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Investigating risk factors of traffic casualties at private highway-railroad grade crossings in the United States

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ABSTRACT

Private highway-railroad grade crossings (HRGCs) are intersections of highways and railroads on roadways that are not maintained by a public authority. Since no public authority maintains private HRGCs, fatal and injury crashes at these locations are of concern. However, no study has been conducted at private HRGCs to identify the safety issues that might exist and how to alleviate them. This study identifies the significant predictors of traffic casualties (including both injuries and fatalities) at private HRGCs in the U.S. using six years of nationwide crashes from 2009 to 2014. Two levels of injury severity were considered, injury (including fatalities and injuries) and no injury. The study investigates multiple predictors, e.g., temporal crash characteristics, geometry, railroad, traffic, vehicle, and environment. The study applies both the mixed logit and binary logit models. The mixed logit model was found to outperform the binary logit model. The mixed logit model revealed that drivers who did not stop, railroad equipment that struck highway users, higher train speeds, non-presence of advance warning signs, concrete road surface type, and cloudy weather were associated with an increase in injuries and fatalities. For example, a one-mile-per-hour higher train speed increases the probability of fatality by 22%. On the contrary, male drivers, PM peak periods, and presence of warning devices at both approaches were associated with a fatality reduction. Potential strategies are recommended to alleviate injuries and fatalities at private HRGCs.

1. Introduction

Highway-railroad grade crossings (HRGCs) are critical locations where the railway and the roadway intersect. Two types of HRGCs typically exist, public and private HRGCs. Public HRGCs are intersections of highways and railroads on roadways that are open to the public and are maintained by a specific public authority (Federal Highway Administration "FHWA", 2015). Private HRGCs are intersections of highways and railroads on roadways that are not open to public travel or not maintained by a public authority (Peck et al., 2010). An example of a private HRGC is shown in Fig. 1 (American Trails, 2015). There are two main types of private HRGCs; active and passive crossings. Active HRGCs are those crossings with active warning devices, such as flashing lights, gates, and bells. On the other hand, passive HRGCs are those crossings without active warning devices and they include passive warning devices, such as crossbucks, yield or stop signs, and railroad crossing signs.

According to the "One Year Accident/Incident Overview – Combined" report that is maintained by the Federal Railroad Administration (FRA), there are 79,975 private crossings in the United States as of February 2016. Percentage-wise, this represents around 38% of HRGCs in the U.S. As indicated by Peck et al. (2010), approximately 400 annual incidents on average occur at private HRGCs, resulting in more than 30 fatalities per year. These fatalities at private HRGCs have exceeded the total number of on-duty deaths among railroad employees in all rail operations. Despite this unfavorable fact, safety studies at private HRGCs still lie in their infancy. Many studies have been conducted at public HRGCs (Zwahlen and Schnell, 2000; Eluru et al., 2012; Khattak, 2013; Hao and Daniel, 2013); however, private HRGCs have not received many of the public grade crossing treatments and initiatives (Peck et al., 2010). One reason is the inherent characteristics and responsibilities regarding private properties (Peck et al., 2010). Another reason might be the lack of collecting traffic predictors compared to those at public HRGCs, e.g., the annual average daily traffic (AADT).

Understanding the significant factors that affect crash injury severity at private HRGCs is an essential step toward devising

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Fig. 1. Private highway-railroad grade crossing (American Trails, 2015).

the countermeasures to reduce fatalities at these critical locations. Analyzing crash injury severity at HRGCs, as opposed to analyzing severity at traditional roadways, is a more involved procedure, mainly due to the complex interaction between highway users and the highway-railroad crossing environment. In other words, highway users are more accustomed to seeing regular intersections (either at-grade or grade-separated), but when it comes to HRGCs, their behavior varies.

To better account for this interaction complexity, the mixed logit model (also called the random parameters logit model) has been implemented in this study. The mixed logit approach can better account for the influence of the unobserved highway user behavior nearby private HRGCs by allowing the error term in the model structure to follow a random normal distribution. Previous studies have used the mixed logit model to analyze injury severity of crashes, e.g., Gkritza and Mannering (2008), Milton et al. (2008), and Kim et al. (2010). Another modeling approach that is commonly used to analyze crash injury severity has been implemented in the study, which is the binary logit model (see for example, Carson and Mannering, 2001; Sze and Wong, 2007). The objective of using more than one modeling scheme in this study is to compare the difference in the significant predictors of crash casualties (including both injuries and fatalities) at private HRGCs using an approach that accounts for the unobserved highway user behavior nearby the HRGC (i.e., the mixed logit model) with another approach that ignores this unobserved behavior (i.e., the binary logit model).

This paper aims to identify the significant predictors or risk factors of casualties at private HRGCs in the U.S. by applying the mixed logit and binary logit models while using a comprehensive list of risk factors. These include factors related to geographic crash location, temporal crash characteristics (e.g., time and season of crash), roadway, railroad, traffic, vehicle, highway user, and environment. The study uses six recent years of national crashes on private HRGCs in the U.S. from 2009 through 2014.

2. Prior research

The majority of safety studies on HRGCs were conducted at public HRGCs, whereas studies at private HRGCs are limited. One study on the safety of private HRGCs was conducted by Peck et al. (2010). The authors aimed to initiate a national discussion on safety issues at private HRGCs in the U.S. The study was intended to respond to an inquiry by FRA to determine the current practices and regulations that pertain to private HRGC safety and the best course of action to improve safety. As part of the study, several parallel tasks were conducted, which included literature reviews, surveys of state authorities, analyses of existing data, interviews with representatives from international partnering nations, public meetings, and outreach sessions. The study has identified the need of specific areas of interest regarding private HRGCs, which included identification of crossing categories, national crossing inventory requirements, signage requirements, engineering treatments, education, rights and responsibilities, and funding sources.

Other safety studies at HRGCs can be classified into crash frequency and crash injury severity categories. Studies that modeled the frequency of crashes or violations at HRGCs include Nam and Lee (2006), Millegan et al. (2009), Yan et al. (2010), Khattak and Luo (2011), Khattak et al. (2012), Hu et al. (2012), and Hu and Lin (2012). For example, Yan et al. (2010) used the hierarchical tree-based regression technique to predict train-vehicle crash frequencies at public, passive HRGCs in the U.S. They found that stop-sign treatments were effective in improving safety at HRGCs.

Studies that identified the risk factors that affect crash injury severity at HRGCs include Hu et al. (2010), Eluru et al. (2012), Khattak (2013), Hao and Daniel (2013, 2014), Fan and Haile (2014), and most recently, Zhao and Khattak (2015) and Hao and Daniel (2016). Khattak (2013) applied the ordered probit model using four years of crash data at HRGCs in the U.S. to identify the significant factors affecting pedestrian injury severity at these locations. He found that more severe injuries were associated with higher train speeds and female pedestrians. Hao and Daniel (2013) also used the ordered probit model with ten years of crash data to determine the significant factors influencing the severity of drivers at HRGCs in the U.S. They found that female and older drivers were more likely to be involved in severe injuries compared to male and younger drivers, respectively. Eluru et al. (2012) applied the latent ordered response model using ten years of crash data at HRGCs in the U.S. They found that crashes in the off-peak period, vehicles struck by train, and aggressive driver maneuvers were associated with higher severe injuries. Recently, Hao and Daniel (2014) applied an ordered probit model to explore the significant factors of driver injury severity under various control measures at HRGCs. They found that schedule factor (peak hour), visibility, motor vehicle speed, train speed, driver's age, area type, and traffic volume affected driver injury severity at both active and passive highway-rail crossings.

Apart from the ordered probit model, some studies applied the logit models. For example, Hu et al. (2010) used crash data from 1995 to 1997 in Taiwan and applied a generalized logit model to identify the significant factors affecting crash severity at Taiwan's railroad grade crossings. They found that increasing the number of daily trains and number of daily trucks was associated with a higher injury severity. Fan and Haile (2014) used eight years of crashes and developed a multinomial logit model to identify the significant variables affecting the crash injury severity at HRGCs in the U.S. The model showed that male vehicle drivers were more likely to be involved in more severe crashes. On the other hand, foggy and snowy weather conditions, and higher daily traffic volumes were more likely to result in less severe crashes.

One of the promising approaches in analyzing crash injury severity is the mixed logit model. This model allows the parameter estimates to randomly vary across the observations to yield reliable parameter estimates. The model can better account for the unobserved highway user predictors such as driver behavior at HRGCs. Applications of the mixed logit model in roadway injury severity studies have included Gkritza and Mannering (2008), Milton et al. (2008), Kim et al. (2010, 2011), Moore et al. (2011), Haleem and Gan (2013), and Islam et al. (2014). However, the application of this model in identifying injury severity predictors at HRGCs has been limited. One recent study that applied the mixed logit approach was conducted by Zhao and Khattak (2015). They identified the fac-