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A comparative study of rail-pedestrian trespassing crash injury severity between highway-rail grade crossings and non-crossings

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ABSTRACT

Rail-trespassing crashes that involve various levels of injuries to pedestrians are under-researched. Rail trespassing could occur at crossings where pedestrians are present at the wrong time and at non-crossings where pedestrians are not legally allowed to be present. This paper presents a comparative study examining rail-trespassing crashes in two contexts: highway-rail grade crossings vs. non-crossings. How pre-crash trespassing behaviors and other factors (e.g., crash time, locations, and socio-demographics) differ between grade crossings and non-crossings are explored. The analysis relies on a ten-year (2006–2015) database of rail-pedestrian trespassing crash records extracted from a Federal Railroad Administration safety database. Of these 7157 rail-pedestrian trespassing crashes, 6236 (87%) occurred at non-crossings, while 921 (13%) occurred at grade crossings. About 60% of the crashes were fatal at both crossings and non-crossings. The most prevalent pre-crash trespassing behavior is running or walking, 63% at grade crossings and 44% at non-crossings. Lying or sleeping account for 29% of non-crossing crashes, whereas they are 3.6% at grade crossings. A unique aspect of the study is that a diverse set of variables based on geographic variations across counties along with crash or injury data are modeled. Considering the data structure and heterogeneity that may exist due to unobserved factors, the multilevel mixed-effect ordered logistic regressions models are estimated. The results show that the correlates of injury severity differ across highway-rail grade crossings and non-crossings. For example, lying or sleeping on or near tracks contributed to higher chances of fatal injury in both contexts, however, they were relatively more injurious at grade crossings. The analytical results can provide guidance on railway safety improvement plans.

1. Introduction

The safety of rail transportation remains a societal concern. Crashes between trains and motor vehicles, especially at highway-rail grade crossings, are extensively scrutinized by researchers, highway and railway practitioners (Oh et al., 2006, Hu et al., 2010, Russo, 2013, Hao and Daniel, 2014, Liu et al., 2015a, Liu et al., 2015b, Zhao and Khattak, 2015). Though train-involved crashes with non-motorists, e.g., pedestrians, are relatively under-discussed, such crashes constitute a sizable portion of fatalities and injuries in rail-related crashes (Pelletier, 1997, Silla and Luoma, 2012, FRA, 2015). Most of these involved pedestrians were reported as trespassers, as they are not authorized to be present on railroad property used for operations and whose presence is prohibited and unlawful. In 2015, pedestrians trespassing on rail properties resulted in more than 450 fatalities and 300 injuries (FRA, 2015). These crashes annually produce billions of dollars in personal and societal costs (Trottenberg and Rivkin, 2013). According to the Federal Railroad Administration (FRA) statistics, pedestrian trespassing related fatalities and injuries have continued to rise in recent years (FRA, 2015). With increasing exposure of trespassers and train activities, rail crashes with pedestrian trespassers will remain a critical concern.

The FRA defines trespassers as individuals who should not be present on the railway right-of-way. Based on crash location, this study separates trespassers into two groups: trespassers at highway-rail grade crossings and non-crossings (on or along the railway track). Note, normally a person at highway-rail grade crossing would not be recognized as a trespasser unless the person goes around or through crossings with physical barriers, e.g., when gates are down. Thus, a person or vehicle deliberately ignoring the barrier in an attempt to cross will be coded as a trespasser (FRA, 2011). Most trespassers are

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pedestrians, but some are individuals who are driving or riding a bicycle, an all-terrain vehicle (ATV), snowmobile, etc. (George, 2008). Motorized trespassers and non-motorized trespassers should be treated separately owing to the differences in speed and other characteristics. This study focuses only on non-motorized trespassers, i.e., pedestrians. In addition, railroad employees who are on duty are excluded, as they are railway workers whose presence are lawful and will not be reported as trespassers in crash reports.

The key question to be answered in this study is how pre-crash behaviors and other correlates (e.g., crash time, locations, and socio-demographics) of rail-pedestrian trespassing crash injury severity vary between highway-rail grade crossings and non-crossings. Notably, exploring similarities and differences in these two contexts with regards to risk factors may point to different countermeasures for these two contexts. To the best of our knowledge, studies have dealt with rail-trespassing crash frequency (Lobb et al., 2001, Silla and Luoma, 2012). However, injury severity in rail-trespassing crashes remains under-researched. Injury severity is a critical aspect of railway safety-improvement projects. A frequency-dominant method may tend to benefit locations with more but less severe crashes. Railway safety-improvement strategies can be more effective if correlates of severe crashes are revealed. Furthermore, non-crossing crashes are relatively under-researched. While efforts to improve prediction models at highway-rail grade crossings are underway (Lu and Tolliver, 2016), this study offers insights on risk factors and points to potential safety improvements at non-crossings. Crashes at crossings and non-crossings can be different in many respects, e.g., correlations with environmental factors, pedestrian attitudes/behaviors, and railroad safety controls can vary, which has not been fully explored. Therefore, this study aims to compare and quantify these risk factors related to rail-pedestrian trespassing in these two contexts.

In summary, the objective of this study is to understand different patterns of injury severity and correlates of injury severity with pre-crash behaviors as well as other factors (e.g., timing and location) between two different railway contexts: grade crossings and non-crossings. Instead of suggesting similar improvements for both contexts, relevant strategies can be made customized to grade crossings or non-crossings. The analysis involves estimation of injury severity models together and separately for highway-rail grade crossings and non-crossings.

2. Literature review

Previous studies investigated crashes between trains and pedestrians or cyclists from various aspects (Khattak and Luo, 2011, Metaxatos and Sriraj, 2013, Gabree et al., 2014, Ghomi et al., 2016, Guadamuz-Flores and Aguero-Valverde, 2017). Examining trespassing motivations enhanced the understanding of trespassers' original intentions. Studies have shown various types of trespassing motivations (Pelletier, 1997, Lobb et al., 2001, Savage, 2007). Choosing a shorter or more convenient path to a destination was a common motive for trespassers (Lobb et al., 2001, Board 2007). Some studies reported suicide as a motive for trespassing. According to a European report, more than 3000 people were killed in train crashes yearly due to suicides or trespassing (Burkhardt et al., 2014). However, the determination of whether a fatality is suicide or an (un-intentional) accident was always questioned due to inadequate information (Mishara, 2007). In addition to inadequate information, the social, legal, financial, and ethical implications also lead to the difficulty in identifying rail suicide as a cause of fatality (Lobb, 2006). Nonetheless, about 20% to 27% of deaths were recorded as suicides (Gabree et al., 2014, George, 2008). Although the Rail Safety Improvement Act of 2008 (RSIA) requires information about suicides to be collected, such information is not available included in individual crash reports that are used in this study. However, the suicide information is publicly available in an aggregate format on FRA's website (FRA, 2011).

The literature on rail-related crashes also highlighted other associated factors, including personal or environmental characteristics, timing and location attributes, trespassers' behaviors (pre-crash behaviors), and countermeasures implemented to prevent trespassing events (Cina et al., 1994, Pelletier, 1997, Silla and Luoma, 2012).

2.1. Rail-pedestrian crash analysis

Previous studies investigated trespasser socio-demographic characteristics extensively. Individuals belonging to a specific social group, e.g., young males, intoxicated with alcohol, may be frequently involved in rail-pedestrian fatality crashes. Youths and seniors would seem to be more vulnerable as trespassers, though few rail crashes included youths under 10 years old and seniors over 60 years old (Pelletier, 1997, Silla and Luoma, 2012). Nixon et al. illustrated that young person involved in rail crashes were associated with risk-taking and daring behavior (Nixon et al., 1985). Most fatalities in rail-pedestrian crashes were young males (Cina et al., 1994, Pelletier, 1997, Silla and Luoma, 2012, George 2008). Compared to females and seniors, young males tended to lack awareness of dangers for a specific traffic situation (Lobb et al., 2001). Pelletier reported that trespassing fatalities typically involved individuals who were unmarried males without high school education (Pelletier, 1997). Also, individuals who were under the influence of alcohol or drugs were more likely to be struck by a train (Silla and Luoma, 2009, George, 2008).

Previous studies have explored the timing and location of rail-pedestrian crashes; for example, fatal crashes frequently occurred from March to August (Pelletier, 1997). Rail-pedestrian crashes have shown temporal clustering. They occur regularly at the end of a week (from Friday to Sunday) and during rush hours (Silla and Luoma, 2012). Lerer and Matzopoulos noticed that rail injuries commonly occurred during peak commuting times in the city of Cape Town, South Africa (Lerer and Matzopoulos, 1996). As for geographic clustering, many trespasser fatalities tended to be specific to locations, such as densely populated areas and rail yards (Matzopoulos and Lerer, 1998, Silla and Luoma, 2009, 2012. Geographically Weighted Logistic Regression (GWRL) models were estimated to investigate the spatial patterns of rail non-crossing trespassing crashes across the United States (Wang et al., 2016). However, little information is available about how patterns of rail-trespasser crashes differ between grade crossings and non-crossings. This study investigates injury severity levels of rail-trespasser crashes given a crash, focusing on the role of pre-crash behaviors at grade crossings vs. non-crossings.

Trespassers' pre-crash behaviors were found to be highly associated with the consequences of train crashes. Lying or walking on the railroad track was common precursor behaviors (Patterson and Authority, 2004, Savage, 2007). Several studies showed that most fatal train crashes happened when individuals were walking, sitting, or lying on or near to the railroad tracks (Cina et al., 1994, Lerer and Matzopoulos, 1996, Pelletier 1997). Information on pre-crash behavior helped address reasons of trespassing crashes, such as committing suicide (Savage, 2007, Silla and Luoma, 2012). A retrospective analysis of suicidal behavior (jumping, lying, and wandering) revealed that higher fatality rates occurred when the victim was lying but lower fatality rates when jumping. A text mining method was used to extract additional information, e.g., wearing headphone or talking on a cell, from rail-trespassing crash narrative reports (Wali et al., 2018). The results indicated that trespassers who are wearing headphone or talking on a cell are more likely to sustain fatal injuries.

2.2. Rail-related injury severity

Injury severity is another concern in rail-trespasser crashes. Published research on rail-related crash injury severity largely relates to drivers or pedestrians at grade crossing (Fan et al., 2015, Liu et al., 2015b, Zhao and Khattak, 2015, Liu et al., 2016b, Liu and Khattak,