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Motor vehicle driver injury severity study under various traffic control at highway-rail grade crossings in the United States

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ABSTRACT

Introduction: Based on the Federal Railway Administration (FRA) database, approximately 62% of the collisions at highway-rail crossings occurred at locations with active controls (gate and flashing lights), followed by passive controls (cross bucks and stop signs) with approximately 28% of accidents. *Method:* The study applied an ordered probit model to explore the determinants of driver injury severity under various control measures at highway-rail grade crossing in the United States. *Results:* The analysis found that schedule factor (peak hour), visibility, motor vehicle speed, train speed, driver's age, area type, traffic volume and highway pavement impact driver injury severity at both active and passive highway-rail crossings. *Practical Applications:* For both active and passive control highway-rail grade crossings, speed control for both trains and vehicles will significantly reduce driver injury severity. However, the level of influence by vehicle speed and train speed at passive control is higher compared with active control. Paving highways at highway-rail grade crossings will also help to reduce driver injury severity at highway-rail crossing accidents.

1. Introduction

According to Yan, Han, Richards, and Millegan (2010), vehicle-train crash collisions are the most dangerous traffic accidents at highway-rail grade crossings because the average weight ratio of a train to a motor vehicle is about 4000 to 1. Although the annual average collision rate for highway-rail grade crossings is relatively low when compared to highway crossings, these highway-rail crossing collisions result in high fatality rates making the study of highway-rail crossing collisions critically important.

Although grade separation provides the safest solution, grade separation is not always possible due to the cost associated with this approach. Instead, the use of active and passive grade crossing devices have been used as countermeasures. Active grade crossing devices detect approaching trains by initiating sequences of flashing lights, bells, and gates. Passive grade crossings do not have devices to detect approaching trains (Millegan, Yan, Richards, & Han, 2010).

Based on the Federal Railway Administration FRA database (FRA, 2011), there were 25,945 Highway-rail crossing accidents in the United States between 2002 and 2011. As shown in Fig. 1, approximately 62% of the collisions at highway-rail crossings occurred at locations with active controls (gate and flashing lights), followed by passive controls (cross bucks and stop signs) with approximately 28% of accidents, and 10% occurred at locations with no signs. These results may indicate differences in the crash frequency for different types of traffic control at highway-rail crossings. However, the factors contributing to the higher crash frequency at active control was not the focus of this research.

1.1. Research objectives

Previous studies on crash modeling at highway-rail grade crossings were aimed at exploring the factors that are likely to increase the crash frequencies at highway-rail grade crossings. In recent years, modeling driver's injury severity at highway-rail grade crossings has received interest. Missing from these studies, however, is an understanding of the impact of control type on driver injury at highway-rail grade crossing. Using an ordered probit modeling approach, the study explores the determinants of driver injury severity under various control measures at highway-rail grade crossings in the United States. A literature review and a description of the data are provided, followed by a discussion of the model estimation results. A marginal analysis is also provided to explain the significant independent variables for each severity level.

1.2. Literature review

Previous studies have been performed examining the effects of various traffic control measures on accident frequencies at highway-rail grade crossings. Raub (2006) examined highway-rail grade crossing collisions over 10 years in seven Midwestern states to compare four

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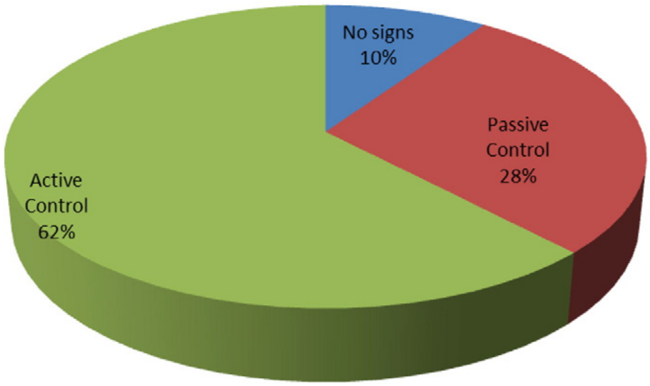

Fig. 1. Highway-rail crossing collision by control type (2002–2011).

major classes of warning devices for highway-rail grade crossings. The data covers a 10-year period from 1994 to 2003 for collisions including injuries and fatalities. The study showed: (a) gates usually had the lowest collision rates; and (b) collisions at highway-rail crossings with STOP signs were more likely to occur than with other types of warning systems. For STOP signs, drivers were found to misjudge the speed of the approaching train and therefore believed they had sufficient time to cross the intersection before the train arrived. Zwahlen and Schnell (2012) compared driver behavior at the standard crossbuck with two experimental reflectorized crossbuck systems in a before-and-after study. The study found that reflectorization increased the time between a noncompliant vehicle crossing the track and the on-coming train.

Berg, Knoblauch, and Hucke (1982) studied causal factors in highway-rail grade crossing accidents controlled by flashing lights or cross buck warning devices. A random sample of 22 flashing-light crossings in Wisconsin (with 24 accidents in 1978 and 1979) and 19 flashing-light crossings (with 19 accidents in 1978 and 1979) in North Carolina were chosen. The study found that 33% of accidents investigated were associated with driver recognition error and 53% of accidents were attributed to decision error. The most frequent recognition error was from driver's failure to detect the presence of either the signal or the train.

Meeker, Fox, and Weber (1997) provided a comparison of driver behavior at railroad grade crossings with two different protection systems. The effectiveness of a flasher-only protection system was compared to gates where flashers and barrier gates were incorporated into the crossing. The addition of the gates significantly reduced the percentage of drivers crossing in front of trains from 67% to 38%. Abraham, Datta, and Datta (1998) also examined driver behavior at highway-rail grade crossings to determine the difference between gate control and flashers. Drivers tended to commit more violations at the gated highway-rail grade crossings with more traffic control devices compared to crossings with only flashers. The likely reason for increased violations with gates was that drivers had a sense of how much time is available to violate depending on the position of the gates as a violator crossed during flashing of the lights. For locations without gates, it can be harder to determine how much time is available to violate if there is no activation of the device on approach.

Based on the above mentioned studies, there is clear evidence documenting the decreased risk of train-vehicle collision occurrence as a result of the presence of junction control measures. However, research investigating the motor vehicle driver injury severity resulting from differing highway-rail crossing control types is scant. Instead, more research has been performed studying the relationship between control type and injury severity due to highway motor vehicle crashes.

A recent study performed by Haleem and Abdel-Aty (2010) examined traffic crash injury severity at unsignalized intersections including 2,043 unsignalized intersections in Florida from 2003 to 2006. Based on this study, the probability of higher severities was found to be associated with a reduction of Average Annual Daily Traffic (AADT) and an increase of the roadway speed limit. In addition, heavily-populated and high-urbanized areas were found to have lower injury severities. The most related study looking at the relationship between traffic control at highway locations and injury severity was a study performed by Pai and Saleh (2007) where the impact of various traffic control measures on motorcyclist injury severity was determined. That study was performed using data from the UK and looked at injury as a function of demographic, vehicle, and environmental factors. Although this study did not evaluate highway-rail grade crossings, the results from this research are useful in understanding the impact of traffic control on driver injury at highway-rail grade crossing. The database used in that study was extracted accident injuries from 1999 to 2004 in the UK. Control measures were divided into three categories: (a) Stop, give-way signs or marking; (b) Uncontrolled; and (c) Signal measures. The model results suggest that the combined effect of riding in darkness and uncontrolled junctions were dangerous to motorcyclists. The study concludes that a reduction of the speed limit at unsignalized crossings would be effective in decreasing injury severity to allow more reaction time for last-minute breaking that may occur before impact.

Lee and Abdel-Aty (2005) studied vehicle-pedestrian crashes occurring at intersections from 1999 to 2002 in Florida. Using ordered probit models, the study estimated the likelihood of pedestrian injury severity when pedestrians are involved in crashes. The research found an increased likelihood of higher pedestrian injury severity at intersections without traffic control devices in urban areas. The reason given was that in the absence of traffic control, vehicle speeds were higher, which increased the collision impact if a vehicle struck a pedestrian.

Another study by Zhang, Lindsay, Clarke, Robbins, and Mao (2000) investigated factors affecting the severity of motor vehicle traffic crashes involving elderly drivers aged 65 and over between 1988 and 1993 on Ontario public roads. This study indicated that elderly drivers involved in crashes at non-controlled intersections had an increased risk of fatal outcome compared with those involved at controlled intersections.

2. Method

2.1. Ordered probit model

In this study, driver injury severity is estimated using an ordered probit model. Ordered probit models establish relationships among ranked outcomes such as injury severity. According to Zhang, Li, Liu, and Zha (2011), the general specification of the ordered probit model is given by Eq. (1):

$$y_i^* = X_i\beta + \varepsilon_i \tag{1}$$

Where, X_i is a $(K * 1)$ vector of observed non-random explanatory variables measuring the attributes of accident victim i, β is a $(K * 1)$ vector of unknown parameters and ε_i is a random error term with zero mean and unit variance for the ordered probit model. In addition, the error terms for different outcomes are assumed to be uncorrelated.

The dependent variable in this study, Y, is coded as 1, 2,…, J, defined in Eq. (2):

$$Y = \{ \begin{matrix} 1 \text{ if} -\infty \le y_i^* < \tau_1 \\ j \text{ if } \tau_{j-1} \le y_i^* < \tau_j \\ J \text{ if } \tau_{J-1} \le y_i^* < \infty \end{matrix} \tag{2}$$

Where J is the number of driver injury levels, and τ_j is the threshold value to be estimated for each level. The ordered probit model in