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The odds of wrong-way crashes and resulting fatalities: A comprehensive analysis

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ABSTRACT

The United States of America and other nations are grappling with the incidence of wrong-way driving (WWD). The issue is as important today (NTSB, 2012) as it was a half-century ago (Hulbert and Beers, 1966). In the absence of a comprehensive analysis, any effort to implement WWD countermeasures can be counterproductive. Hence, this effort began with the express intent to identify the factors that cause WWD crashes and fatalities. This work is sizeable in that it evaluated one million complete crash records from Florida. The methodology comprised (a) administering a survey on the perceptions about WWD; (b) developing binomial logistic models for computing the odds of WWD crashes, and of fatal crashes within the WWD space; (c) analyzing the contributing variables; and (d) comparing perceptions with crash analysis results. The study parameters 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 conditions, road geometrics, and traffic volumes. Individual variable analysis of 23 parameters and the model development process included the determination of odds ratios and statistical tests for the predictive power and goodness-of-fit. The results of this work are generally consistent with expectation, yet surprising at times. This work concludes with decision-making inputs to the scientist, policy-maker and practitioner on the need for effectively engineering the roads, actively educating people about wrong-way driving, and strictly enforcing traffic laws, rules and regulations.

1. Introduction

Analysis and countermeasures development of wrong-way driving (WWD) is not new, for it was discussed a half-century ago by Hulbert and Beers (1966) and Tamburri (1969). Tamburri noted that more than 50% of WWD incidents on California freeways resulted from drivers entering via the exit ramps and that 60% of fatal and injury WWD incidents occurred where sight distance was 1200 feet or less. Elsewhere (Friebele et al., 1971), while 0.2% of all crashes in Texas were WWD-related, about 1.4% of fatal crashes resulted from WWD. More recently, the National Transportation Safety Board (NTSB, 2012) noted that during 2004–2009, on an average, there were about 357 WWD fatalities per year in the United States of America, and that they comprised about 2.8% of all fatal crashes on divided highways. The NTSB Report also noted that 69% of the WWD drivers were impaired and that the 70-plus year-olds are at a particularly high risk. The impact of alcohol and drugs, and the need for accommodating the elderly driver were also stressed by Poulsen et al. (2014) and Sagberg (2003). Experiences from France (Kemel, 2015) and the Netherlands (De Niet and Blokpoel, 2000) provide a comprehensive background on WWD incidence in the European Union. These works provided an over-arching view to addressing road crashes from a policy perspective. For instance, the Swedish Parliament's 'Vision Zero' initiative aimed at zero fatalities (Whitelegg and Haq, 2006) with its applications (Tingvall and Haworth, 1999) and a systems management approach (Larsson et al., 2010) including the need for cultural change (Johnston, 2010). Other efforts studied the impact of 'Vision Zero' (Elvik, 1999; Elvik and Amundsen, 2000). The Netherlands also developed policy-oriented programs to reduce road traffi crashes (Wegman et al., 2005; Wegman et al., 2008) followed by an after-study ten years later (Weijermars and Wegman, 2011). These works differ from that of the United States in that they combined policy with practice, but may have lacked the rigor that is required for proposing a comprehensive crash data-evaluation-based solution framework.

The key to any WWD analysis is to eventually consider the use of the traffic control devices to counter WWD incidence

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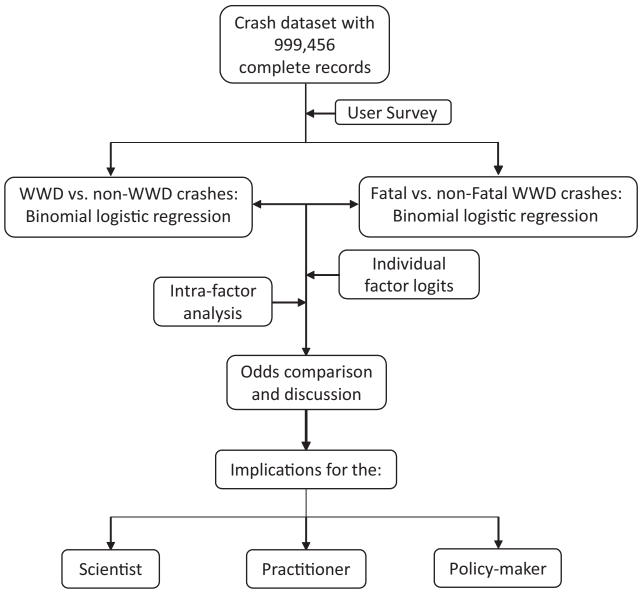

Fig. 1. Research Methodology.

(Gabriel, 1974; Shepard, 1976; Vaswani, 1977; Copelan, 1989) and technological applications, the concepts of which date back to the 1970s (Friebele et al., 1971; Forthoffer et al., 1996). The accumulated knowledge helped the recent works (FDOT, 2015; Zhou et al., 2014; IDOT, 2012; Sandt et al., 2015) to be holistic and base them on detailed WWD crash reviews.

That said, none of the works is comprehensive enough to fully appreciate the scope and scale of WWD and its impacts. Studies have typically focused on one theme or another, and did not document the statistical significance of the various driver, roadway and vehicular characteristics, nor their odds of leading to a WWD crash or a fatality. Further, none of the studies has presented the influence of these variables in causing a fatality within the WWD space. This work comprehensively compares the WWD and non-WWD crashes, and the fatal and non-fatal crashes within the WWD domain, and applies binomial regression to compute the odds of WWD incidence. A total of 999,456 complete crash records with non-missing values for the parameters were analyzed in this study. Thus, the magnitude of the dataset is immense to the extent that the results stand the significance test both quantitatively and qualitatively. The methodology presented here has approached WWD from the perspective of understanding the fundamental reasons for these incidents so that the scientist, the practitioner and the policy-maker may gain through a better understanding of the odds of a WWD and fatal WWD crash from the individual and collective influence of the studied parameters.

2. Methodology

The author's experience with leading the statewide WWD mitigation effort in Florida helped conclude that the general public and transportation professionals (TP) form strong opinions about WWD. This methodology (Fig. 1) comprised a user survey on the perceptions about WWD. The objective was to examine if a set of opinions regarding WWD resemble and contrast with actual crash analysis results. As a second step, the crash records were studied to understand the form and structure of the datasets. The data elements were then reviewed to better understand the choice of variables that need further evaluation. In Florida, during the eight-year period from 2003 to 2010, about 1.243 million crashes occurred. These data are arranged in three separate datasets, one each relating to crashes, occupants and vehicles. A comprehensive dataset was then compiled using the structured query language (SQL) procedure contained in SAS® version 9.4. The eight-year dataset was then systematically reduced to 999,456 complete crash records with non-missing values for the study parameters that are to be analyzed using the binomial logistic regression procedures contained in SAS®. The dataset was thoroughly examined for any sample bias.

The first set of the binomial regression procedures has analyzed WWD and non-WWD crashes. Each variable was individually subjected to logistic regression. Each of these variables and interactions among them were then included into a multivariable model. Stepwise regression helped extract a model with only those variables that were statistically significant at 5% level. The objective here was to determine the odds of a WWD crash for each variable. The odds of a WWD crash for the multivariable model were developed to study the impact of variables within a fitted model. This process was repeated for the WWD-only crash dataset; the analysis comprised fatal versus non-fatal WWD crashes. Thus, the odds of a fatal crash within the WWD space were computed for individual variables and for the multivariable model. Results from the two logistic regressions were then juxtaposed to draw conclusions.

Field experience, literature review, user surveys, previously conducted studies and the statewide effort in Florida provided a clear indication on the need to consider important variables such as roadway lighting and driving under the influence (DUI) of alcohol or drugs in relation to the odds of WWD. Finally, the results were discussed to gain a better understanding of WWD, and to offer decision-making support to the scientist, practitioner and the policy-maker.

3. Data analysis

3.1. User survey

Recognizing that there is a plethora of opinions on traffic engineering, operations and road safety, this work intended to explore the perceptions on WWD; therefore a ten-question survey was prepared and administered. The author is aware of those to whom requests were made but was unaware of who responded. A total of 60 responses, 30 each from the TP group and 'others' were received. Both the 'TP' and 'other' groups included driving population, all of whom were adults. While the former group exclusively included transportation professionals from a range of disciplines, i.e., traffic engineers, planners, designers, and decision-makers, the latter group included working professionals from all walks of life. Both groups were road users of all types, i.e., drivers, bicyclists, pedestrians and a few who used transit. The author requested survey responses until this reasonable sample size was obtained. Using the logistic procedure in SAS®, an analysis of variance was performed on each parameters to examine if there is a statistically significant difference in the responses of the TP group and all others. The results with percent responses to each query and the statistical significance levels are shown in Table 1.

Results indicate that those in the transportation profession and all others showed a statistically significant different response with regard to 'weather conditions'. The other attributes did not show such a statistically significant difference. That said, the response distribution is interesting. The odds ratios (OR) for each variable are shown in the Table. According to the respondents, and modeling for the responses of the TP group with reference to that of 'others', arterials were twice as likely to result in a WWD crash than do the freeways. Respondents also either did not agree or partially agreed with the involvement of DUI in WWD crashes. The likelihood of fog involvement in WWD crashes, according to the TP group, was only 8% of that of clear weather and 27% during rain. Complete dark