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# Assessment Of Accident Severity For Rural Multilane Road Using Random Parameters Models

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## ABSTRACT

The frequency of accidents is often used as a foundation for prioritizing improvements to roadway safety by several transportation organizations. However, the use of accident severities in safety programming has frequently been restricted to the locational assessment of accident fatalities, with little or no emphasis being placed on the full severity distribution of accidents (slight damage, serious damage) which is required in order to properly evaluate the advantages of several competing efforts aimed at improving safety. Within the scope of this research, we provide a sufficient modeling technique that may be used to get a better understanding of the accident severity level that occur on highway segments, as well as the influence of traffic characteristics such as annual daily flow, percentage of heavy vehicle and free flow speed. The modeling approach that used in this research (random parameters model) provides the possibility that the estimated values of the model parameters might differ from one road segment to another to account the heterogeneity of the independent variables. The estimated random parameters models are developed using accident severity data and traffic characteristics data that obtained from Fallujha – Al-Qaeam rural multilane road in Al-Anbar province, Iraq. The results of the estimated results suggest annual daily flow, percentage of heavy vehicle and free flow speed all have significant effect on the accident severity level. For the purpose of prioritizing highway safety improvements, a number of government transportation authority's base their decisions on accident rates and statistical models of accident rates.

## 1. Introduction

For many highway safety agencies, the improvement programs have traditionally placed emphasis on the reduction of accident frequency (which only takes into account the number of accidents) rather than accident severity (which takes into account the level of accidents and the number of injuries). The accident frequency methods are more likely to favor urban and suburban areas, which have more accidents, than rural areas, which may have fewer accidents overall but are known for having more accident severity. In terms of the method approach that has been used to assess the accident severity, much research has used a random parameter approach to model the accident severity. For instance, Anastasopoulos and Mannering (2009) used a random parameter model to evaluate the effects of pavement, geometrics, and traffic characteristics on the frequency of accidents. This study gave an example of how a random-parameter model can provide an accurate result compared to other

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approaches. The method made it possible to take into account and make adjustments for the heterogeneity that may result from a variety of factors relating to traffic, geometric, and pavement characteristics, as well as other unobserved factors. In another study, a random parameter model was suggested as an outstanding approach for the development of an accident prediction model to estimate the accident frequency on a 200-kilometer stretch of highway segments on a two-lane undivided rural highway (Dinu & Veeraragavan, 2011). The estimation of random parameter models for numerous aggregations of accidents was implemented. The aggregations were based on several different characteristics, such as the severity of the accidents, the number of cars involved, the location, and the type of collision. The findings that were generated by this model show that, in general, the improvement in log-likelihood that occurred when the random parameters model was utilized (Venkataraman et al., 2013). Chen and Tarko (2014) conducted yet another study in which they employed random parameter models to explore the impact of exposure factors, highway characteristics, work zone features, and temporal variables on the frequency and severity of accidents. The research presented and examined a random parameter model as well as a random effects model, both of which were statistical models built to analyze work zone safety. This research came to the conclusion that random parameter models were the most accurate in terms of parameter estimations and gave the most useful insights. Random parameter models were utilized in a study that was conducted in the United Kingdom by Kamla et al. (2016). The purpose of the study was to investigate the traffic and geometric characteristics and their influence on accident statistics at 70 roundabouts located on A-class roads and motorways. The findings of this thesis led to the conclusion that the random-parameter model was a superior choice. These findings were presented in the form of a conclusion. Random parameter models were utilized in research that was carried out in the province of Gyeonggi-Do over the course of four years, between 2007 and 2010, to investigate the factors that impacted the accident frequency and severity at a total of 72 signalized junctions. The experimental findings show that the random parameter model is superior to those produced by the fixed parameter model. It was also shown that the random parameters model offers a better understanding of the factors that impact the frequency of accidents at junctions that are equipped with traffic lights (Park et al., 2016). In addition, Park and Lee (2017) evaluated variables that cause accidents in road segments. The authors also employed random-parameter models in their investigation. The purpose of this research was to find a solution to the problem that was caused by the fixed parameter model, which required that the estimated parameters remain the same from one set of observations to the next. The utilization of a random parameter model made it possible to account for the unobserved heterogeneity in the data. In most cases, the data suggests that the inferences provided by random parameter models are of higher quality when compared to the inferences provided by standard fixed parameter models. It has also been demonstrated to be the superior option in terms of accounting for heterogeneity among sites caused by unobserved variables, which may have an effect on accident rates. This might have an effect on how frequently and severely accidents occur.

## 2. Methodology

For the purpose of accident severity analysis, count-data modeling approaches are frequently utilized since the number of accidents that occur on a road segment during a specific period of time is a positive integer. As was just discussed, a Poisson regression or one of its variations, such as the negative binomial or zero-inflated model, is typically used to model count data, see Washington et al. (2010). According to the fundamental Poisson model, the likelihood that road segment (*i*) would have ($n_i$) accidents is denoted by the formula P($n_i$).

$$\boldsymbol{P(n_i) = \frac{EXP(-\lambda_i \lambda_i^{n_i})}{n_i!}} \qquad \textbf{(1)}$$

Where $\lambda_i$ is the Poisson parameter for road segment (*i*), which is the predicted number of accidents for road segment (*i*), denoted by E($n_i$). In Poisson regression, the Poisson parameter (*i*), which stands for the predicted number of accidents, is specified as a function of the explanatory variables through the use of a log-linear function, as is common.

$$\boldsymbol{\lambda_i = EXP(\beta X_i)} \qquad \textbf{(2)}$$

where $X_i$ is a vector of the explanatory variables and is a vector of the estimable parameters (Washington et al., 2010).

Because the Poisson distribution requires the mean and variance to be the same ($E[n_i] = VAR[n_i]$), a Poisson model might not always be the best fit for the data. This is because the Poisson distribution restricts the mean and variance to be equal. If this equality does not hold, the data are said to be under dispersed ($E[n_i] > VAR[n_i]$) or over dispersed ($E[n_i]VAR[n_i]$), and the standard errors of the estimated parameter vector will be incorrect, which could lead to incorrect inferences being drawn. If this equality does hold, the data are said to be evenly distributed ($E[n_i] = VAR[n_i]$). In order to take into account the existence of this option, the negative binomial model was constructed by rewriting the original equation.

$$\boldsymbol{\lambda_i = EXP(\beta X_i + \varepsilon_i)} \quad \textbf{(3)}$$

Where $EXP(i)$ is an error term that follows a gamma distribution and has a mean of 0 and a variance of.1 The inclusion of this element makes it possible for the variance to deviate from the mean, as shown by the equation $VAR[ni] = E[n_i].\left[1 + E[n_i]\right] = E[n_i] + E[n_i]^2$. The following is the formula for the negative binomial probability density function:

$$\boldsymbol{P(n_i) = \left(\frac{\frac{1}{\alpha}}{\left(\frac{1}{\alpha}\right)+\lambda_i}\right)^{\frac{1}{\alpha}} \frac{\Gamma\left[\frac{1}{\alpha}+n_i\right]}{\Gamma\left(\frac{1}{\alpha}\right)n_i!}\left(\frac{\lambda_i}{\left(\frac{1}{\alpha}\right)+\lambda_i}\right)} \quad \textbf{(4)}$$

.As the value of becomes closer to zero, the negative binomial regression becomes a limiting model, and the Poisson regression becomes the dominant alternative. Therefore, the negative binomial model is acceptable if it is statistically different from 0, whereas the Poisson model is appropriate if it is not significantly different from 0 (Washington et al., 2010). Greene (2008) has developed estimation procedures (using simulated maximum likelihood estimation) for incorporating random parameters in Poisson and negative binomial count-data models. These procedures are used in order to account for heterogeneity, which is defined as the presence of unobserved factors that may vary across observations when using random parameters. Estimable parameters can be stated as follows in order to account for the possibility of random parameters in count-data models:

$$\boldsymbol{\beta_i = \beta + \varphi_i} \quad \textbf{(5)}$$

Where $\varphi_i$ is a random variable (for instance, a normally distributed term with a mean of 0 and a variation of 2) and r is the correlation coefficient. With this equation, the Poisson parameter is transformed into $i|i = EXP(Xi)$ in the Poisson model and $i|i = EXP(Xi + I)$ in the negative binomial, with the associated probability for Poisson or negative binomial now being $P(ni|i)$ (see Eq. (1)). The log-likelihood may be expressed as such when using this information.

$$\boldsymbol{LL = \sum\nolimits_{\forall i} ln \int_{\varphi_i} g(\varphi_i) P(n_i|\varphi_i)\ d\varphi_i} \quad \textbf{(6)}$$

Where g(.) is the probability density function of the $i^{th}$ iteration. Because the maximum likelihood estimation of the random parameters of the Poisson and negative binomial models is computationally difficult to accomplish (due to the required numerical integration of the Poisson or negative binomial function over the distribution of the random parameters), a simulation-based maximum likelihood method is used instead (the estimated parameters are those that maximize the simulated loglikelihood function; and to allow for heterogeneity, =/ 0). It has been demonstrated that the Halton draws method provides a more efficient distribution of draws for numerical integration than just random draws; see Bhat (2003). As a result, the Halton drawing method is now the most often used technique for simulation.

## 3. Data description

The selected rural multilane road (Fallujha-Al-Qaem) in Al-Anabr province, Iraq, begins at Fallujha city and ends at the Iraq-Syrian boundary at Al-Qaeam city, with a length of 345 km. The selected road is divided into 345 road segments, each 1 km long. Two types of data have been used in the research. The first set of data represents the accident severity (slight damage and serious damage) that has occurred on the Fallujha-Al-Qaem rural multilane road between 2017 and 2021 were the primary focus of this investigation. This set consists of 388 accident records, each of which includes detailed information on the drivers and vehicles involved.

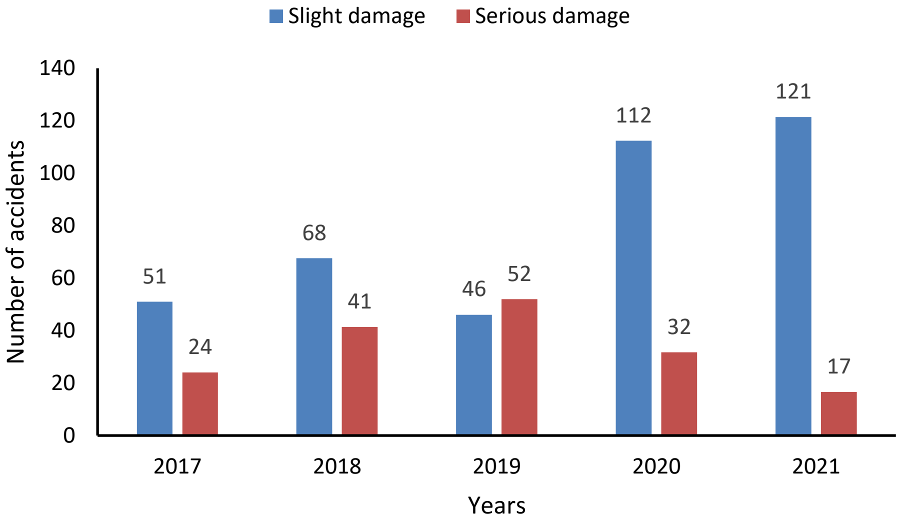

**Fig. 1 Slight and serious accidents over the study duration**

The second set of data consists of annual average daily flow, percentage of heavy vehicles, and free flow speed. Table 1 provides a summary of slight and serious accidents and traffic characteristics for all road segments.

**Table 1 – Summary of slight and serious accidents and traffic characteristics.**

| Variable | Mean | Standard deviation | Min. | Max. |
|---|---|---|---|---|
| Slight damage accidents | 80 | 1.5 | 0 | 10 |
| Serious damage accidents | 33 | 0.8 | 0 | 4 |
| Annual average daily flow | 10508 | 2144 | 8124 | 12344 |
| Percentage of heavy vehicles | 15 | 4 | 6 | 22 |
| Free flow speed | 80 | 20 | 65 | 150 |

## 4. Model estimation results

The findings of the models are presented in Table 2. The table contains an illustration of two models: one focuses on minor accidents, while the other emphasizes the results of serious accidents. At the 0.1 level of statistical significance, each of the parameters displayed is statistically significant.

Based on the coefficient estimates provided by random parameter models, the annual average daily flow was a significant positive independent variable that was included in both slight and serious accident models. The annual average daily flow is considered a significant variable in all models. According to Table 2, the annual average daily flow resulted in fixed parameters in both models. This means this variable will not vary for all road segments, and increasing traffic flow leads to an increase in both slight and serious accidents in all road segments.

**Table 2 – Random parameters models for slight and serious accidents.**

| Variables | Slight damage | | Serious damage | |
|---|---|---|---|---|
| | **Coef.** | **t** | **Coef.** | **t** |
| Constant | -3.587 | -11.47 | -5.521 | -8.24 |
| Annual average daily flow | 1.047 | 11.27 | 0.847 | 12.34 |
| Std. | - | - | - | - |
| Percentage of heavy vehicles | 0.092 | 23.66 | 0.366 | 12.64 |
| Std. | 0.599 | 17.03 | 2.888 | 8.842 |
| Free flow speed | 0.094 | 8.38 | 0.126 | 6.24 |
| Std. | 0.308 | 8.05 | 2.558 | 7.44 |

Regarding the percentage of heavy vehicles, there was a significant positive correlation between this variable and both slight and serious accidents, as shown in Table 2. The coefficient of the percentage of heavy vehicles in both slight and serious accident models resulted as a random parameter. The mean and standard deviation of slight damage accidents were 0.092 and 0.599, respectively, while the values for serious damage accidents were 0.366 and 2.888, respectively. These distributional data revealed that an increase in the percentage of heavy vehicles on 41 and 45% of road segments led to an increase in both slight and serious accidents. On the other hand, an increase in the percentage of heavy vehicles on 59 and 55% of road segments led to a decrease in both slight and serious accidents.

The effect of free flow speed on both slight and serious damage accidents was evaluated in random parameter models as presented in Table 2. The results of both models revealed that this variable was a random parameter in the booth models. This highlighted that this variable varied across road segments for both models. The coefficient of free flow speed follows a normal distribution, with a mean of 0.0945 and a standard deviation of 0.308. This gives us a distribution with 39% of the values being less than 0, and 61% of the values being more than 0. Therefore, an increase in free flow speed increases the slight damage accidents for 39% of road segments. On the other hand, an increase in free flow speed for 61% of the road segment will decrease the slight damage accidents. In the same approach, the coefficient of free flow speed follows a normal distribution, with a mean of 0.126 and a standard deviation of 2.558. This gives us a distribution with 48% of the values being less than 0 and 52% of the values being more than 0. Therefore, an increase in free flow speed increases the slight damage accidents for 48% of road segments. On the other hand, an increase in free flow speed for 52% of the road segment will decrease the slight damage accidents.

After the slight and serious damage parameter coefficients were calculated, it was discovered that the comparative importance of the variables had been verified. In order to do this, the elasticity value was utilized as a tool for determining the relative impact that the variable had on the incidence of accidents and their rate (Shankar et al., 1995). Elasticity may be thought of as roughly denoting the percentage change in the mean of accidents as a result of a certain percentage change inside the independent variable. The elasticity effect of all independent variables is presented in Figure 2. This figure shows the change in both slight and serious accidents due to a 10% change in annual average daily flow, percentage of heavy vehicles, and free flow speed on both slight and serious damage accidents.

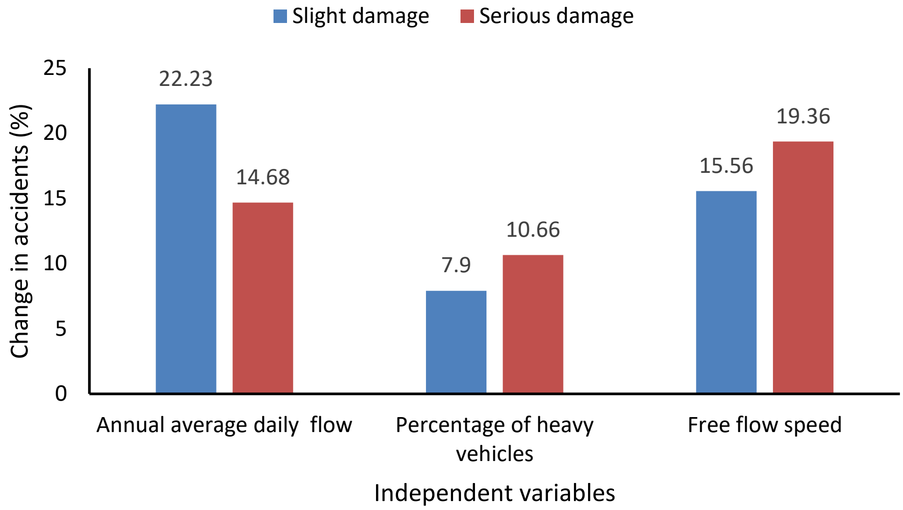

**Fig. 2 Estimated elasticity effects of a 10% increase in annual average daily flow, percentage of heavy vehicles and free flow speed on slight and serious damage accidents**

## 5. Conclusions

Due to the challenges involved in predicting accident severity, many highway authorities have shifted their attention to safety improvement programs that focus largely on accident frequency. Understanding how many factors impact accident severity is a goal for any and all transportation agencies, and having the capacity to comprehend and manage the accident severity potential in a multivariate context is a priority for these agencies as well. This research aims to develop models to predict the slight and serious damage accidents that occurred on rural multiline roads.

In addition, these developed models are also used to evaluate the effect of traffic characteristics such as annual daily average flow, percentage of heavy vehicles, and free flow speed on both slight and serious damage accidents. The random parameter model technique that was provided in this research gives methodological flexibility that may be utilized as a basis for safety initiatives that want to gain a better understanding of the variables that affect accidents. Agencies are able to gain a much better understanding of the effect that potential safety enhancements will have on overall roadway safety if they use a combination of frequency models and the proposed mixed logit model to determine severity proportions. From an econometric point of view, the random parameter models provide the flexibility to capture segment-specific heterogeneity, which can arise as a result of a number of factors relating to traffic characteristics and interactions among these factors. These factors can all have an effect on the likelihood of an accident occurring on a particular segment of roadway. The ability to consider traffic factors directly as they relate to accident severity proportions provides a much fuller understanding of the complex interaction of the numerous variables that determine transportation safety. This is because these factors directly relate to the proportion of accident injuries that are severe. The methodological approach that is described in this research has the potential to bring new insights into accident severity analysis and to open the door for the creation and deployment of new data-modeling approaches. Both of these outcomes are desirable.

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