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Modeling wrong-way crashes and fatalities on arterials and freeways☆

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ABSTRACT

Wrong way driving (WWD) research and mitigation measures have primarily focused on limited access facilities. This is most likely due to the higher incidence of fatal WWD crashes with dramatic consequences on freeways, media attention, and a call for innovative solutions to address the problem. While public agencies and published literature address WWD incidence on freeway systems, the crash analyses on non-limited access facilities, i.e., arterial corridors, remains untouched. This research extends previous works and attempts to provide many new perspectives on arterial WWD incidence. In particular, one work showed that while WWD fatalities are more likely to occur on freeways, the likelihood of these crashes is higher on arterials. Hence this work with univariate and multivariate analyses of WWD and non-WWD crashes, and fatal and non-fatal WWD incidents. Results show the impressive negative impacts of alcohol use, driver defect, nighttime and weekend incidence, poor street lighting, low traffic volumes, rural geography, and median and shoulder widths. The objective here is to highlight the need for paying greater attention to WWD crashes on arterial corridors as is done with fatal WWD incidents on freeway systems. It suffices to say that while engineering countermeasures should evolve from the traditional signing and pavement markings to connected vehicle technology applications, there is a clear and compelling need to focus on educational campaigns specifically targeting drunken driving, and enforcement initiatives with an objective to mitigate WWD in the most efficient manner possible.

1. Introduction

The use of multivariate statistical models and their application to analyzing road traffic crashes is on the rise [1], especially given the research and development on areas of importance to safety planning [2] and engineering practice [3]. While the road safety literature is replete with crash prediction models for freeways [4] and with particular emphasis on real-time prediction [5], the effect of geometry and the environment [6], data mining to estimate incident delays [7] and crash frequency analysis [8], relating crash-based flow-density to flow-volume/capacity [9] and real-time prediction using weather data [10], very limited knowledgebase is available for arterials. For instance, [11] presented several negative binomial models of accident frequency, while Ma, et al. [12] established the statistical relationships between traffic crashes and contributing factors. A similar pattern becomes visible upon a scan of literature for wrong way driving (WWD) crashes. Since the earliest documented crash history of WWD [13] [14], much work has progressed over the last decade [15] [16] [17] [18], partly due to the efforts of the National Transportation Safety Board [19] but with an almost exclusive focus on freeway systems. Excepting Vaswani [20] who observed that WWD injuries and fatalities on arterials were 2.2 to 2.8 times more likely than other crash types, very few works extended beyond referencing the WWD phenomenon on arterial systems. From a WWD perspective, Ponnaluri [18] made one of the first comparisons of arterials and freeways, and showed that the likelihood of a WWD crash and fatality were respectively 2.3 times and 0.24 times than those on freeways.

The main purpose of this work is to compare and contrast the incidence of WWD between arterials and freeways, and to highlight the need for paying greater attention to arterial corridors as is done with fatal WWD incidents on freeway systems. In this work, 'wrong-way' is defined as the movement of a vehicle in a direction opposite to the one designated for travel.

2. Previous work

This work extends earlier efforts [18] [21] and adds to the more recent works [15] [17]. The 2003–2010 dataset from Florida comprised 1.243 million crashes. Only those records with non-missing values were included by systematically reducing the data; the resulting 999,456-crash dataset formed the basis for this and an earlier work [18]. The structured query language (SQL) procedure contained in SAS® version 9.4 was used to develop the dataset. The study parameters of this earlier study included driver's age, gender, licensing state, physical defect, blood alcohol concentration, vehicle use, seatbelt compliance, day and time of crash, roadway lighting, facility type, weather

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conditions, road geometrics, and traffic volumes. Analysis of 23 parameters and the model development process included determining odds ratios (OR) and statistical tests for the predictive power and goodness-of-fit. The set of results was found to be consistent with expectations, though surprising at times. This work also helped identify specific areas where the freeway and arterial systems differ in both the magnitude of OR and their directional influence, i.e., positive or negative with regard to WWD crashes and fatalities. Areas of difference included driver's residence, driving under the influence of alcohol or drugs, roadway directional separation, average annual daily traffic, and median and shoulder widths. Ongoing experiences with WWD incidents across the state of Florida also helped note that is a need to distinguish arterial and freeway WWD incidence, and hence this effort as presented in Fig. 1.

3. Methodology

The comprehensive dataset [18] was further subdivided to perform comprehensive analyses using the binomial logistic regression procedures contained in SAS®; a two-fold analysis ensued: one for arterials and another for freeways (see Figure 1). The first step involved a review and analysis of WWD and non-WWD crashes with a percent distribution breakdown for each covariate. Next, for each of the two scenarios, a series of univariate analyses were performed for each covariate to determine the likelihood of a WWD crash (WWDC) over a non-WWD crash. The process was repeated to determine the likelihood of a WWD fatality (WWDF) over non-WWDF.

The latter analysis included the space comprising WWD crashes only. Given that the size of the WWD crashes only was 3823, or 3.84% of all crashes, the weighted maximum likelihood method was applied for the WWD-only crash analyses. Thus, each covariate was a subject of binomial logistic regression; later a combined model with the covariates and their interactions was developed. Stepwise regression helped develop a multivariate model with only those covariates that were statistically significant at the 5% level. The objective here was to determine the odds of a WWD crash for each covariate and its sub-categories in the event it was categorical. The odds of WWD crashes for a multivariate model were developed to study the impact of the covariates and their internal characteristics within a fitted model. This process was repeated for the fatal versus non-fatal WWD crashes. Thus, the odds of a fatal crash within the WWD space were obtained for individual covariates and for a multivariate model. WWD space is defined as all crashes that constituted WWD incidence. Results from the two multivariate models for arterials and two such models for freeways were discussed. Relevant tests such as Hosmer-Lemeshow (HL), Somer's D and McFadden R-square were used to evaluate the goodness-of-fit and model strength.

Based on the results from the univariate and multivariate analyses, and model outputs, a discussion was presented on the role of the covariates in each of the four models - two each for arterials and freeways that included WWD crashes versus non-WWD crashes and fatal versus non-fatal crashes within the WWD space. Finally, the major conclusions on WWD crash mitigation for implementing agencies and opportunities for future research are presented.

3.1. The logit form

Although the probability of an event 'Y' to occur, i.e., $P(Y = 1)$ can be expressed as $\alpha + \beta X$ [22], the fact that the former lies between 0 and 1, but the latter can extend outside these boundaries makes a logical case for replacing $P(Y = 1)$ with odds of $Y = 1$. The odds, Ϙ, of $Y = 1$ can in turn be expressed as $Ϙ = \{\frac{P(Y=1)}{1-P(Y=1)}\}$ whose natural logarithm yields the equation $logit(Y) = \ln\{\frac{P(Y=1)}{1-P(Y=1)}\}$. The resulting values expand significantly in the negative direction as the odds drop from 1 to 0, and sharply increase in the positive direction as the odds rise from 1 to infinity. With multiple independent covariates $X_{i=1 \text{ to } j}$, the dependent covariate may be expressed as $logit(Y) = \alpha + \beta_1X_1 + \beta_2X_2 + \dots + \beta_jX_j$, for which the converted form is $Ϙ(Y=1) = e^{\ln[Ϙ(Y=1)]} = e^{\alpha+\beta1X1+\beta2X2+\dots\dots\dots+\beta jXj}$, leading to the inference that a unit change in X_i multiplies the odds by $e^{\beta1}$. Lastly, it is worth nothing that the probability can be re-written as $P(Y = 1) = \{\frac{Ϙ(Y=1)}{1+Ϙ(Y=1)}\}$.

As noted earlier, four distinct multivariate models were developed, two each for arterials and freeways. In addition to the parameter estimates, standard errors and Wald χ^2, the odds ratio characteristics are

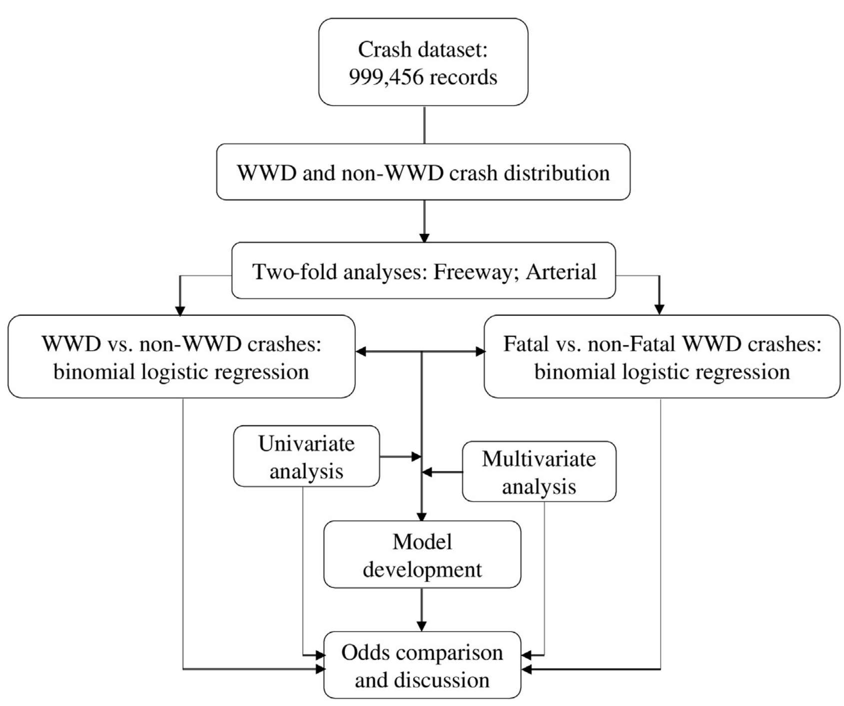

Fig. 1. Research methodology.