Drivers' Perceptions of Highway-Rail Grade Crossing Safety and Their Behavior

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16. Abstract

This project investigated motor vehicle drivers' characteristics, their perceptions of safety at crossings, understanding and comprehension of traffic signs/signals at crossings, and their self-reported unsafe maneuvers at HRGCs in many cities of Nebraska. A three-stage mail contact survey design was used, including an initial mail notification, a survey questionnaire mailing, and a postcard reminder about mailing back the completed questionnaire, to solicit responses from a sample of motor vehicle drivers in Nebraska. Analysis of the survey responses showed that drivers generally had good knowledge of safely driving at HRGCs. However, some drivers lacked knowledge of certain safety aspects, such as violations under ascending gates, proper actions when emergencies occur, and correct comprehension of some traffic signs at HRGCs. Drivers' level of knowledge was associated with factors such as outreach of safety education programs, frequency of using HRGCs, years of driving experience, and the drivers' education levels. This research also found that drivers with negative/indifferent attitude towards safety at HRGCs, relatively less knowledge of driving at HRGCs, higher education levels, higher income levels, frequent users of HRGCs and younger and female drivers were more likely to involve themselves in inattentive driving at HRGCs. Therefore, future educational programs advocating attentive driving could be targeted to these groups of drivers.

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Executive Summary

The focus of this project was to investigate motor vehicle drivers' perceptions of safety and their behaviors at highway-rail grade crossings (HRGCs) to obtain insights for improving safety at these locations. During 2012, the Federal Railroad Administration (FRA) reported 1,970 crashes at HRGCs in the U.S. that involved 272 fatalities and 951 injuries. Therefore, there is a need for improving public safety at HRGCs.

Motor vehicle drivers are expected to yield the right-of-way to oncoming trains since trains cannot stop on short notice. Therefore, almost all train-motor vehicle crashes at HRGCs are due to encroachments by motor vehicle drivers. Such crashes are due to a variety of reasons on part of motor vehicle drivers including misunderstandings of train warning signs, aggressive/distracted driving, or willful neglect of crossing signs, signals, and gates. However, drivers' perceptions of safety at HRGCs and behaviors are not well-understood and there is a need for obtaining insights into their behaviors at HRGCs.

In this project, the researchers investigated motor vehicle drivers' characteristics, their perceptions of safety at crossings, understanding and comprehension of traffic signs/signals at crossings, and their self-reported unsafe maneuvers at HRGCs in different Nebraska cities. A three-stage mail contact survey design was used that included an initial mail notification to households in Nebraska, a survey questionnaire mailing, and a postcard reminder about mailing back the completed questionnaire. The researchers analyzed collected survey data using statistical summaries and models and revealed drivers' characteristics involved in unsafe maneuvers at HRGCs. The study found that drivers generally had good knowledge of safely driving negotiating HRGCs. However, some drivers lacked knowledge of certain safety aspects, such as violations under ascending gates, proper actions when emergencies occur, and the correct interpretation of some traffic signs at HRGCs. Drivers' levels of knowledge was associated with factors such as outreach of safety education programs, frequency of using HRGCs, years of driving experience and the drivers' education levels. The research also found that drivers with negative/indifferent attitude towards safety at HRGCs, less knowledge of driving at HRGCs, higher education levels, higher income, frequent users of HRGCs and younger and female drivers were more likely to involve themselves in inattentive driving at HRGCs. Therefore, future educational programs advocating attentive driving could be targeted to these groups of drivers.

Chapter 1 Introduction

1.1 Problem Statement

Motor vehicle crashes with trains at highway-rail grade crossings (HRGCs) remains a concern as each year hundreds of fatalities and injuries are reported across the U.S. Motor vehicle drivers are expected to yield the right-of-way to oncoming trains since trains have no realistic way to stop on short notice. Therefore, almost all train-motor vehicle crashes at HRGCs are due to encroachments by motor vehicle drivers. These crashes are due to a variety of reasons on part of motor vehicle drivers including misunderstandings of train warning signs, aggressive/distracted driving, or willful neglect of crossing signs, signals, and gates. However, drivers' perceptions of safety at these locations and their behaviors are not well-understood, and there is a need for obtaining insights into their behavior at HRGCs.

1.2 Research Objectives and Hypotheses

The objectives of this research were first to report driver's perceptions of safety at highway-rail grade crossing in Nebraska, their unsafe inattentive driving behaviors, and their knowledge of safely negotiating at HRGCs, and then to identify potential factors that affect drivers' knowledge as well as inattentive driving behaviors at HRGCs.

As part of the research, data were collected through a three-stage mail survey that was conducted in Nebraska. Using the collected data, the researchers were interested in testing the following hypotheses presented in Table 1.1.

Table 1.1 Research Hypotheses

Number	Hypotheses Description
1	Drivers' knowledge of HRGCs increases with driving experience.
2	Drivers' knowledge of HRGCs increases with educational level.
3	Drivers' knowledge HRGCs increases with usage of HRGCs.
4	Drivers' knowledge of HRGCs increases with attitudes towards safety at HRGCs.
5	Drivers' knowledge of HRGCs increases with exposure to HRGC safety programs.
6	Drivers' knowledge of HRGCs may be also related to gender, income, age, attitudes towards local HRGCs, etc.
7	Drivers' involvement of inattentive driving increases with the intent of violations at HRGCs.
8	Drivers' involvement of inattentive driving decreases with age.
9	Drivers' involvement of inattentive driving increases with familiarity with HRGCs.
10	Drivers' involvement of inattentive driving decreases with knowledge at HRGCs.
11	Drivers' involvement of inattentive driving decreases with attitudes towards safety at HRGCs.
12	Drivers' involvement of inattentive driving may be also related to gender, income, education level, income, etc.

1.3 Research Approach

The research approach consisted of conducting a survey of motorists in Nebraska to collect data on motor vehicle drivers' perceptions of HRGC safety and their behaviors when crossing train tracks. A three-stage mail contact survey design was used including an initial mail invitation, a postcard reminder, and one subsequent mail invitation to solicit responses from a sample of drivers in many cities in Nebraska. In this project, the researchers investigated motor vehicle drivers' characteristics, their perceptions of safety at crossings, understanding and comprehension of traffic signs/signals at crossings, and their self-reported unsafe maneuvers at HRGCs in Nebraska. The collected data were analyzed to obtain insights into drivers' perceptions and their reported behaviors.

Task 1: Survey design

During this task the survey data collection instrument was designed consisting of a questionnaire with an appropriate coding scheme. The survey instrument was submitted for the approval of UNL's Institutional Review Board (IBR). The UNL Bureau of Sociological Research helped with the IRB approval.

Task 2: Survey administration

This task consisted of mailing the survey to residents of many cities to sample drivers in Nebraska. The planned number of mailings was 2,000 addressees, and a response rate of 20% was expected to generate around 400 completed surveys. A three-stage mail contact was used including an initial mail invitation, a postcard reminder and one subsequent mail invitation. Each mail invitation included a letter explaining the survey, the questionnaire, and a business reply envelope for the questionnaire to be mailed back to UNL. The BOSR prepared for and completed all data entry of completed questionnaires and provided the data file to the project PI.

Task 3: Analysis of collected data

The research team analyzed the collected data to obtain insights into the respondents' perceptions of safety at highway-rail grade crossings and their self-reported behaviors at such locations.

Task 4: Safety implications and final report

In the last task, the research team assessed safety implications for improving safety, and recommendations were prepared for improving public safety at highway-rail grade crossings. A final report that documented the research was submitted to the Railway Safety Center.

1.4 Research Assumptions

This research firstly assumed that safety at HRGCs was closely associated with driver perceptions, knowledge and behaviors at such locations. Although inattentive driving does not necessarily cause crashes at HRGCs, it is an indicator of hazards at HRGCs. Therefore, understanding driver behaviors and influencing factors is very important to improve HRGC safety.

The second assumption is that drivers' perceptions of safety, knowledge of HRGCs, attitudes towards issues at HRGCs and inattentive driving behaviors all can be quantified and measured through certain questions. The reliability of this assumption was guaranteed by carefully designing the survey instrument and conducting the survey process.

The third assumption of this research is that drivers have different levels of knowledge at HRGCs and the knowledge is associated with many driver-specific factors and thus education programs at HRGCs should be targeted to those groups of people with low knowledge of safely driving at HRGCs.

1.5 Report Organization

The report consists of this introductory chapter (Chapter 1), followed by a review of previously published literature (Chapter 2). Design of the survey and data collection process are introduced in Chapter 3. Analysis of the collected data is presented in Chapter 4. Chapter 5 summarizes the research findings and proposed recommendations for future educational programs at HRGCs. A reference list completes the report.

Chapter 2 Literature Review

This chapter includes a literature review of driver behavior studies at highway-rail grade crossings (HRGCs). Emphases were put on the reasons people violate rules at HRGCs and on the inattentive behaviors of drivers at these locations.

2.1 General Statistics

In accidents reported at HRGCs, highway users are usually at fault because trains have the right of way. In 2004, about 94% of the motor vehicle accidents reported at rail crossings were associated with motor vehicle drivers' risky behaviors or poor judgements (Ngamdung and DaSilva, 2012a; U.S. DOT of Inspector General, 2004). In 2005, 82% of the U.S. rail crossing accidents were attributed to highway users, while motor vehicle driver inattentiveness attributed to 41% of all the reported accidents (Federal Railroad Administration, 2005; Searle et al., 2011). Many times highway user behaviors at rail crossings are different from those at other road locations: they may seek excitement in passing around gates before the arrival of a train, display lack of patience, or display low expectations of train encounters, misjudge train speed, or otherwise underestimate the risks of non-compliance at rail crossings.

2.2 Behaviors at Different Rail Crossings

Freeman et al. (2013) found greater HRGC accident frequency at passive crossings than active crossings. Berg et al. (1982) examined contributing factors of rail crossing crashes at flashing light and crossbuck crossings. A total of 79 train-vehicle accidents were reconstructed and analyzed for patterns of motor vehicle driver errors and other factors. They reported that the credibility of the warning devices was an important issue at crossings equipped with flashing lights. While at crossings equipped with crossbuck signs, the principle contributing factors was drivers' failure to detect a crossing or an approaching train, which they attributed to possible drivers' low expectancy of hazards, inadequate sight distances, or inattentive driving.

Yeh and Multer (2008) also emphasized credibility of warning devices and the conspicuity of the crossings. They concluded that noncompliance at crossings equipped with active warning devices was quite often, which may be caused by drivers' failure to detect the crossing or an approaching train. According to their study, the situation may be improved by installing barriers or four-quadrant gates to increase the level of protection, or by improving the credibility of the warning devices.

Åberg (1988) conducted an observational study of 2,000 drivers at 16 rail crossings with drivers' head movements as the major variable of interest. Results showed that many drivers turned their heads to look for trains, even at crossings equipped with flashing lights. But fewer drivers looked when their sights were restricted and when significant efforts were needed. Drivers' previous experience of trains at crossings affected their motivation to acquire information at the crossing, and the impulse to look for trains increased as the number of trains at the crossing increased.

The impact of stop signs at rail crossings is controversial (Yeh and Multer, 2008). Compliance with stop signs at passive rail crossings is relatively low, and this noncompliance can potentially increase drivers' disrespect of stops signs at other locations (e.g., roadway intersections). The Federal Highway Administration (FHWA) recommends the use of a yield sign as the default traffic control at passive rail crossings while the use of stop sign is limited to unusual situations and subject to engineering studies. Lenné et al. (2011) conducted a driving simulator study and compared driver behaviors at rail crossings with different warning devices such as flashing red lights, traffic signals and stop-signs. They found that vehicle speed reduced more rapidly in response to flashing lights than to traffic signals. Stop-sign crossings had the lowest speed but also had the highest number of noncompliance.

2.3 Roots of Noncompliance

Highway user noncompliance behaviors at HRGCs can have a variety of reasons, such as restricted sights of crossings or trains, highway user's distraction and inattention, lack of knowledge, inaccurate risk perception, deliberate risk-taking behaviors, etc. (Searle et al., 2011). Except in rare cases when there are problems with the rail crossing design or warning devices are malfunctioning, most of the noncompliance is on behalf of highway users (Ngamdung and DaSilva, 2012b). The noncompliance is either deliberate or by mistake (Freeman and Rakotonirainy, 2015). It is not uncommon that drivers may not be familiar with rail crossing safety. Drivers generally can recognize the advanced warning and crossbuck sings but some did not fully understand the signs in relation to crossings and what actions were required (Yeh and Multer, 2008).

Through a survey that investigated the origin of pedestrians' rule violation behaviors at railroad crossings in Australia, Freeman and Rakotonirainy (2015) reported that pedestrians were more likely to deliberately violate rules rather than make errors. In their study, 24.52% of the participants reported having intentional violations, and only 3.46% of the participants had made errors at a crossing. And the most commonly indicated reason for those deliberate violations was being in a hurry. Males, minors (<18 years), frequent users, and people seeking higher sensations are more inclined to make deliberate violations. Similar results were found by Edquist et al. (2011), who did a literature review and conducted field observations in Australia. They concluded that typical non-compliant crossers are adult, male, crossing alone and in a hurry. Those non-compliances were mostly deliberate. Distraction was not found to be a common reason for crossing pedestrians. Based on the findings, the authors recommended improving warnings and physical barriers and designing good education and enforcement campaigns other than changing the crossing layout. Therefore, deliberate pedestrian violations can be largely prevented.

Motor vehicle drivers, on the other hand, were generally considered more likely to get involved in railroad crossing violations as a result of judgment errors or failure to detect the crossing or the train (Freeman and Rakotonirainy, 2015). By analyzing data from detailed police reports at rail crossings in Victoria, Wigglesworth (2001) concluded that the majority of accidents were due to driver distraction, inattention, and cognitive overload rather than deliberate violations.

Many studies differentiated intentional and unintentional violations at railroad crossings (Salmon et al., 2013a, 2013b). Intentional violations at rail crossings may result from sensation seeking or risk taking behaviors (Witte and Donohue, 2000), low perceptions of risks (Davey et al., 2008), being in a hurry (Freeman and Rakotonirainy, 2015), etc. Unintentional violations are due to drivers' failure to detect the train, crossing, or signals, misunderstanding the meaning of signals and proper actions to take, etc. Unintentional violations account for about half of all crashes at rail crossings in Australia (Young et al., 2015). Motor vehicle driver inattention and low awareness of risks are potential key factors leading to unintentional violations (Caird et al., 2002; Freeman and Rakotonirainy, 2015; Salmon et al., 2013b; Young et al., 2015).

Driving skill and driving style are two driver aspects that explain drivers' behaviors at rail crossings (Yeh and Multer, 2008). Driving skill is the ability of conducting correct and safe driving. It may be affected by age, experience, or distractions. Driving style is more about a driver's decision: how s/he perceives the danger at a rail crossing and whether s/he decides to comply or not. Driving skill may be related to unintentional violations while a risky driving style can lead to intentional noncompliance. Yeh and Multer (2008) concluded that alcohol and drug uses, fatigue, and distraction decrease a drivers' driving skill. Drivers' expectations, gender, and age affect their driving styles. Drivers tend to underestimate the dangers at rail crossings, do not expect to encounter a train, and sometimes do not even look for a train. Those who were familiar with the crossings were more likely to get involved in an accident. Male and young drivers were found more aggressive in driving styles.

Driver age and vehicle type may play a role in explaining the differences in the type of noncompliance as well. Old people may suffer from the degeneration of critical judgment abilities while young drivers may have extra risks of seeking sensations. Wallace (2008) investigated motorist behaviors at rail grade crossings and the effectiveness of educational interventions for improving safety. The investigation included three studies. The first study identified three user groups with the highest risks -- older, younger, and heavy vehicle drivers. Each of the three groups has unique problems: older drivers suffer from problems associated with judgment errors; risk taking is a major problem for younger drivers; and for heavy vehicle drivers, intentional risk taking and the length of heavy vehicles are major concerns. The second study examined the characteristics of each risk group. The third study developed interventions specifically targeted to each group, investigated the present context of unsafe driving behaviors at rail crossings and piloted a safety radio advertisement as an intervention method. The main methods of data collection in Wallace's study were expert and train driver panels, focus group discussions, and non-sampling interviews.

2.4 Driver Inattention and Distraction

Much research has addressed this topic in general highway settings but research regarding the contribution of these factors to rail crossings were limited (Yeh and Multer, 2008). Although some research on highway-rail grade crossing had studied distracted driving behaviors (Ngamdung and DaSilva, 2012a, 2012b), the reason why drivers divert their attention from safe driving and looking for a train and the direct influences of these inattentive actions on noncompliance and crashes are not clear.

Research has been conducted on distracted driving behaviors at rail crossings using data collected through naturalistic driving studies. The U. S. DOT FRA conducted a research on driver behaviors at or on approach to HRGCs and aimed at identifying potential driver education/awareness strategies that would best mitigate risky driver behavior at these locations (Ngamdung and DaSilva, 2012a, 2012b). A total of 4,215 grade crossing events involving light vehicle drivers and a total of 3,171 involving heavy vehicle drivers were collected from a field operational test of vehicle safety systems. A set of information including drivers' activities, driver and vehicle performances, driving environments, and vehicle locations at the crossings were collected. The study found that on average light vehicle and heavy vehicle drivers engaged in secondary tasks 46.7% and 21% of the driving time, respectively. The most common secondary tasks conducted by light vehicle drivers were talking to or looking at passengers (15.5%) and talking on or listening to cellphones (6.6%). As to heavy vehicle drivers, the most common distractors were talking on or listening to cellphones (6.5%) and smoking or lighting cigarettes (4.9%). The studies also looked into drivers' looking behaviors and found that on approach to passive rail crossings, 35% of the light vehicle drivers failed to look either left or right to look for a train, and the percentage among heavy vehicle drivers was 41%. At active crossings, 68.8% of the light vehicle drivers and 39.3% of the heavy vehicle drivers kept looking straight.

In the National Rail Level Crossing study undertaken by Roy Morgan Research in Australia, a survey of 4,402 participants revealed that 25% of people had engaged in risky behaviors at rail crossings; 22% did not notice a rail crossing until they had driven through it. Driver inattentiveness and impatience were identified as the most significant risk factors (Searle et al., 2011).

Distraction can directly lead to rail crossing accidents. At passive crossings where there are low train and highway traffic, motorists can easily fall inattentive and fail to notice a crossing or an approaching train (Edquist et al., 2009; Searle et al., 2011). The National Transportation Safety Board (1998) investigated 60 accident cases at passive grade crossings. Of these cases, driver distraction was cited as a primary cause in 10 cases and was cited as a contributing factor in another two cases. This accounted for 20% of all cases investigated. Driver inattention caused by drug impairment, as stated in this study, was considered as a primary cause for four of the 60 accident cases. As to distraction sources, stereo systems and passengers were the frequently mentioned in-vehicle distractions; highway traffic was the external distraction most frequently cited. A nearby highway intersection can also be a source for distraction, especially at passive grade crossings.

Caird et al. (2002) developed a taxonomy of factors that contributed to the highway-railway grade crossing accidents which included unsafe actions such as distraction and risk taking behaviors, low train visibility, etc. The analysis of accident narratives additionally revealed that intentional risk actions and distraction were accident contributors. In the 3,990 accident narratives that were queried, 86 of them indicated intentional actions as a contributing factor and 39 of them found driver distraction was a contributing factor. Of those 39 cases, 12 completely failed to detect the train or signal and 10 did not see the train until it was too late. As to the distraction causes, seven of the drivers were using a cellular phone, four involved internal distraction such as cognitive processes, three were interacting/talking with passengers, three were distracted by outside objectives, and one was adjusting in-vehicle equipment. But since it is unclear how many of the 3,990 narratives were effective in terms of completeness and usefulness, it is difficult to determine the percentage of distraction-involved accidents out of all the accident records.

Driver inattention can also be a result of drivers' low expectance of a train. Drivers seem to underestimate the number of train through movements at a crossing (National Transportation Safety Board, 1998). All 18 drivers interviewed in this study underestimated the frequency of train crossings per day; the actual train crossings are typically two to three times as many as drivers expected and sometimes are 10 times more than expected. This low expectancy gets reinforced each time a driver passes the crossing without seeing a train and, as a result, can probably relax a driver's vigilance in searching for trains.

Different from at ordinary highway locations, other traffic outside of the vehicle or highway signals can easily become a distraction to the driver at a rail crossing and makes him/her unable to detect an approaching train (National Transportation Safety Board, 1998). Young et al. (Young et al., 2015) examined driver attention on approach to urban railroad crossings by using on-board monitoring equipment. They found rail crossings were not the key focus of drivers' attention; drivers were over-dependent on warning signals and surrounding vehicles' behaviors to alert them to the presence of crossings and trains rather than relying on their own scanning activities and judgment. Behaviors were also found different between experienced drivers and novice drivers. Even a train itself can become a distraction to roadway users because the users may simply have their attention focused on one approaching or stationary train while a second train is coming from another track (Caird et al., 2002; Wallace, 2008). This can occur at active crossings where highway users may think the activation is only due to the first train. Mental inattention, which means the driver is not distracted by an obvious outside or inside object or event, can also be detrimental and sometimes results in drivers' "looking but not seeing" (Salmon et al., 2013b).

2.5 Method and Data

The naturalistic driving study is one of the most effective methods to investigate driver behaviors such as inattention. The Second Strategic Highway Research Program (SHRP2) is to date the largest and most comprehensive naturalistic driving database that contains information on driver pre-crash and pre-near-crash behaviors. The database has 3,900 vehicle-years and 12,500 roadway centerline miles. A previous well-known naturalistic study is the 100-Car naturalistic driving study, the data for which was collected in North Virginia with 100 vehicles in one year. Advantages of using naturalistic driving data to study driver inattention behaviors include allowing researchers to directly observe the subjects in a natural setting, to see exactly what drivers were doing (any distraction or inattention) before crashes or near-crashes, etc. But there are some disadvantages, too. Data collection through instrumented vehicles is costly; participates are usually not randomly chosen but voluntary; people may behave differently when they know they are being watched; different observers may draw different conclusions from the same witnessed behaviors, etc. Also, due to the limited number of crashes observed in naturalist data, it is difficult to use naturalistic data to investigate the association between injury severity and inattentive driving behaviors. The studies of driver behaviors at highway-rail grade crossings using field observational test data for light and heavy vehicles are naturalistic studies (Ngamdung and DaSilva, 2012a, 2012b). As mentioned earlier, these studies found that vehicle drivers engaged in secondary tasks 21% - 46.7% of the time when driving at highway-rail grade crossings.

The fixed-site observational data collection method is used to observe driver behaviors at selected rail crossings. It can be used either for direct observation (Åberg, 1988) or video-based observations (Khattak and Luo, 2011; Khattak et al., 2012; Ko et al., 2003; Tung, 2014). Fixed-site observation usually can collect data such as driver distraction behaviors, head movements, drivers' looking behaviors, the presence of passengers in the vehicle, etc. Compared to naturalistic data, fixed-site observational data is confined to a "fixed-site" and the accuracy of the observations or the resolution of cameras, and cannot provide as much detailed information as naturalistic data. But fixed-site data collection is much less costly and more feasible, can be exactly pertaining to driver behaviors at highway-rail grade crossings, can have a good sample size, normally does not influence drivers, and has a better control of location selection.

Crash reports are also used to investigate driver behaviors such as distractions. NHTSA (2010) currently has three major sources of data to assess the effects of distraction. The first is the Fatality Analysis Reporting System (FARS) that contains fatal crash data. The second is the National Automotive Sampling Systems (NASS) General Estimate System (GES) that provides a sample of all police-reported crashes of varying severities. Crash data showed that 17% of all police-reported crashes in 2010 involved some distraction (NHTSA, 2013). The third data source of NHTSA is the National Motor Vehicle Crash Causation Survey (NMVCCS, available at http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx), which is a national representative database that contains in-depth investigations of 6,949 crashes that occurred between 2005 and 2007. This data indicated that 11% of the crashes involved in-vehicle distraction as a primary reason. The first two data sources are all based in police accident reports. One potential problem of using this type of crash data to evaluate the role of distraction is that there is a wide range of variability in the data because of the collection and reporting differences from different states. Driver inattention may be underestimated among these police-reported crashes (Abay, 2015; David M. Neyens and Boyle, 2008), especially in fatal crashes. People may not always honestly report their actual behaviors (such as distracted by a cellphone) or psychology at the time of the accident (Salmon et al., 2013b), and this can lead to significant bias in evaluating the impact of inattentive driving on injury severities. There is a consensus that underestimation exists in police-reported data but there are few detailed analyses of how biased those reports are. But on the other hand, police-reported crash data is often the only source of accurate and comprehensive crash data. In traffic accident studies, for example those focused on injury severities at rail crossings, police-reported data is the only available source that is comprehensive enough to include decent sample sizes for every injury level.

Questionnaire surveys or focus group interviews are another way that can be used to collect information of driving behaviors at rail crossings. Davey et al. (2008) made semi-structured focused group interviews to 53 young drivers from regional and metropolitan settings. Motorists' self-reported behaviors, attitudes, and knowledge at highway-rail grade crossings were explored. Freeman and Rakotonirainy (2015) conducted a survey on pedestrians using rail crossings and examined the origins of pedestrians rule breaking behaviors. Roy Morgan Research (2008) surveyed 4,402 drivers and identified the significant role of inattentiveness in increasing rail crossing risks. A survey of 891 randomly selected residents in Michigan was conducted by Witte and Donohue (2000), who found that males with strong sensation seeking tendencies are risk takers at rail crossings. Overall, many studies had conducted surveys or interviews that investigated highway users' knowledge, risk-taking attitudes, behaviors at rail crossings, but surveys especially focusing on driver inattention and distraction were rare to see.

Besides discussions on varied data sources, researchers also paid attention to the improvement of analysis methods. Read et al. (Read et al., 2013) indicated that current studies of user behaviors at railway crossings are mostly from an individual perspective instead of a systemic perspective. They advocated the systems approach and discussed the key concepts and criteria for this approach. Previous research that focused on individuals usually only considered one user group, no or limited relations between components of the system, established uni-directional cause and effect relationships, etc. A systems approach, on the contrary, treats safety as an emergent property, considers the variability of the system and the performance of all components, and notes the system is dynamic and has a hierarchical structure. Salmon et al. (2013b) used a system analysis framework, and an individual psychological schema theory explained an accident between a semi-trailer truck and a passenger train. In that accident, the truck driver refused to be interviewed by the investigators for the reason that he did not react properly to the crossing warning devices. The authors utilized other information obtained from the Office of Chief Investigator (OCI) investigation report and selected court transcripts and concluded that the primary cause of the accident was that the driver looked but failed to see. This was an application of Accimap.

A review of previous studies found that researchers have been focused on driver behaviors and sometimes at HRGCs but drivers' knowledge of correctly maneuvering at HRGCs, their perceptions and attitudes toward safety at these locations, their exposure of safety educational programs, their inattentive driving behaviors, crash history, and the association between all these have not been widely discussed. A survey questionnaire that asks motor vehicle drivers' inattentive driving experiences, knowledge, attitudes, and expectations towards safety at HRGCs can be very useful in explaining inattentive driving behaviors. Previous programs of educating drivers' safe behaviors at HRGCs may have received good effects but no known research has discussed what groups of people are in an urgent need of receiving such information and what knowledge drivers are lacking. In this case, a study of identifying groups of drivers that have lower levels of knowledge of correct rail crossing negotiation, higher risks of inattentive driving and higher chances of being involved in accidents, is needed. Again, a survey questionnaire that includes information on motor vehicle drivers' knowledge and experiences at HRGCs and an analysis towards this direction can helpfully fill this gap.

Chapter 3 Data Collection

3.1 Survey Questionnaire Design

The questionnaire was designed to contain the following eight sections: (1) drivers' perceptions of safety, reliability, delay, etc., at local HRGCs; (2) drivers' usages of HRGCs and their expectation of encountering trains; (3) drivers' knowledge of safe driving at HRGCs; (4) drivers' attentive and inattentive driving activities at HRGCs; (5) drivers' attitudes towards safety and safety improvement at HRGCs and their intent of violating rules; (6) drivers' accident experience; (7) drivers' general information (e.g., age, gender, etc.); and (8) other comments or feedback.

Section 1 (Question 1 and 2) used five single choice questions to acquire drivers' perceptions of delays, safety, whether the traffic signs and pavement markings are confusing, and the reliability of train warning devices at rail crossings locally in their city as well as their perceived information outreach about rail crossing safety. All five questions were measured on a five-level Likert Scale, which allows individuals to expresses how much they agree or disagree with a particular statement. For example, the first question states that "I believe motorist delays at rail crossings in my city (the city of your residence at the time of the survey) are excessive," and the choices were "strongly agree; agree; neutral; disagree; strongly disagree". An open-ended question was also included in this section to ask drivers' to provide other comments on their local rail crossings.

Section 2 (Question 3 to 7) included two single choice questions asking drivers' which motor vehicle types were used for personal and work purposes as well as three gap filling questions asking drivers' usage of rail crossings, the most frequently used rail crossings, and perceived trains at those rail crossings. The objective of this section was to get an idea of drivers' usage of rail crossings. The use frequency variable was used later on as a potential factor impacting drivers' inattentive driving behaviors. The reason for asking drivers' most frequently used HRGCs was to match them with the FRA rail crossing inventory and thus have more information on the configurations of these rail crossings.

Section 3 (Question 8 to 16) included nine questions testing drivers' knowledge of safe driving at HRGCs and proper actions under emergency situations. There were in total six single choice questions and three multiple choice questions. Specifically, knowledge tested included understanding of crossbuck signs, use of railway 1-800 phone number, proper actions when lights are flashing, proper actions when lights start flashing while crossing, the meaning of "No Train Horn," proper actions when stalled on tracks, actions that are considered violations at gated crossings, actions when gates did not ascend immediately after a train passed, and what types of vehicles must stop at rail crossings.

Section 4 (Question 17) had 14 questions asking drivers' attentive or inattentive driving behaviors at HRGCs in the past 14 days. All questions were single choice questions based on the five-level Likert scale (always to never). These behaviors included looking left and right to check for trains, crossing when warning devices are activated, crossing when gates are descending, ascending, or leveled, stopping at STOP signs at rail crossings, talking to passengers, eating or drinking, talking on a phone, texting or using apps, reaching for objects inside the vehicle, adjusting in-vehicle equipment, distracted by an outside person or object, involved in mental distraction, smoking cigarettes, or any other inattention.

Section 5 (Question 18) contained 13 questions asking drivers' attitudes towards safety, safety reinforcement strategies, and intent of breaking the rules at HRGCs. All question were single choice questions based on the five-level Likert scale (strongly agree to strongly disagree).

The questions included whether they agree or disagree that safety at rail crossings is a significant issue, whether they like to wait for trains to pass, whether they like to accelerate to cross through when warning devices are activated, whether they routinely stop when warning devices are activated even if there is a chance to cross, whether they regret for stopping for trains when there is a chance to cross, whether they like to cross after train passage but warning devices are still active, whether they ensure warning devices are off before crossing, whether they like to drive around fully lowered gates, whether they support technology that blocks cell phone signals at rail crossings, whether they support stronger law enforcement, whether they are familiar with Operation Lifesaver, whether they would like to receive information on rail crossing safety, and whether they feel it is fun to play “chicken” at rail crossings.

Section 6 (Question 19 to 22) asked participants to report their crash or near crash experience at HRGCs in the past three years. One filter question asking whether they had a crash or near crash in the past three years was used to guide the participants to continue this section or skip to the next section. Those who had a crash/near crash experience were then being asked the type of crashes, whether there were inattentive driving behaviors involved in that crash, and what types of inattention were involved.

Section 7 (Question 23 to 30) was a collection of general information that included asking participants their years of residency in the current city, household size, years of driving, gender, age, education, occupation, and household income level.

Section 8 (Question 31) ended the survey with an open-space question asking for other comments to the survey or to rail crossings.

3.2 Data Collection Process

The following contents (3.2.1 – 3.2.7) were provided by the Bureau of Sociological Research (BOSR) of the University of Nebraska-Lincoln (with minor changes).

3.2.1 Introduction

This report presents a detailed account of the design and fielding of the Railroad Crossing Safety Survey commissioned and funded by Dr. Aemal Khattak, and conducted by the Bureau of Sociological Research (BOSR). Users of the Railroad Crossing Safety Survey data will find it an important reference source for answers to questions about methodology.

3.2.2 Questionnaire Design

The questionnaire was designed by Dr. Aemal Khattak in consultation with BOSR. The survey, which was fielded in English only, can be found in Appendix A.

3.2.3 Sampling Design

The Railroad Crossing Safety Survey consisted of a general population sample of households in Nebraska. In order to reach the general population, the survey used a postal delivery sequence based sample of household addresses (ABS). In order to randomize the household members, instructions in both cover letters and the postcard reminder were included to have the licensed driver 19 years of age or older living in the household, who has the next upcoming birthday, complete and return the questionnaire.

The sample for the Railroad Crossing Safety Survey was purchased from Survey Sampling International, LLC (SSI). A total of 2,500 households were provided to BOSR by SSI on July 6, 2015. These addresses were drawn throughout Nebraska with equal probability of selection.

3.2.4 Data Collection Process

Data collection began on July 10, 2015 with the first survey packet. A cover letter, $1 bill incentive, survey, and postage-paid return envelopes were mailed to all households. Reminder postcards were sent to each household sampled on July 16, 2015. Non-responders were mailed replacement packets, containing a cover letter, a copy of the survey, and a postage-paid return envelope on July 22, 2015. Completed surveys were collected by BOSR through August 10, 2015. All communications were sent in the English language only.

3.2.5 Response Rate

A total of 915 households completed the survey. The overall response rate for this survey, calculated using AAPOR's standard definition for response rate 2 is 36.6%. It should be noted, however, that due to the mode of data collection (mail), it is uncertain if surveys reached the entire sample. From the original 2,500 households, 210 surveys were returned as undeliverable with no forwarding address available.

3.2.6 Data Processing

Data entry was completed by professional data-entry staff. Many of the data-entry workers had previous experience in data entry on other mail survey projects. The data-entry staff was supervised by permanent BOSR project staff.

Data entry was completed in two steps. First, one data-entry worker would enter responses from a single survey. Second, another data entry worker would re-key the survey and be alerted to any discrepancies with the first entry. Supervisory staff members were available to answer questions about discrepancies or illegible responses. The data-entry staff is paid by the hour, not by the number of surveys entered. This method of payment is used so that we can ensure the high quality of the data collected by our staff.

3.2.7 Data Cleaning

The data are recorded and stored on a secure server located within the Sociology Department at the University of Nebraska-Lincoln (UNL). The Statistical Package for the Social Sciences (SPSS) software package was used to process and document the dataset.

The first step in data cleaning was to generate variables and value labels. The second step was to run frequency distributions on each of the variables in the survey to identify and correct any out of range responses. Third, responses given in the “specify” portion of the “other” response category that fit into one of the answer options were recoded (e.g., other, “farmer” recoded into “Construction/Farming/Technical”). No other changes were made to open-ended responses.

Chapter 4 Data Analysis

4.1 General Statistics of the Survey

As mentioned earlier, the questionnaire contained eight sections: (1) drivers' perceptions of safety, reliability, delay, etc., at local HRGCs; (2) drivers' usages of HRGC and expectation of encountering trains; (3) drivers' knowledge of safe driving at HRGCs; (4) drivers' attentive and inattentive driving activities at HRGCs; (5) drivers' attitudes towards safety and safety improvement at HRGCs and their intent of violating rules; (6) drivers' accident experience; (7) drivers' general information (e.g., age, gender, etc.); and (8) other comments or feedback. The following contents provide summary statistics for major questions included in the survey questionnaire. The collected sample size is 915.

4.1.1 Drivers' Perceptions of Local HRGCs

Table 4.1 presented a summary of the responses of the first five single choice questions. It can be seen that people generally believed that the traffic signs and pavement markings at their local rail crossings are clear (81.1% = 56.0% + 25.1%), that the rail crossings are safe (74.8% = 47.4% + 27.4%), and that the train warning devices such as flashing lights, bells, gates, etc., are reliable (74.0% = 50.1% + 23.9%). Most of the complaints came from excessive delays at rail crossings (16.1% = 5.0% + 11.1% agree or strongly agree the delays at their local rail crossings are excessive with 24.0% of the respondents reporting neutral) and no safety information was received on local rail crossings (42.4% = 14.1% + 28.3% with 17.8% of the respondents feel natural to this question). Although these questions were based on drivers' perceptions, which means the responses do not necessary reflect the "real" situation, the collected responses are still a good indicator of people's attitudes towards their local rail crossings. These attitudes usually played a role in drivers' behaviors (e.g., violation of regulation rules) at rail crossings.

Table 4.1 Driver perceptions of local rail crossings (in percentage %)

Aspects of perceptions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not answered
Excessive delays	5.0	11.1	24.0	35.4	18.6	5.8
Unsafe	1.4	4.9	12.7	47.4	27.4	6.1
Confusing signs and markings	0.7	2.0	10.2	56.0	25.1	6.1
Unreliable warning devices	1.7	5.9	12.0	50.1	23.9	6.3
No safety information outreach	14.1	28.3	17.8	22.5	10.6	6.7

Sample size: 915 responses.

A participant was given a score, from 1 to 5, for each of the above five questions. For example, if a driver chose “strongly agree” for “excessive delays” at his/her local rail crossings, he/she was given a score of 1, meaning that he/she had a low satisfaction with delays at local rail crossings; if he/she selected “strongly agree” to the same question, he/she was given s score of 5, meaning that he/she was very satisfied with traveling delays caused by local rail crossings. If a participant did not answer the question, he/she received an average score that was calculated from the responses of other participants. The average scores for each question for all participants were shown in Figure 4.1. As can be seen from the figure, on average, the participants are mostly satisfied with safety, clarity and reliability of HRGCs, had some complains of delays at HRGCs and did not receive much information of safety at HRGCs.

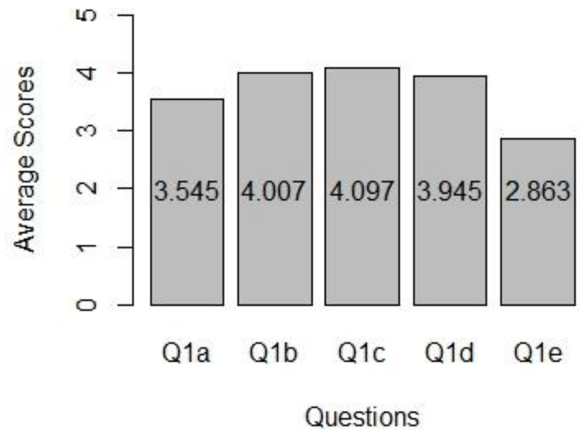

Figure 4.1 Average perceptions of delays, safety, signs and markings, reliability, and safety outreach of local HRGCs

For each participant, the five scores were added up to get a cumulative score of perceptions of local HRGCs. The cumulative score ranged from 8 to 25. A lower score indicated a low satisfaction of local HRGCs while a higher score represented a high satisfaction. Figure 4.2 presented the distribution of this cumulative score.

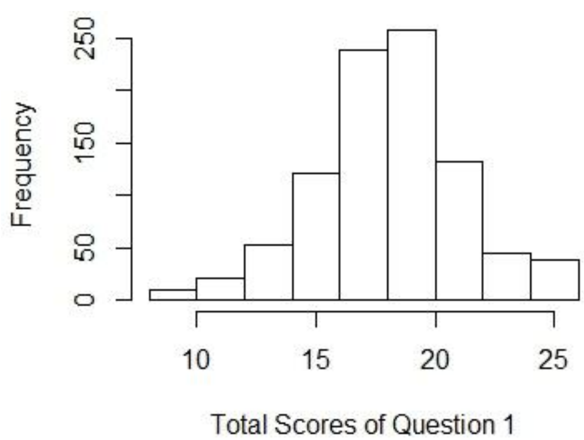

Figure 4.2 Distribution of cumulative perceptions of local HRGCs

The open-ended question included in this section asked drivers' other comments on their local rail crossings. Responses of the 179 participants, who responded to this question, were examined one by one and summarized in table 4.2. These responses indicated some important issues that current rail crossing in Nebraska may have, such as poorly maintained crossings where the surfaces were too rough to go through, holes at abandoned crossings that tore up vehicles, not enough warning devices were present in some areas, objects or trees at rail crossings that obstruct drivers' sights, trains blocking the crossing for an unnecessarily long time period, etc. Also, though it is important to educate young kids to act safely at rail crossings, the survey results strongly suggest rail crossing safety education programs being designed and open to adults, too.

Table 4.2 Other comments of local rail crossings

Design/Control/Maintenance of Rail Crossings
Rough, bumpy or get rough quickly (11 responses)
Need upgrade from none/stop signs to active warning devices, such as gates/guards/arms and flashing lights (9 responses)
Malfunction of the crossing warning devices, distrust of the devices, devices activated without trains passing (5 responses)
Poor sight/visibility because of obstructions/plants, especially at night or no light at night (5 responses)
Poorly maintained crossing (including abandoned ones) (4 responses)
Too many crossings in busy areas (2 responses)
Would like to see more overpasses/viaducts (3 responses)
Feel unsafe (2 responses)

May be stuck in a line when trains approach (maybe because the rail crossing is next to a highway intersection) (1 response)

Operation of Trains

Train stops for too long of a time period, blocks traffic especially for emergency vehicles (14 responses)

Too much noise, especially at night in country area (6 responses)

Too many trains in rush hours, would like to see trains operate at non-busy hours (3 responses)

Education

Did not receive any safety information since grade school (9 responses)

Safety information only received through drivers' manual (2 response)

Wittiness others' violation or feel culpable of punishment for those who violate (3 responses)

Other

Feel good/safe regarding their local rail crossings or feel safe because of overpasses (15 responses)

Have good knowledge of driving safety at rail crossing (6 responses)

Explanations to previous questions (11 responses)

Not/rarely use rail crossings, have no comments to their local rail crossings or not relevant (72 responses)

4.1.2 Drivers' Usages of HRGC and Expectation of Encountering Trains

In this section, two questions were asked about the types of motor vehicles that drivers use daily for personal and work purposes. Table 4.3 presented the percentages of different types of motor vehicles used. Passenger cars include both sedans and SUVs. Those who chose "5 other (specify)" and wrote down SUV were combined to the Passenger Car category. The majority of the respondents (67.4%) drive passenger cars (including SUV) for personal uses, the next largest category is pickup trucks. Among people who drive a work or company motor vehicle, the first two categories are passenger cars and pickup trucks. When designing a rail crossing, roughness and clearance height for those types of vehicles should be taken into account.

Table 4.3 Types of vehicles (in percentage %)

Vehicle type	Passenger car	Pickup truck	Minivan	Motorcycle	Other	Not drive a personal/work	Not answered
Personal	67.4	16.8	6.6	0.2	0.3	1.4	7.4
Work motor	14.3	11.7	2.2	-	2.6	65.0	4.4

Sample size: 915 responses.

Also included in this section is a question asking drivers' frequencies of using HRGCs. A numeric answer for how many times a HRGC was used in the past 14 days (i.e., times/2 weeks) was expected. The responses were then grouped into six categories, as shown in table 4.4. About 17% of the respondents did not use a rail crossing in the past 14 days. The majority of the respondents (76.5% = 33.9% + 14.1% + 12.0% + 16.5%) used one at least one time in the past two weeks. The research assumed that for people who did not use HRGCs in the past 14 days or who did not answer this question, their responses to other questions in the survey were still valid.

Table 4.4 Use frequency of rail crossings (in percentage %)

Use frequency of rail crossings (times/day)	None	0<freq.<7 (i.e., less than 1/2days)	7≤freq.<14 (i.e., less than 1/day)	14≤freq.<28 (i.e., less than 2/day)	freq.>=28 (i.e., more than 2/day)	Not answered
Percentage %	16.8	33.9	14.1	12.0	16.5	6.9

Sample size: 915 responses.

The drivers who participated were asked to report their most frequently used rail crossing. There are in total 548 participants who reported one or more rail crossings that can be identified in the map, the remaining 367 answered "NA" (43 responses), "visitor" (3 responses), "unknown" (4 responses), "overpass/underpass" (8 responses), "not use" (65 responses), did not answer this question (137 responses), or their responses were not specific enough to locate the rail crossing (107 responses).

4.1.3 Drivers' Knowledge of Safety at HRGCs

Questions 8-16 tested drivers' knowledge about safety at HRGCs, which included questions asking basic understanding of signs at HRGCs (e.g., crossbuck, no train horn), correct maneuvers when facing flashing lights and activated gates, proper actions when an emergency occurs (e.g., stalled on the tracks), and other knowledge about HRGCs (e.g., 1-800 number, vehicles must stop at crossings). Table 4.5 shows the results of the testing. Each cell represents the percent of drivers choosing that particular answer, and the correct answers for each question were highlighted in green.

Table 4.5 Questions testing drivers knowledge of driving at rail crossings (in percentage %)

	Choices (cells highlighted in green indicate the				
Questions	A	B	C	D	Not
Meaning of crossbuck sign	24.0	45.4	23.0	1.4	6.2
Use of railroad 1-800 number	73.6	30.7	57.9	18.8	3.5
Actions when lights flashing	0.2	5.2	90.9	0.1	3.5
Actions when lights start flashing while	0.4	92.5	2.4	1.1	3.6
Meaning of Quite Zone	9.1	3.8	67.1	15.4	4.6
Actions when stalled on tracks	0.2	7.7	84.6	1.3	6.2
Considered of violations	77.6	92.5	64.9	1.7	3.4

Actions when gates did not ascend immediately after train passed	1.1	91.4	0.2	3.4	3.9
Vehicles must stop at rail crossings	95.7	79.6	81.9	1.2	3.4

Sample size: 915 responses.

It is surprising that more than half of the participants did not fully understand the meaning of a crossbuck sign. Only 45.4% of the participants selected the correct answer that a crossbuck sign means yielding to train traffic. Many of the drivers either think a crossbuck sign is just a reminder that there is a rail crossing but no particular actions need to be taken (24.0%), or consider the crossbuck as a stop sign that requires a full stop (23.0%). Similarly, although the majority of the participants (67.1%) know the meaning of the “no train horn” sign, many other people misunderstand it (12.9%) or have no idea at all (15.4%).

In comparison, most people took correct actions when warning devices at a rail crossing were activated. Over 90% of the drivers know to stop before the crossing and wait for the train to pass when lights start flashing, even the train is still at some distance. Over 92% of the drivers know to proceed across the crossing if the lights start flashing after their crossing maneuver has already started. Most of the drivers (92.5%) know it is a violation to cross a gated rail crossing when the gates are fully-lowered. But fewer people consider passing under descending gates (77.6%) or ascending gates (64.9%) to also be violations. This may indicate a lack of education on dangerous behaviors at HRGCs. Again, over 91% of the participants correctly choose to wait till the gates fully open when encountering a rail crossing where the gates do not open after a train has passed. This is important because in cases like this another train might be on its way to approach the crossing.

When an emergency occurs, such as stalling on the tracks, the majority of the participants (84.6%) know that they need to get out of the vehicle and call 911 and rail 1-800. But some people (7.7%) incorrectly think trying to push the vehicle off the track is the option. In fact, staying on the track and not informing the emergency number can be very dangerous because a train might come at any time.

With regard to other rail crossing knowledge, such as the use of the rail 1-800 number, many of the participants (73.6%) know it is used to report a malfunction of a warning device, but fewer people (57.9%) know they should also report a vehicle/object on the tracks, and even fewer people (30.7%) realize they need to report a trespassing to this number too. These reports are important because these issues or incidents may risk the safety of the public in some way and thus should be reported immediately.

The results of this section indicated that people generally take correct actions at rail crossings with active traffic control devices, but many people do not fully understand the signs at rail crossings, the risks of certain violations, and the necessary actions to take when an emergency occurs. Corresponding education programs on rail safety should be taken to offer the public a better understanding.

For each question of testing drivers' knowledge on safe driving at HRGCs, a participant received a score on that question based on his/her responses. For single choice questions, a correct mark deserved 1 point; an incorrect mark equally 0 point; and those who did not answer a question got an average score (the mean score among people who answered it) on that particular question. For multiple choice questions, people received full credits (i.e., 1 point) if all correct choices were marked; got partial credits if were partially correct; got 0 if "I don't know" was selected; and got an average score if the question was not answered at all. This section of questions finally gave an accumulated score on drivers' knowledge of safe driving at HRGCs. A summary of the accumulated scores (i.e., mean, median and standard deviation) and a distribution of the accumulated scores were shown in Figure 4.3. The average accumulated score was 7.2, with a standard deviation of 1.3, indicating that the participants generally had a good knowledge of safely driving at HRGCs and not much variance was observed among the participants.

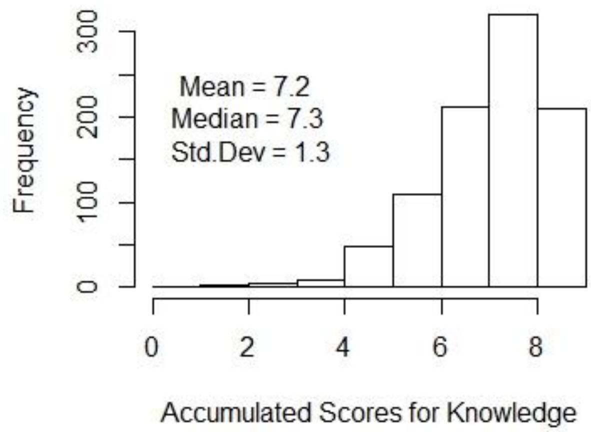

Figure 4.3 Distribution of accumulated scores for knowledge at HRGCs

4.1.4 Inattentive Driving Behaviors

This section summarized the inattentive driving behaviors reported by the participated drivers. Table 4.6 listed the most common attentive or inattentive driving behaviors and the frequencies of these behaviors. Each cell in the table represented the percent of drivers that selected that particular frequency. Cells highlighted in green were considered as safe behaviors.

Table 4.6 Participation of attentive and inattentive driving activities (in percentage %)

Activities	Participation frequency (cells highlighted in green indicate choices that are considered safe driving)					
	Always	Often	Sometimes	Rarely	Never	Not answered
Look left and right to check for trains	70.9	13.6	5.8	3.0	3.2	3.6
Cross when warning devices activated	0.7	0.1	1.9	11.1	82.3	3.9
Cross when gates descending ascending or leveled	0.5	0.3	1.3	7.0	86.0	4.8
Stop at STOP signs	77.9	8.0	2.2	1.1	5.5	5.4
Talk to passengers	2.2	11.6	36.5	19.1	26.3	4.3
Eat or drink	1.1	5.6	25.0	23.0	41.2	4.2
Talk on a phone	0.5	3.8	19.5	18.3	54.0	3.9
Text or use apps	0.2	0.8	3.7	9.1	82.4	3.8
Reach for objects	0.3	1.4	9.0	19.3	66.2	3.7
Adjust in-vehicle equipment	0.5	2.8	13.9	27.8	51.1	3.8
Distracted by outside object	0.1	1.5	13.4	36.3	44.4	4.3
Mental distraction	1.0	1.2	9.1	31.8	52.6	4.4
Smoke cigarettes	0.8	2.7	5.0	2.5	85.0	3.9
Other inattention	0.1	0.1	3.3	15.1	77.0	4.4

Sample size: 915 responses.

As seen from table 4.6, the majority of people (over 82%) did not cross rail crossings when warning devices or gates were activated. Texting or using apps are considered dangerous by most people and they never conducted such behaviors when cross a rail crossing (82.4%). These behaviors require drivers' eyes being diverted from the road and focused on their handheld devices instead and thus post the highest risks to the drivers. Most people always stopped at STOP signs (77.9%) and did always look left and right to check for trains (70.9%). Some activities are not considered as dangerous and only around half of the drivers always kept from involving in such activities, including reaching for objects in the vehicle (66.2%), talking on a phone (54.0%), mental distraction (52.6%), and adjusting in-vehicle objects (51.1%). These activities involve some degree of visional, manual, or mental distraction and can be very dangerous in critical locations such as a rail crossing. Fewer drivers consider the following behaviors as risky: distraction by outside objects, eating or drinking, or talking to passengers. These behaviors were therefore conducted by the drivers from time to time. As to smoking, because some participants may not smoke at all, the high percentage of people choosing "Never" (85.0%) cannot be evaluated properly.

For each question asking drivers' experience of attentive/inattentive driving, a driver received a score based on his/her responses. All questions were single choice questions. Safe behaviors (e.g., always look left and right to check for trains, never drive across a rail crossing when the gates were descending, ascending or in a level position) were given a high credit (5 points) and unsafe behaviors were given a low credit (1 point). Questions not answered received an average credit of people who answered the question. This section of questions finally gave an accumulated score on drivers' involvement of inattentive driving behaviors. Figure 4.4 presented a summary of the accumulated scores (i.e., mean, median and standard deviation) and a distribution of the accumulated scores. The accumulated scores ranged from 26 to 70, and a higher score indicates fewer involvements of inattentive driving activities. The average accumulated score was 62.5, with a standard deviation of 6, indicating that the participants have a relatively good driving habit and did not often involve themselves in inattentive driving actives at HRGCs.

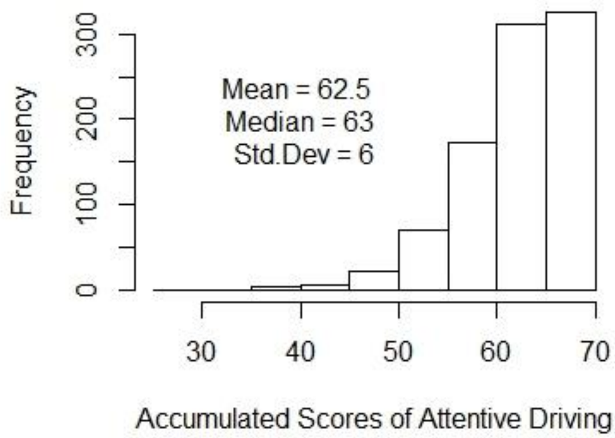

Figure 4.4 Distribution of Accumulated Scores of Attentive Driving at HRGCs

4.1.5 Drivers' Attitudes Towards Safety at HRGCs and Intent of Violating Rules

Questions 18 (a to m) asked drivers' attitude towards safety and safety improvement strategies at HRGCs as well as drivers' intent to violate rules at HRGCs. Table 4.7 presents a summary for this section. Questions a, i, j, k, and l are about attitudes toward rail crossing safety and strategies to improve safety. The majority of people agreed that safety is a significant issue at rail crossings (83.9% = 54.9%+29.0%). Over 54% supported technologies that can block cellphone signal at rail crossings (except for emergency calls) to reduce distracted driving. About 59% of the drivers supported stronger law enforcement towards rule violations at HRGCs. On the other side, although people seemed to know little about public information programs dedicated to reducing collisions, injuries, and fatalities at HRGCs (only 21.4% acknowledged they knew), such as Operation Lifesaver, not many people would like to receive information on rail crossing safety (only 23.9%).

Noticeably, a large portion of the participants (34.2%) chose “neutral” for the question whether they would like to receive information on rail crossing safety. This probably can be interpreted as “it depends”. It depends on what information is going to be distributed and how is it going to reach each person. A good education program that is tailored to people’s needs and broadcasted properly should be able to attract more people’s attention to rail safety. Similarly, people who are not sure about technology and law reinforcement (21.1% and 27.8%, respectively) at rail crossings probably will show more support if these reinforcements are welled developed.

As far as rule violation intent is considered, Questions b to h and Question m were used to evaluate drivers’ patience to wait for trains, intent of various rule violations, regret for waiting for trains, and excitement of breaking rules. The survey found that although people generally do not like to wait for trains to pass (43.4% agreed), most of the drivers do not accelerate to cross when warning devices are activated (87.6%). They routinely stop when warning devices are activated (83.1%), they do not regret for stopping for trains even if there is a chance to cross (76.2%), they do not cross under activated warning devices even if a train has passed (92.7%), they ensure all warning devices went off before crossing (91.7%), they do not like to drive around fully lowered gates (96.8%), and they do not find it fun to play “chicken” with an approaching train (96.9%).

Table 4.7 Attitudes and intentions of safe driving at rail crossings (in percentage %)

	Agreement or disagreement					
Questions	Strongly	Agree	Neutral	Disagree	Strongly	Not answered
a. Safety at rail crossing is significant	54.9	29.0	9.2	4.7	0.9	1.4
b. Do not like to wait for trains to pass	10.6	32.8	28.7	13.0	12.8	2.1
c. Like to accelerate to cross through when warning devices are activated	2.0	2.5	6.2	33.8	53.8	1.7
d. Routinely stop when warning devices are activated even if there is a chance to cross	49.0	34.1	5.5	3.4	6.2	1.9
e. Regret stopping for trains when there is a chance to cross	2.4	6.0	13.6	34.6	41.6	1.7
f. Like to cross after train passage but warning devices are still active	1.1	1.2	3.3	35.1	57.6	1.7
g. Ensure warning devices off before crossing	56.9	34.8	2.8	1.6	2.2	1.6
h. Like to drive around fully lowered gates	1.0	0.1	0.3	16.5	80.3	1.7
i. Support technology that blocks cell phone signals at rail crossings	34.1	20.7	21.1	10.9	11.4	1.9
j. Support stronger law enforcement	29.3	29.7	27.8	6.8	4.4	2.1
k. Familiar with Operation Lifesaver	10.3	11.1	21.7	26.7	26.0	4.2
l. Would like to receive info on rail crossing safety	9.1	14.8	34.2	21.5	17.5	3.0
m. Feel it is fun to play “chicken” at rail crossings	1.2	-	0.3	3.7	93.2	1.5

Sample size: 915 responses.

Again, a participant receives a score for each question included in this section. All of the 13 questions are single choice questions. For questions asking about safety and safety improvements at HRGCs (Questions a, i, j, k and l), a positive attitude received a high credit, while a negative attitude was given a low credit. For questions testing the intent of violations (Questions b to h and Question m), a higher intent of violating rules (e.g, crossing when warning devices are activated or gates are descending) was given a lower credit while a lower intent of violating rules was given a higher credit. Therefore, questions in this section finally produced two variables: accumulated attitude towards safety and accumulated intent of violation. Figure 4.5 and 4.6 showed the distributions of the values of the two variables. The accumulated attitudes towards safety ranged from 5 to 25; the higher the score, the more positive attitude a participant has towards safety and safety improvements at HRGCs. From Figure 4.5, it seems many drivers have a neutral attitude toward this issue (around the score 15), with the distribution slightly skewed to the positive side. The accumulated intent of violations at HRGCs ranged from 16 to 40; the higher the score, the lower intent of violating HRGC rules a participant has. From Figure 4.6, it is good to see that drivers generally have a low intent of violations at HRGCs.

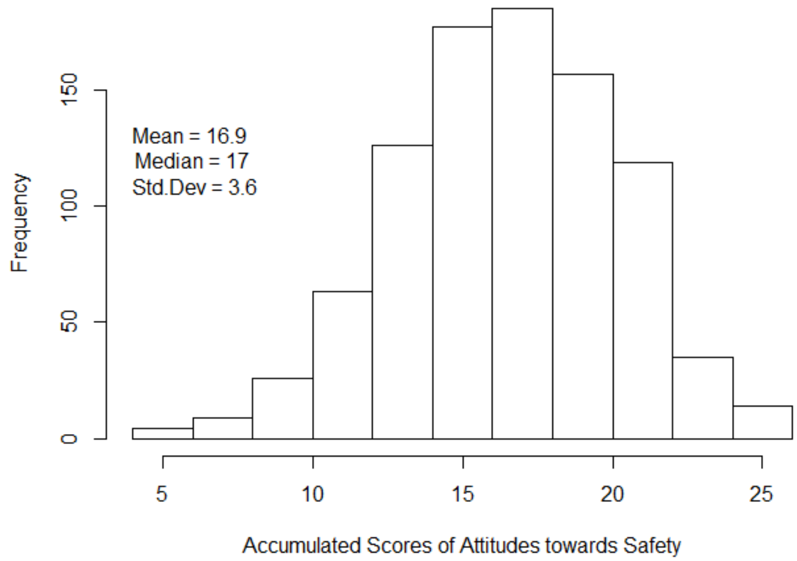

Figure 4.5 Distribution of Accumulated Scores of Attitudes towards Safety

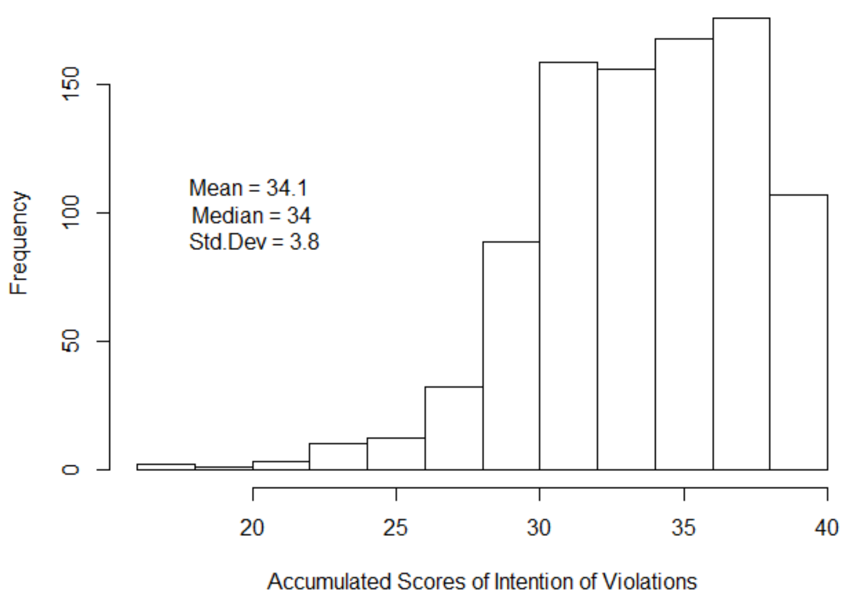

Figure 4.6 Distribution of Accumulated Scores of Intent of Violations

(A higher score indicates a lower intent of violations)

4.1.6 Drivers' Accident Experience at or near HRGCs

Eight out of the 915 participants reported that they have been involved in an accident or near-accident at or near rail crossings in the past 3 years. Except for one participant who did not specify which type of accident s/he had been involved in, the other 7 participants reported in total 2 single-vehicle accidents, 2 multi-vehicle accidents, 1 single vehicle near-accident, and 2 multi-vehicle near-accidents. Five of the 7 drivers who reported having accident experiences at rail crossings believed that there were some forms of inattentive driving involved in the accidents: talking to passengers (mentioned twice), texting or using apps (mentioned twice), distracted by persons or objects outside of the vehicle (mentioned twice), eating or drinking (mentioned once), talking on cellphones (mentioned once), adjusting in-vehicle equipment, and mentally distracted (mentioned once). Figure 4.7 presents the number of different types of crashes or near crashes reported by the drivers and any inattentive driving involved.

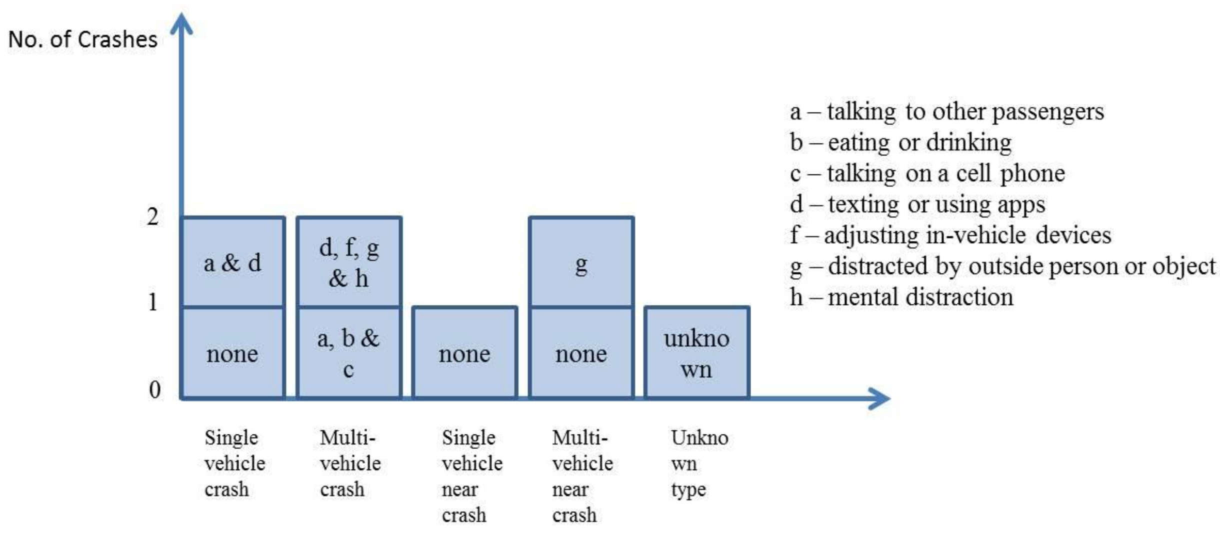

Figure 4.7 Crashes and near-crashes involving inattentive driving

4.1.7 Drivers' General Information

This section included summaries of general information of the participated drivers, including years of residence, household size, years of driver's license, gender, age, education level, occupation, and household income. Table 4.8 presents the summary. This survey sample covered a wide range of residence years in their local cities, from less than 1 year to more than 70 years. The sample has a predominant group of experienced drivers, with 90.7% of the participants having a driver's license more than 10 years. Household types covered in the sample included 55% two-adults households, 27.2% single-adult households, and 10.7% more than two-adult households. Females are a bit overrepresented (55.3%) but still considered a fair sample.

Table 4.8 General information of participants (in percentage %)

Variable	Distribution
Years of residence in his/her current city	<1 yr (0.7%), 1-3 yrs (10.5%), 4-10 yrs (13.7%), 11-20 yrs (15.1%), 21-30 yrs (16.5%), 31-40 yrs (11.5%), 41-50 yrs (11.3%), 51-60 yrs (7.2%), 61-70 yrs (5.5%), >70 yrs (2.8%), not answered (5.4%)
Number of adults in household	0 (3.7%), 1 (27.2%), 2 (55.0%), >2 (10.7), not answered (3.4%)
Years of a licensed driver	<1 (0.2%), 1-2 yrs (0.8%), 3-5 yrs (1.0%), 6-10 yrs (5.0%), >10 yrs (90.7), not answered (2.3%)
Gender	Female (55.3%), male (42.0%), not answered (2.7%)
Age	<20 yrs (0.4%), 20-24 yrs (3.2%), 25-29 yrs (5.9%), 30-34 yrs (5.5%), 35-39 yrs (5.9%), 40-44 yrs (6.1%), 45-49 yrs (5.4%), 50-54 yrs (9.2%), 55-59 yrs (12.2%), 60-64 yrs (13.0%), 65-69 yrs (10.7%), >=70 yrs (20.1%), not answered (2.4%)
Highest level of education	Less than High School (2.1%), high school diploma or equivalent (20.5%), some college (no degree) (21.6%), associate's degree (9.9%), bachelor's degree (25.0%), master's degree (11.6%), doctorate degree (3.4%), other (1.2%), not answered (4.6%)

Primary occupation	Management/financial (6.6%), government/military (2.6%), student (2.6%), leisure/hospitality/sales/art (3.4%), construction/farming/technical (9.3), healthcare/legal/protective services (10.4%), transportation/production (5.9%), office/administration (6.8%), community/social/family (3.4%), computers/architecture/engineering/ science (4.0%), other (9.4%), unemployed/laid off (1.3%), retired (28.4%), not answered (5.9%)
Annual household income	Less than \$20k (9.3%), \$20k – 30k (9.1%), \$30k – 40k (8.1%), \$40k – 50k (10.7%), \$50k – 60k (7.9%), \$60k – 70k (6.3%), \$70k – 80k (6.0%), \$80k – 90k (5.2%), \$90k – 100k (4.3%), \$100k – 110k (5.6%), \$110k – 120k (2.4%), \$120k or higher (12.9%), not answered (12.2%)

This section (4.1) gave a general statistical description of the survey results. The following sections 4.2 and 4.3 present two more sophisticated models of the investigated factors impacting driver inattentive behaviors as well as drivers' knowledge of safely driving at HRGCs.

4.2 Inattentive Driving Model

Before building any sophisticated models, variables asking drivers' perceptions of local rail crossings, testing drivers' knowledge, reporting drivers' inattentive driving activities, and evaluating drivers' attitudes towards safety at HRGCs, needed to be processed before entering them into a model. The following were the processing procedures.

Q1a-e: Questions asking drivers' perceptions on safety, delay, signs and markings, and reliability and safety program outreach of local HRGCs. Each question was used to create one continuous variable. Although the variable is in fact integers (i.e., only 1, 2, 3, 4, and 5), it is treated as continuous to simplify the model.

Q8-16: Questions testing drivers' knowledge of safe driving and dealing with emergencies at HRGCs. Each driver received a score on each question. For single choice questions, a correct mark deserved 1 point; an incorrect mark got 0 points; and those who did not answer a question got an average score (the mean score among people who answered it) on that particular question. For multiple choice questions, people received full credits (i.e., 1 point) if all correct choices were marked; was given partial credit if they were partially correct; got 0 if "I don't know" was selected; and got an average score if the question was not answered at all. This section of questions finally gave an accumulated score on drivers' knowledge of safe driving at HRGCs.

Q17a-n: Questions asking drivers to recall their driving activities during the past 14 days at HRGCs and choosing corresponding frequencies of involvement in such activities. The listed activities included many inattentive driving behaviors and some expected, correct driving behaviors. All questions were single choice questions. Safe behaviors (e.g., always look left and right to check for trains, never drive across a rail crossing when the gates are descending, ascending, or in a level position) were given a high credit (5 points), and unsafe behaviors were given a low credit (1 point). Questions that were not answered received an average credit among people who answered the question. This section of questions finally gave an accumulated score on drivers' involvement of inattentive driving behaviors.

Q18 a-m: Questions asking drivers attitudes towards safety at HRGCs and the intent of violating rules. All of the 13 questions are single choice questions. A positive attitude towards safety and safety improvements at HRGCs received a high credit while a negative attitude was given a low credit. A higher intent of violating rules (e.g., crossing when warning devices are activated or gates are descending) had a high score while a low intent of violating rules was given a low score. This section of questions finally contributed two variables: accumulated attitude towards safety and accumulated intent of violation.

Q23 – 30: Questions recording participants' general information. Variables were included in the model as categorical variables. Table 4.9 provided a summary of the variables considered in the two models.

Table 4.9 Variables Considered in the Regression Models

Variables		Mean	Freq.
Inattentive Driving	A driver was rarely or never involved in any inattentive driving activities in the past 14 days at HRGCs; accumulated score of Question 17 was above 56	85.6%	132
	A driver was sometimes involved in some inattentive driving actions in the past 14 days at HRGCs; accumulated score of Question 17 was below or equal to 56	14.4%	783
Knowledge	Accumulated score of questions testing knowledge of safe driving at HRGCs; accumulated score of Questions 8-16	7.2	
Attitude	Attitude towards safety and safety improvement at HRGCs; accumulated score of Questions 18 a, i, j, k, and l	16.9	
Intent	Intent of violation at HRGCs; accumulated score of Questions 18 b, c, d, e, f, g, h, and m	34.1	
Gender	Male	42.0%	384
	Female	55.3%	506
Age	>20	0.4%	4
	20-29	9.1%	83
	30-39	11.4%	104
	40-49	11.5%	105
	50-59	21.4%	196

	60-69	23.7%	217
	≥70	20.1%	184
Bachelor	Bachelor degree or above	41.2%	377
	Does not have a bachelor’s degree	54.2%	496
Income	Household annual income < 30,000	18.4%	168
	3,0000 ≤ Household annual income < 6,0000	26.7%	244
	Household annual income ≥ 6,0000	42.7%	391
Usage	Use of HRGCs ≥ 2/ day	16.5%	151
	Use of HRGCs < 2/ day	76.8%	703
Local_delay	Perception of delay at local HRGCs	3.5	
Local_safety	Perception of safety at local HRGCs	4.0	
Local_sign	Perception of clarity of signs and signals of local HRGCs	4.1	
Local_reliability	Perception of reliability of warning devices at local HRGCs	3.9	
Local_program	Perception of safety program outreach of local HRGCs	2.9	
License	Years of licensed driver < 1 yr	0.2%	2
	Years of licensed driver: 1-2 yrs	0.8%	7
	Years of licensed driver: 3-5 yrs	1.0%	9
	Years of licensed driver: 6-10 yrs	5.0%	46
	Years of licensed driver > 10 yrs	90.7%	830

The following presented the model used to investigate impacting factors of drivers’ involving in inattentive driving actions. The data analysis utilized a binary logit regression to investigate probabilities of inattentive driving behaviors at HRGCs. Mathematically the model is:

$$\pi_i = Pr(Y_i = 1 \,|X_i \; = \; x_i) = \frac{e^{(\beta_0 + \beta_i x_i + \varepsilon)}}{1 + e^{(\beta_0 + \beta_i x_i + \varepsilon)}} \quad (1)$$

Where,

π_i = probability of never involving in any kind of inattentive driving in the past 14 days at HRGCs;

Y_i = binary response variable; Y_i=1 if the driver was never or rarely involved in any inattentive driving activities in the past 14 days at HRGCs, and Y_i=0 if at the driver was involved sometimes in some inattentive driving actions; and

X_i = vector of the explanatory variables (e.g., driver information such as knowledge of safely driving at HRGCs, attitudes towards safety at HRGCs, gender, age, income, etc.).

The link function of the binary logit model indicates the cumulative standard logistic probability distribution function. To simplify the model, logit transformation (i.e., logit(π_i)) is employed, and equation (1) can be expressed as:

$$logit\ (\pi_i) = \log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_i X_i + \varepsilon \qquad (2)$$

The advantage of the logit transformation is allowing the right side of the equation to be a linear function of explanatory variables.

The dependent variable of the model is y = 1 if never or rarely involving inattentive driving in the past 14 days and y = 0 if sometimes involving inattentive driving.

Independent variables that were statistically significant at the 90% level were shown in table 4.10.

Table 4.10 Factors impacting drivers' involved in inattentive driving

	Estimate	Std.Error	z value	Pr(>|z|)
(Intercept)	-6.9075	1.2691	-5.4429	0.0000
Knowledge of safe driving at HRGCs	0.1561	0.0953	1.6381	0.1014
Attitude towards safety issues at HRGCs	0.0897	0.0347	2.5334	0.0113
Intent of violation at HRGCs	0.1746	0.0325	5.3789	0.0000
Female	-0.6378	0.2440	-2.6138	0.0090
Age (5 yrs increment)	0.2366	0.0397	5.9573	0.0000
Bachelor degree or above	-0.4097	0.2488	-1.6463	0.0997
30000≤Household annual income<60000	-1.0141	0.4020	-2.5229	0.0116
Household annual income≥60000	-0.7594	0.3910	-1.9421	0.0521
Use of HRGCs≥2/ day	-0.5214	0.2715	-1.9203	0.0548

The above binomial regression model can be written as

Logit ($\hat{\pi}$) = log ($\frac{\hat{\pi}}{1-\hat{\pi}}$) = -6.91 + 0.16*Knowledge + 0.09*Attitude towards safety + 0.18*Intent of violation – 0.64 *Female + 0.24*Age – 0.41*Bachelor degree or above – 1.01*HH income between 30k and 60k – 0.76*HH income greater or equal to 60k - 0.52*Use HRGCs greater or equal to 2 times per day (3)

In which, $\hat{\pi}$ is the estimated probability that a participant rarely or never involved in any inattentive driving behaviors. 1-$\hat{\pi}$ is the estimated probability that a participant sometimes involve in some inattentive driving behaviors.

It can be seen from Table 4.10 and Equation (3) that

(1) Independent variables that have positive relationship with the dependent variable included: knowledge of safe driving at HRGCs, attitudes towards safety and safety improvements at HRGCs, intent of violations and driver age. This finding indicated that drivers

with more knowledge of HRGCs were less likely to involve in distracted/inattentive driving at HRGCs. It, therefore, emphasizes the importance of educating more drivers of safety at HRGCs. Drivers who had positive attitudes towards safety at HRGCs and who supported safety improvement strategies were more likely to be the cautious drivers. Undoubtedly, drivers with a higher intent of violations (i.e., a decrease in the independent variable "Intent of violation at HRGCs") were more involved in distracted/inattentive driving at HRGCs. The model also indicated that older drivers were less likely to conduct inattentive behaviors than younger drivers.

(2) Independent variables that were negatively associated with the dependent variable included: female, bachelor degree or above, household income between 30k and 60k, household income greater or equal to 60k and average usage of HRGCs is greater or equal to 2 times per day. It indicated that female drivers, drivers with higher educational level (such as bachelor and above), drivers with higher household income (i.e., annual household income greater than 30k) and drivers who used HRGCs frequently (i.e., >=2 times/day) and familiar with local HRGCs were more likely to involve in distracted/inattentive driving behaviors at HRGCs. This finding may cast some light on future educational programs of safety at HRGCs.

4.3 Knowledge of Driving at HRGCs

In this section, a linear regression model was used to investigate the potential factors affecting drivers' knowledge of safely driving at HRGCs. The HRGC negotiation knowledge was the aggregated number of correct answers to the nine questions (Question 8-16) in Appendix A. The variable was treated as continuous. The data analysis utilized a multiple linear regression to investigate factors potentially affecting drivers' knowledge of safe driving at HRGCs. The mathematical principle behind the model is:

$$y_i = \beta_0 + \beta_i x_i + \varepsilon \quad (4)$$

Where,

y_i = accumulated scores on corrected answered questions that test drivers' knowledge and understanding of signs, signals, emergencies, etc. at HRGCs;

X_i = vector of the explanatory variables (e.g., drivers' attitudes, use frequency, gender, age, etc.);

β_i = coefficients for the explanatory variables; and

ε = error term.

The dependent variable is drivers' knowledge of safely driving at HRGCs. The independent variables that were statistically significant at the 90% level were presented in table 4.11.

Table 4.11 Factors affecting drivers' knowledge at HRGCs

	Estimate	Std.Error	t value	Pr(>|t|)
(Intercept)	3.3866	0.8646	3.917	0.0001
Safety program outreach	0.1342	0.0332	4.041	0.0001
Use of HRGCs≥2/ weekday	0.2838	0.1073	2.644	0.0083
Intent of violation at HRGCs	0.0491	0.0112	4.393	0.0000
1-2 yrs licensed driver	1.7973	0.9813	1.831	0.0674
3-5 yrs licensed driver	1.9868	0.9622	2.065	0.0393
6-10 yrs licensed driver	1.8736	0.8671	2.161	0.0310

>10 yrs licensed driver	1.6680	0.8527	1.956	0.0508
bachelor degree or above	0.1592	0.0835	1.901	0.0569

The above linear regression model can be written as

$\hat{y}$ = 3.39 + 0.13*Perception of safety program outreach + 0.28*Usage of HRGCs equal to or above 2 times/day + 0.05 *Intent of violation + 1.80*1-2 yrs licensed driver + 1.99*3-5 yrs licensed driver + 1.87*6-10 yrs licensed driver + 1.67*>10 yrs licensed driver + 0.16*Bachelor degree or above (5)

In which, $\hat{y}$ is the estimated score of knowledge at HRGCs.

As can be seen from Equation (5) and Table 4.11, drivers' knowledge of safe driving at HRGCs is associated and increased with factors including safety program outreach, more frequent usage of HRGCs, lower intent of violations, longer driving experience and higher educational level (e.g., bachelor degree or above).

Other variables were also tried in the model specification but found to be statistically insignificant. These included: there were no significant difference between male and female drivers in their knowledge of HRGCs; driver age does not seem to play a significant role in levels of knowledge; household income does not make any difference.

Chapter 5 Conclusions and Recommendations

The objectives of this research were first to report driver's perceptions of safety at highway-rail grade crossing (HRGC) in Nebraska, their unsafe inattentive driving behaviors, and their knowledge of safely negotiating at HRGCs, and then to identify potential factors that affect drivers' knowledge as well as inattentive driving behaviors at HRGCs.

Data were collected from Nebraska through a three-stage mail survey. The survey contained sections inquiring drivers' perceptions of local HRGCs, usage of HRGCs, knowledge of correctly behaving at HRGCs, experience of attentive and inattentive driving at HRGCs, accident or near-accident experience at HRGCs, attitudes towards safety and safety improvement strategies as well as their demographic information. The survey provided a sample of 915 completed questionnaires.

The statewide survey found that in Nebraska drivers mostly believe signs and markings at HRGCs are clear (81.1%), HRGCS are safe (74.8%) and reliable (74.0%). Many people think there are excessive delays at HRGCs (16.1%) and not enough information are received on HRGC safety educational programs (42.4%). Problems such as the HRGCs are rough, bumpy or getting rough quickly, trains possessing the crossings for too long time and blocking traffic especially for emergency vehicles, education information on HRGC safety were not received for adults, etc., were frequently mentioned by the participants of the survey. Most of the surveyed drivers (76.5%) used HRGCs at least once in the past 14 days ahead of the survey. Some drivers (16.5%) used HRGCs more than two times per day on average. The surveyed drivers generally have a good knowledge of safely driving at HRGCs. The mean score of knowledge is 7.2 out of 8 points. The majority of the drivers know how to act correctly when the lights are flashing or when the gates are descending or ascending. But many people (35.1%) do not know it is a violation to go through a crossing when the train has passed, the gates are ascending but are not fully open yet. About half of the drivers do not fully understand the meaning of a crossbuck. Most of the drivers (73.6%) understand there is a need to report a malfunction of a warning device to the rail 1-800 number, but few of them know a vehicle/object on the track (57.9%) and a trespassing behavior (30.7%) also need to be reported to the 1-800 number. Drivers on average received a high credit with respect to attentive driving at HRGCs. The mean score is 62.5 out of a total of 70. But there are still many drivers conducted some distracted/inattentive behaviors at HRGCs. Distractions such as outside objects, eating or drinking, talking to a passenger, adjusting in-vehicle objects or devices, mental distraction, talking on a phone, or reaching for objects inside the vehicle, are sometimes not considered as dangerous by the drivers and the drivers thus involve themselves in these activities from time to time. More than 80% of the participants believe safety is a significant issue at HRGCs. Over 54% of them supported technologies blocking cellphone signals at rail crossings (except of emergency calls) and 59% supported stronger law enforcement towards violations at HRGCs. Many of the drivers did not receive information about crossing safety but neither did they seem to be strongly interested in receiving such information. However, a large portion of the participants chose “neutral” for the question asking their willingness of receiving safety information on rail crossings. This probably gave a hint of designing attractive educational programs that fits drivers’ needs. As far as intent of violation is considered, although drivers do not like to wait for trains (43.4% agree), they do routinely stop for activated warning devices (83.1%), do not accelerate to cross (87.6%), do not regret for waiting for trains (76.2%), and wait until warning devices turned off (91.7%). It is worth noticing that, based on the researchers’ field observations in previous projects, there is actually a large proportion of drivers who conducted violations (e.g., driving through a crossing when the gate is still ascending) at rail crossings. The survey results are more optimistic than the field observations. Only eight out of the 915 drivers reported a crash or near-crash at HRGCs but seven out of the eight crashes involved in some types of inattentive driving, such as talking to a passenger, texting or using apps, distracted by outside person or object, etc.

The statistical model of inattentive driving revealed that factors that may decrease drivers' involvement of inattentive driving activities at HRGCs included: higher knowledge of safe driving, positive attitudes towards safety, lower intent of violation, increased driver age. Factors that are probably associated with higher likelihood of inattentive driving included female drivers, higher educational level, higher household income and drivers who are familiar with HRGCs. The regression model of knowledge at HRGCs found that drivers' knowledge of safe driving at HRGCs are closely related to the outreach of safety education programs, the frequency of using HRGCs, the intent of violation, the years of driving and the drivers' education level.

Based on these findings, the following conclusions and recommendations were reached.

(1) Drivers still lack knowledge in some aspects of safely driving at HRGCs. These aspects include but not limit to violations that are easily neglected (e.g, going across when the gates are descending or ascending), correct actions when emergency such as stalling on the tracks occur, meanings of signs, markings and signals at rail crossings, the importance of reporting trespassing and occupying vehicles/objects/persons, etc. More targeted and attracting educational programs (to adult drivers) on safety at HRGCs should be well designed and applied.

(2) Education programs on safety at HRGCs should be targeted to people who need them the most: drivers with less driving experience, with higher intent of violation, with fewer experience of using HRGCs, and with relatively lower education levels.

(3) Safety education programs should also pay attention to distracted/inattentive driving activities at HRGCs. Groups of drivers that are more inclined to conduct inattentive driving behaviors and thus need to be more targeted are those people with negative/indifferent attitude towards safety at HRGCs, with higher intent of violation, with less knowledge of driving at HRGCs, with higher education levels, better income, frequent users of HRGCs and younger and female drivers. The difference between (3) and (2) exactly emphasized the importance of having different safety programs (i.e., focusing either on knowledge of HRGC or advocating attentive driving at HRGCs) that are targeted to different groups of drivers.

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Appendix A

RAIL CROSSING SAFETY SURVEY

Local Rail Crossings

1. As a motor vehicle driver, please indicate your agreement or disagreement with the following statements.

	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
I believe motorist delays at rail crossings in my city (*the city of your residence at the time of this survey*) are excessive.	◯	◯	◯	◯	◯
I feel unsafe when driving at rail crossings in my city.	◯	◯	◯	◯	◯
I feel traffic signs and pavement markings at rail crossings in my city are confusing.	◯	◯	◯	◯	◯
I doubt the reliability of the train warning devices *(e.g., flashing lights, bells, gates, etc.)* at the rail crossings in my city.	◯	◯	◯	◯	◯
I've never received information on rail crossing safety.	◯	◯	◯	◯	◯

2. Other comments on rail crossings in my city:

____

Use and Knowledge of Rail Crossings

3. What type of personal motor vehicle do you drive on a daily basis most often?

◯ Passenger car

◯ Pickup truck

◯ Minivan

○ Motorcycle

○ Other *(specify):* _______________

○ Do not drive a personal motor vehicle on a daily basis

4. What type of work or company motor vehicle do you drive on a daily basis most often?

   ○ Passenger car

   ○ Pickup truck

   ○ Minivan

   ○ Motorcycle

   ○ Other *(specify):* ________________

   ○ Do not drive a work or company motor vehicle on a daily basis

5. During the past 14 days, how often did you drive across rail crossings? *For example, if you drive across one rail crossing on your way from home to work and drive back from work to home using the same route on the same day, you drove 2 times across rail crossings.*

   ____________ times during the past 14 days.

6. Which rail crossing did you use most frequently during the past 14 days? *(e.g., crossing at 27th and Highway 2, Lincoln, NE)*

   Railroad crossing location: ___________________

7. Based on your experience, how many trains do you think pass through this crossing *(the crossing you mentioned in Question 6)* on a daily basis?

   _________________ trains pass through on a daily basis.

Questions 8-16 ask your current knowledge driving through a rail crossing.

8. What does a crossbuck sign require a driver to do when approaching a rail crossing?

   ○ Nothing in particular, it’s just to let drivers know that there is a rail crossing.

   ○ Yield to train traffic.

   ○ Stop at all the rail crossings and then proceed cautiously.

   ○ I don’t know.

9. Railroad companies post an emergency 1-800 number at crossings. The purpose of this number is to *(check all that apply):*

   ☐ Report a malfunctioning gate or lights.

   ☐ Report trespassing at the crossing.

☐ Report a vehicle or object on the tracks.

☐ I don't know.

10. What should a motor vehicle driver do when approaching a rail crossing and the crossing lights start flashing?

○ Speed up to cross over to the other side.

○ Stop at the crossing and proceed across if the train is at some distance from the crossing.

○ Stop and wait for the train to cross and only proceed across when the lights cease flashing.

○ I don't know.

11. What should a motor vehicle driver do if the crossing lights start flashing after he/she has started to cross the tracks?

○ Stop and get out of the vehicle immediately.

○ Proceed across to clear the tracks.

○ Stop and back up to clear the tracks.

○ I don't know.

12. At a rail crossing that is designated as a Quiet Zone indicated by 

, the train will:

○ Never sound its horn.

○ Not sound its horn during nighttime.

○ Not sound its horn but can do so in emergency situations.

○ I don't know.

13. What should a motor vehicle driver do if his/her vehicle stalls on a rail crossing?

○ Stay in the vehicle and attempt to drive the vehicle clear of the tracks.

○ Get everyone out immediately and try to push the vehicle off the tracks.

○ Get everyone out and off the tracks immediately then call 911 and the rail 1-800 emergency number.

○ I don't know.

14. Which of the following may be considered a motor vehicle violation at a gated rail crossing? *(Check all that apply)*

☐ Passing under gates that are descending because a train is on its way.

☐ Passing around/between fully-lowered gates.

☐ Passing under gates that are ascending after a train has passed.

☐ I don’t know.

15. What should a motor vehicle driver do at a gated rail crossing if the gates do not open after a train has passed?

○ Proceed around/between the gates to the other side as the gates are likely malfunctioning.

○ Wait till the gate is fully open as another train may be on its way.

○ Wait for some other vehicle to start crossing around/between the gates and then follow it.

○ I don’t know.

16. Which of the following vehicles must stop at all rail crossings unless the crossing is abandoned, exempted, or a flagman is present? *(Check all that apply)*

☐ A school bus.

☐ A bus carrying passengers.

☐ A commercial vehicle carrying hazardous materials.

☐ I don’t know.

Activities and Experiences While Driving Across Rail Crossings

17. Following is a table listing different types of activities that some motor vehicle drivers might do while driving. Please indicate how often you participated in each of the following activities <u>during the past 14 days</u> while driving across rail crossings.

	Always	**Often**	**Sometimes**	**Rarely**	**Never**
Look left and right to check for trains when approaching a rail crossing.	○	○	○	○	○
Drive across a rail crossing when the train warning devices *(e.g., lights, bells, etc.)* were activated.	○	○	○	○	○
Drive across a rail crossing when the gates were descending, ascending or in a level position.	○	○	○	○	○
Stop and check for trains when there is a STOP sign at the crossing.	○	○	○	○	○

Talk to other passengers in the vehicle while driving across a rail crossing.	○	○	○	○	○
Eat or drink while driving across a rail crossing.	○	○	○	○	○
Talk on a cell phone while driving across a rail crossing *(including using hands-free arrangements).*	○	○	○	○	○
Text or use Apps on a cellphone or other electronic device while driving across a rail crossing.	○	○	○	○	○
Reach for objects inside the vehicle *(e.g., food, phone, map, etc.)* while driving across a rail crossing.	○	○	○	○	○
Adjust any in-vehicle equipment *(e.g., radio, heater/air conditioning, windows, etc.)* while driving across a rail crossing.	○	○	○	○	○
Distracted by a person, object or event *(e.g., accident)* outside of the vehicle while driving across a rail crossing.	○	○	○	○	○
Mentally not focused on the driving task while driving across a rail crossing.	○	○	○	○	○
Smoking cigarettes while driving across a rail crossing.	○	○	○	○	○
Other distraction *(e.g., personal grooming)* while driving across a rail crossing.	○	○	○	○	○

18. As a motor vehicle driver, please indicate your agreement or disagreement with the following statements.

	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
I believe safety is a significant issue at rail crossings.	○	○	○	○	○
I do not like to wait for passing trains at rail crossings.	○	○	○	○	○
I like to accelerate my vehicle and quickly get across whenever train warning devices get activated.	○	○	○	○	○
I routinely stop when train warning devices are active even if I have a chance to cross the tracks before train arrival.	○	○	○	○	○
I regret stopping when train warning devices were active and I had a chance to get across before arrival of the train at the crossing.	○	○	○	○	○
I like to drive across the tracks after a train has passed even though warning devices may still be active.	○	○	○	○	○
I ensure that all warning devices have stopped after the passage of a train before I drive across the tracks.	○	○	○	○	○
I like to drive around/between fully lowered gates when I can.	○	○	○	○	○
I support technology that will block cellphone signals at rail crossings *(except for emergency calls)* to reduce distracted driving.	○	○	○	○	○
I support stronger law enforcement at rail crossings.	○	○	○	○	○

I am familiar with Operation Lifesaver.	◯	◯	◯	◯	◯
I would like to receive information on rail crossing safety.	◯	◯	◯	◯	◯
Playing "chicken", intentionally stopping a vehicle on a rail crossing in front of an oncoming train, is fun.	◯	◯	◯	◯	◯

19. Have you been involved in any accident or near-accident *(evasive maneuvers had to be taken to avoid an accident)* as a motor vehicle driver in the past 3 years in the vicinity *(1/4 mile)* of rail crossings?

◯ Yes → Please go to question 20

◯ No → Please go to question 23 on page 7

20. Which of the following best describes the type of accident(s) or near accident(s) within 1/4 mile of a rail crossing, you've been involved with as a motor vehicle driver in the past 3 years? *If you've been involved in more than one accident in the past 3 years near a rail crossing, please select all that apply*.

☐ Single-vehicle accident *(i.e., only your vehicle was involved).*

☐ Multi-vehicle accident *(i.e., multiple vehicles were involved).*

☐ Single vehicle near-accident *(i.e., only your vehicle was involved and you had to take an evasive maneuver to avoid an accident).*

☐ Multi-vehicle near-accident *(i.e., multiple vehicles were involved and one or more vehicles took evasive maneuvers to avoid an accident).*

☐ Vehicle-train accident

☐ Vehicle-train near accident *(i.e., you had to take an evasive maneuver to avoid a collision with a train).*

21. In at least one of the accidents or near-accidents, do you believe you or other involved drivers were distracted?

◯ Yes → Please go to question 22

◯ No → Please go to question 23 on page 7

◯ I don't know → Please go to question 23 on page 7

22. Please indicate which of the following activities were involved *(for either yourself or the other driver)* in the accident*(s):*

	Yes	**No**
Talking to other passengers in the vehicle.	○	○
Eating or drinking in the vehicle.	○	○
Talking on a cell phone or other electronic device.	○	○
Texting or using Apps on a cell phone or other electronic device.	○	○
Reaching for objects inside the vehicle (*e.g., food, phone, or map, etc.*)	○	○
Distracted by another person, object, or event outside of the vehicle.	○	○
Mentally not focused on the driving task.	○	○
Smoking cigarettes.	○	○
Other distraction (*e.g., personal grooming*).	○	○

General Information

Your information will be kept strictly confidential.

23. How long have you lived in your city *(the city of your residence at the time of this survey)*?

___________ year(s) and_____________ month(s)

24. Including yourself, how many adult(s) age 18 and older live in your household?

Number of adult(s): ________________

25. How long have you been a licensed driver?

○ Less than a year

○ 1 – 2 years

○ 3 – 5 years

○ 6 – 10 years

○ More than 10 years

26. What is your gender?

- ○ Female
- ○ Male
- ○ Other

27. What is your age group?

- ○ Younger than 20
- ○ 20 – 24
- ○ 25 – 29
- ○ 30 – 34
- ○ 35 – 39
- ○ 40 – 44
- ○ 45 – 49
- ○ 50 – 54
- ○ 55 – 59
- ○ 60 – 64
- ○ 65 – 69
- ○ 70 and older

28. What is your highest level of education?

- ○ Less than High School
- ○ High School diploma or equivalent
- ○ Some college (no degree)
- ○ Associate’s degree
- ○ Bachelor’s degree
- ○ Master’s degree
- ○ Doctorate degree
- ○ Other: ___________

29. Which category best describes your primary occupation?

- ○ Management/Financial
- ○ Government/Military
- ○ Student

- ○ Leisure/Hospitality/Sales/Art
- ○ Construction/Farming/Technical
- ○ Healthcare/Legal/Protective Services
- ○ Transportation/Production
- ○ Office/Administration
- ○ Community/Social/Family
- ○ Computers/Architecture/Engineering/ Science
- ○ Other: ____________
- ○ Unemployed/Laid off
- ○ Retired

30. What is your approximate annual household income (i.e., combined for all household members)?
    - ○ Less than $20,000
    - ○ $20,000 – 29,000
    - ○ $30,000 – 39,999
    - ○ $40,000 – 49,999
    - ○ $50,000 – 59,000
    - ○ $60,000 – 69,999
    - ○ $70,000 – 79,999
    - ○ $80,000 – 89,999
    - ○ $90,000 – 99,999
    - ○ $100,000 – 109,999
    - ○ $110,000 – 119,000
    - ○ $120,000 or higher

31. Please use the space below to provide any comments or feedback.