold compared to the right-censored data. The accident data considered for the analysis can be deemed left-censored with clustering at zero bases. This consideration is made because of the difficult observing all or few intersections during the observation ttime. In this case, Tobit model construction is done the following:

$$\begin{aligned} Y_i^* &= \beta X_i + \varepsilon_i, i=1,2,3, \dots, N \\ Y_i &= Y_i^* \text{ if } Y_i^* > 0 \\ Y_i &= 0 \text{ if } Y_i^* \leq 0 \end{aligned} \quad (1)$$

N represents the observations number, Y_i represents the (severe injury crashes rate) which considered the dependent variable, β represents the vector parameters of estimation, X_i represents the independent variable (traffic, geometric and pavement characteristics), and ε_i denotes a normally and independently distributed the term of error which the mean (μ) equal to zero and variance σ^2 equal to one. exactly there are two an index include stochastic and implicit (dormant variable) which it is Y_i^* and can be observed in examples if the value Y_i value exceeds zero. Therefore, the likelihood of the Tobit model is positive and the aforementioned zero observations is as follows [7]:

$$\log LL = \prod_0 \left[1 - \Phi \left(\frac{\beta X}{\sigma} \right) \right] \prod_1 \sigma^{-1} \phi \left[\frac{(Y_i - \beta X)}{\sigma} \right] \quad (2)$$

In Equation (3), Φ refers to the standard normal distribution function, and ϕ represents the standard normal density function that corresponds to a description of the Tobit in the traditional sense (fixed parameter). The main challenge of the fixed parameters is that it does not account for the unobserved factors, which can be incorporated with random parameters, a simulated maximum likelihood estimation procedure as proposed by Greene [7]. Random parameters that can be estimated as the following:

$$\beta_i = \beta + \varphi_i, i=1,2,3, \dots, N \quad (3)$$

Where φ_i represents a term that is randomly distributed (Poisson regression model: $\lambda_i \mid \varphi_i = \exp(\beta X_i)$ and Negative Binomial regression model: $\lambda_i \mid \varphi_i = \exp$

$(\beta X_i + \varepsilon_i)$). Thus, the log-likelihood is re-expressed as follows:

$$LL = \sum_{\forall i} \ln \int_{\varphi_i} g(\varphi_i) P(n_i/\varphi_i) d\varphi_i \quad (4)$$

$g(\varphi_i)$ represents the probability function of density of φ_i . The calculations of the random parameters were performed and using a maximum probability based on a simulation that uses Halton draws.

The elasticity impact refers to the percentage change in the overall emissions that is brought on by a shift of 1, 10, or 100 percent in the variable that is being controlled by itself [17]. Equation 5 should be used to express the elasticity:

$$E_{x_{jk}}^{\lambda_i} = \frac{\partial x_{ji}}{\lambda_i} \cdot \frac{x_{jk}}{\partial x_{jk}} \dots (5)$$

Above the carbon monoxide elasticity emissions, concerning the k-th observations for the j independent variable on the roadway segment i “

DATA DESCRIPTION

The current study aimed to explore the impacts of traffic parameters, namely (HV%), (FFS) and (Ln ADF) and estimate their contribution to total accident rates. All data was collected from Al- Fallujah – Al-Qaim rural road in Al-Anbar province, Iraq. The data was partitioned into uniform sections of the route defined by roadway segments). The data that was used to define the roadway segments included the (HV%), (FFS) and(Ln ADF) and the accidents that occurred on each roadway segment throughout the 5 years. The roadway was divided into 345 sections and the total numbers of accident during the sections was calculated and defined.

The data included the number of crashes that occurred on every roadway segment during five years of investigation. The accident rate (A.R.), which was computed as the number of accidents that occurred for every 100 million vehicle miles traveled, was determined as follows:

$$A.R._i = \frac{\sum_{yr=1}^n Accidents_{yr,i}}{[\sum_{yr=1}^n AADF_{yr,i} * L_i * 365]/100000000} \quad (6)$$

Table 1: Summary Statistics of Total Accident Rates, and Traffic Features.

Variable	Min	Max	Mean	S.D.
Total	0	14557	75.165	273.684
Ln ADF	7.001	10.898	8.587	0.663
%HV	1	27	5.702	3.972
FFS	60	140	81.975	19.804
N			345	

MODELS RESULTS

Table 2: Parameter Calculation of Total Accident Rates Model.

Variable	Coefficient	t- value
Constant	-736.895	-8.86
Ln ADF	60.502	7.21
Std.	-	-
%Hv	19.767	13.27
Std.	64.707	6.42
FFS	0.865	0.32
Std.	1.205	4.55

The findings of the random parameter model for total accident rates that influencing by traffic characteristics are presented in Table (2). These results include the logarithm of (Ln ADF), (%Hv), (FFS).

At a level of confidence equal to or greater than 99%, the calculations (RPTM) indicated that the logarithm of Average Daily Flow was a significant fixed parameter for total accident rates. There is a connection between Ln ADF and the rates of total accidents. In this particular instance, a rise in Ln AADF was linked to an increase in the total rates of accidents.

The random parameters Tobit for the total accident rates reveal that the coefficients for heavy trucks are substantial for all of the models. There was a significant direct relationship between the percentage of heavy vehicles and the total accident rates. The coefficients estimate of the percentage of heavy vehicles that resulted as a random parameter for the total accident rates model has a mean of 19.767, and a standard deviation of 64.707. Based on these criteria, it appears that 38 % the distribution was below 0. While for this distribution 62% was greater than 0. This means that increasing of percentage of heavy vehicles leads to increase the total accident rates in 38% of roadway segments. on the other side for 62% of the roadway segments leads to decrease the total accident rates (see Figure 1).

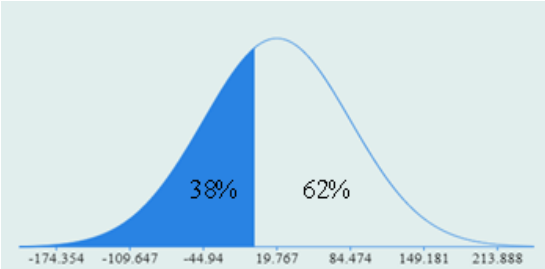


Figure 1: Distribution of (% Hv) Parameter for Total Accident Rates Model.

Increasing the free flow speed at a roadway segment was related with an increase in the total accident rates. The (FFS) parameter followed a normal distribution, with a mean of 0.865, and a standard deviation up to 1.205. In light of these features, 25% of the distribution was lower than 0. On the other hand, 75% of the distribution was greater than 0. According to these findings, an increase in free flow speed leads to an increase the total accident rate for 25%, of the roadway segments. As comparing with 75% for segments of road, a reduction in the total accident rates was expected due to an increase in the free flow speed.

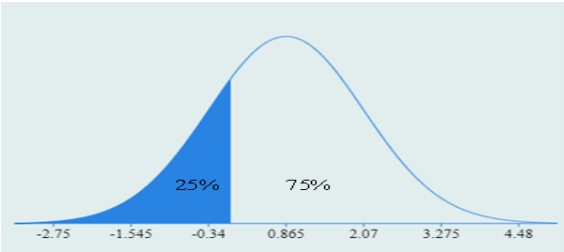


Figure 2: Distribution of (FFS) Parameter for Total Accident Rates Model.

It was necessary to evaluate the elasticity effect in order to determine how much of

an impact of the (HV%), (FFS) and (Ln ADF) on the total accident rates. A 10% rise the average daily flow (Ln ADF), percentage of heavy vehicles (HV%), and free flow speed (FFS) were used to measure the change in the total accident rates that occurred. The elasticity effect of the (HV%), (FFS) and (Ln ADF) on the total accident rates, are shown in Figure 3.

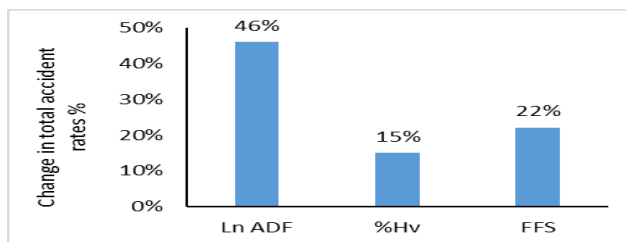


Figure 3: Estimated Elasticity Effects of a 10% Increase in (%Hv), (FFS) and (Ln ADF) on Total Accident Rates.

CONCLUSION

The current study investigated the application of random parameters in Tobit regression to evaluate the traffic characteristics that have a major impact on accident rates. The considered data were obtained by using five years of data on accidents and traffic characteristics from Al- Fallujah – Al-Qaim rural road in Al-Anbar province, Iraq. Regarding the methodology approach, the random parameters Tobit model can give a more comprehensive knowledge of the factors that determine accident rates due to their ability to account for the heterogeneity raised from the traffic characteristics. The random-parameters model demonstrates that several factors relating to traffic characteristics are found to significantly influence total accident rates. These factors include the (HV%), (FFS) and (Ln ADF). It has been determined that the (HV%), (FFS) and (Ln ADF) are statistically significant in terms of the influence they have on the total accident rates. All traffic characteristics have a significant positive effect on the total crashes rates. The findings of the random parameters Tobit model showed that the average daily flow (Ln ADF) resulted in a fixed parameter, this means that the increasing of this factor resulted in to increase in the total accident rates in all roadway segments. For the (FFS) and (HV%) these two factors resulted as random parameters it does means the effect of these two parameters will fluctuate across different sections of the roadway.

REFERENCES

- [1] P. C. Anastasopoulos, A. P. Tarko, F. L. Mannering, *Tobit analysis of vehicle accident rates on interstate highways*, *Accident Analysis & Prevention* **40** (2008), 768-775.
- [2] CSO, *Statistics Roads Traffic Crashes in Iraq in 2018*, Central Statistical Organization, Ministry of Planning, 2019.
- [3] A. K. Debnath, R. Blackman, N. Haworth, *A Tobit model for analyzing speed limit compliance in work zones*, *Safety Science* **70** (2014), 367-377.
- [4] R. Elvik, *Speed Limits, Enforcement, and Health Consequences*, *Annual Review of Public Health* **33** (2012), 225-238.

- [5] P. S. Fancher, K. L. Campbell, *Truck size and weight study Phase I: working papers 1 and 2 combined. Vehicle characteristics affecting safety*, U.S. Department of Transportation, 1995.
- [6] H. Farah, S. Bekhor, A. Polus, *Risk evaluation by modeling of passing behavior on two-lane rural highways*, *Accident Analysis & Prevention* **41** (2009), 887-894.
- [7] W. H. Greene, *Limdep version 9, Econometric modeling guide, Volume 1*, Econometric Software, Inc., Plainview, New York, 2007.
- [8] International Transport Forum (ITF), *Speed and Crash Risk*, International Traffic Safety Data and Analysis Group, Paris, OECD, 2018.
- [9] X. Jiang, G. Zhang, Y. Zhou, L. Xia, Z. He, *Safety assessment of signalized intersections with through-movement waiting area in China*, *Safety Science* **95** (2017), 28-37.
- [10] S. Lassarre, *The introduction of the variables "traffic volume," "speed" and "belt-wearing" into a predictive model of the severity of accidents*, *Accident Analysis & Prevention* **18** (1986), 129-134.
- [11] D. Lord, F. Mannering, *The statistical analysis of crash-frequency data: A review and assessment of methodological alternatives*, *Transportation Research Part A: Policy and Practice* **44** (2010), 291-305.
- [12] F. L. Mannering, C. R. Bhat, *Analytic methods in accident research: Methodological frontier and future directions*, *Analytic Methods in Accident Research* **1** (2014), 1-22.
- [13] National Highway Traffic Safety Administration (NHTSA), *Traffic Safety Facts data 2016: Speeding*, Washington: National Centre for Statistics and Analysis, 2018.
- [14] National Road Safety Council (NRSC), *National Road Safety Program 2013-2020*, Warsaw: Ministry of Infrastructure and Development (in Polish), 2013.
- [15] National Road Safety Council (NRSC), *The state of road traffic safety and related activities in 2017*, Warsaw: Ministry of Infrastructure and Development (in Polish), 2017.
- [16] A. A. Saifzul, H. Yamanaka, M. R. Karim, *Empirical analysis of gross vehicle weight and free flow speed and consideration on its relation with differential speed limit*, *Accident Analysis & Prevention* **43** (2011), 1068-1073.
- [17] V. Shankar, F. Mannering, W. Barfield, *Effect of roadway geometrics and environmental factors on rural freeway accident frequencies*, *Accident Analysis & Prevention* **27** (1995), 371-389.
- [18] W. K. Talley, *Safety Investments and Operating Conditions: Determinants of Accident Passenger-Vessel Damage Cost*, *Southern Economic Journal* **61** (1995), 819-829.
- [19] J. M. Tessmer, *Rural and Urban Crashes: A Comparative Analysis*, National Highway Traffic Safety Administration, 1996.
- [20] S. Thameel, T. Mahmood, A. Mustafa, A. Mohson, *A Proposed Plan for Implementing the Public Transport Policy in the City of Ramadi/Anbar University as a Model*, *Anbar Journal of Engineering Sciences* **12** (2021), 90-99.
- [21] S. S. Thameel, S. F. Al-Chalabi, A. Mustafa, A. A. Mohsin, *An Evaluation of Health Care Waste Generation and Disposal at Ramadi Teaching Hospital in Iraq*, *Iraqi Journal of Civil Engineering* **16** (2022), 1-9.
- [22] S. S. Thameel, A. S. Mustafa, A. A. Mohsin, *Evaluation of Recycled Demolition Waste Aggregates for base and sub-base use in Roads*, *IOP Conference Series: Materials Science and Engineering* **870** (2020), 012089.