2012

Truck Safety at Highway-Rail Grade Crossings

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MID-AMERICA TRANSPORTATION CENTER

Report # MATC-UNL: 225

Final Report
25-1121-0001-225

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A Cooperative Research Project sponsored by the U.S. Department of Transportation Research and Innovative Technology Administration

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A Report on Research Sponsored by

Mid-America Transportation Center

University of Nebraska-Lincoln

June 2012

Technical Report Documentation Page

1. Report No. 25-1121-0001-225	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Truck Safety at Highway-Rail Grade Crossings		5. Report Date June 2012
		6. Performing Organization Code
7. Author(s) Aemal Khattak and Miao Gao		8. Performing Organization Report No. 25-1121-0001-225
9. Performing Organization Name and Address Mid-America Transportation Center 2200 Vine St. PO Box 830851 Lincoln, NE 68583-0851		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Research and Innovative Technology Administration 1200 New Jersey Ave., SE Washington, D.C. 20590		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code MATC TRB RiP No. 18469
15. Supplementary Notes		

16. Abstract

Safety at highway-rail grade crossings (HRGC) is a major concern for different agencies because increasing highway and rail traffic presents a greater risk of crashes at these locations. In 2008, there were 2,391 crashes and 523 fatalities reported at grade crossings across the U.S. Of these, 187 crashes were reported in Nebraska, including 35 involving trucks with trailers and 10 involving trucks only. At gated crossings, gate-related violations by truck drivers are a primary cause of collisions between trains and trucks. The objectives of this research were to report on the frequency and type of gate violations by truck drivers at dual quadrant gated HRGCs in Nebraska, and to empirically identify factors that may be associated with those gate violations. Data on gate violations by truck drivers during train crossing events were collected at two HRGCs in Nebraska. Analysis of the data showed that the most frequent violations by truck drivers were passing under ascending gates, followed by drivers passing under descending gates. Violations increased with greater truck traffic at the HRGCs and with longer times between the onset of flashing lights and train arrivals. Analysis also showed nighttime to be associated with a greater frequency of gate violations by truck drivers. The main recommendation for reducing gate violations is to reduce excessively long time intervals between the onset of flashing lights and train arrivals at HRGCs. Recommendations for future research are provided in the report.

17. Key Words: Trains, rail crossing, trucks, safety		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price

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List of Abbreviations

After Train (AT)
Digital Video Recorder (DVR)
Fatality Analysis Reporting System (FARS)
Federal Railroad Administration (FRA)
Flashing Light (FL)
Highway-Rail Grade Crossing (HRGC)
Mid-America Transportation Center (MATC)
Single Unit (SU)
Typically Enforced Violations (TEV)
United States Department of Transportation (US DOT)
Zero-Inflated Poisson (ZIP)

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Executive Summary

Safety at highway-rail grade crossings (HRGC) is a major concern for different agencies because increasing highway and rail traffic presents a greater risk of crashes at these locations. In 2008, there were 2,391 crashes and 523 fatalities reported at grade crossings across the U.S. Of these, 187 crashes were reported in Nebraska, including 35 involving trucks with trailers and 10 involving trucks only. At gated crossings, gate-related violations by truck drivers are a primary cause of collisions between trains and trucks. The objectives of this research were to report on the frequency and type of gate violations by truck drivers at dual quadrant gated HRGCs in Nebraska, and to empirically identify factors that may be associated with those gate violations. Data on gate violations by truck drivers during train crossing events were collected at two HRGCs in Nebraska. Analysis of the data showed that the most frequent violations by truck drivers were passing under ascending gates, followed by drivers passing under descending gates. Violations increased with greater truck traffic at the HRGCs and with longer times between the onset of flashing lights and train arrivals. Analysis also showed nighttime to be associated with a greater frequency of gate violations by truck drivers. The main recommendation for reducing gate violations is to reduce excessively long time intervals between the onset of flashing lights and train arrivals at HRGCs. Recommendations for future research are provided in the report.

Chapter 1 Introduction

According to year 2008 statistics from the Federal Railroad Administration (FRA), there are 222,178 highway-rail grade crossings (HRGC) across the U.S. Grade-separated crossings mitigate the conflict between highways and railroads, but they are expensive to construct and sometimes face opposition from local communities due to negative impacts on businesses. Safety at HRGCs is a concern of different transportation agencies, as the increasing highway and rail traffic presents greater risks of crashes at these locations. In 2004, the Secretary of Transportation's Action Plan for Highway-Rail Grade Crossing Safety was issued by the US DOT. The objectives of this plan were to elevate the importance of highway-rail crossing safety and of adopting uniform measures to deal with the safety issue. During 2008, 2,391 crashes and 523 fatalities were reported at grade crossings across the U.S. by the Fatality Analysis Reporting System (FARS). Of these, 187 crashes were reported in Nebraska, including thirty-five involving trucks with trailers and ten involving single unit (SU) trucks. Therefore, about 24% of the total reported crashes at rail crossings in Nebraska involved trucks.

According to Veli-Pekka et al. (2002), the passing time for a trailer tuck at rail crossings is about four times greater than the passing time of an automobile at the same location. Davery et al. (2008) reported that the danger posed by heavy vehicles at rail crossings was related to factors associated with their physically larger size and heavier mass, as well as the behavior of motor vehicle drivers. In addition, trucks and railroads frequently carry hazardous materials. Therefore, the implications of a truck-involved crash at an HRGC are more ominous. Since significant economic losses and societal impacts may result from truck-involved crashes at HRGCs, and given that rail and truck traffic in the U.S. is expected to grow, it is prudent to investigate factors that contribute to truck-involved crashes at HRGCs. The ultimate goal is to improve HRGC safety.

1.1 Problem Statement

Knowledge of the frequency and type of gate violations by truck drivers at HRGCs, and the factors associated with these violations, is needed to better understand factors that contribute to truck-involved crashes at HRGCs and subsequently implement appropriate safety countermeasures. Unsafe maneuvers by truck drivers in the vicinity of HRGCs with approaching trains are a primary underlying cause of collisions between trains and trucks. Although not all gate violations by truck drivers result in crashes, the frequency of such maneuvers at crossings is an indication of crossing safety. Council et al. (1980) showed that gate violations are an appropriate surrogate measure of crashes. Several studies on unsafe driver behavior at HRGCs have been reported in the literature (reviewed in chapter 2 of the current study), but no published studies on the frequency and type of gate violations by truck drivers at HRGCs were uncovered in the current research. Therefore, there is a need to investigate gate violations at HRGCs by truck drivers.

1.2 Research Objectives and Hypotheses

The objectives of this research were to report on the frequency and type of gate violations by truck drivers at dual quadrant gated HRGCs located in Nebraska, and to empirically identify factors that may be statistically significantly associated with those gate violations. Data were collected at two HRGCs to assess different types of gate violations by truck drivers and counts of those gate violations. An appropriate statistical model was used to investigate relationships between gate violations and different independent variables. Specifically, the hypotheses listed in table 1.1 were statistically tested for validation.

Table 1.1 Research hypotheses

Hypothesis Number	Description
1	The frequency of gate violations by truck drivers at dual quadrant gated HRGCs increases with greater truck traffic during train crossings at the HRGC.
2	The frequency of gate violations by truck drivers increases with longer times between onset of flashing lights and actual train arrivals at crossings.
3	Greater number of gate violations by truck drivers occurs during nighttime compared to other times.
4	The frequency of gate violations at dual quadrant gated HRGCs by truck drivers decreases in rain.
5	The frequency of gate violations at dual quadrant gated HRGCs by truck drivers increases with longer total duration of gate closure.
6	The frequency of gate violations by trucks is greater on weekends compared to weekdays.

1.3 Research Approach

The two study sites utilized in this research were dual quadrant HRGCs in Nebraska. The frequency of gate violations by truck drivers and other factors that may be associated with such maneuvers were observed at these two locations. Other researchers have adopted a similar methodology; for example, Abraham et al. (1998) identified several factors associated with driving violations in evaluating HRGCs in Michigan. The data collection method for the current study is described in the research program section of this report.

The main variable of interest in this research was the count of gate violations by truck drivers at gated HRGCs during train crossing events. Table 2 provides a list of variables that were deemed to be possibly associated with truck drivers' propensity for gate violations. An attempt was made in this research to collect data on as many factors listed in Table 2 as possible, subject to time and budget constraints.

Table 1.2 Variables possibly associated with truck drivers' propensity for gate violations in proximity of HRGCs

Category	Variable
Traffic control at HRGC	Type of traffic signing at crossing, pavement markings, advance train warning time, Time between start of flashing lights and train arrival
Roadway characteristics	Average daily traffic, motor vehicle queue at HRGC when train has passed, pavement type, angle of intersection
Truck characteristics	Number of trucks at crossings, type of truck, weight of truck, trailer length, onboard load
Rail characteristics	Number of trains at the crossing, train length, train speed, train stoppage, train backup
Temporal characteristics	Time of day (peak hour or off peak time),day of week (weekday or weekend), duration of gate closure
Environmental characteristics	Weather conditions, light conditions, time of day, land use around the HRGC

A digital video recorder (DVR) continuously recorded video footage at the two HRGCs from which train crossing events were extracted. Clips of train crossing videos were visually reviewed and information on gate violations by truck drivers, along with other pertinent data, were extracted and populated in a spreadsheet. Data analysis consisted of initially examining descriptive statistics for the collected variables, followed by statistical hypothesis testing.

1.4 Research Assumptions

This research assumed that different types of gate violations by truck drivers at HRGCs were indicative of truck-train HRGC safety. This assumption is supported by the fact that the vast majority of crashes at HRGCs are the result of errors by motor vehicle drivers. Another assumption in this research was that there were no changes in factors that were not collected in this study that may impact truck drivers' behavior. For example, the intensity of traffic law enforcement at the study site was assumed to remain constant for the duration of the study.

1.5 Report Organization

The current chapter is followed by a description of the published literature in chapter 2. Development of a truck-train safety interaction scheme and data collection at the study site are described in chapter 3. Analyses performed on the collected data are presented in chapter 4. Research conclusions are presented in chapter 5 while a reference list completes this report.

Chapter 2 Literature Review

This literature review covers traffic safety at HRGCs, unsafe driver actions at HRGCs, and categorization of gate violations at HRGCs. It also covers statistical modeling when the variable of interest is a count of events (e.g., number of gate violations at an HRGC by truck drivers). A summary of the literature review appears at the end of this chapter.

2.1 Traffic Safety at HRGCs

Transport of freight via rail and trucks has increased, and will likely keep increasing in the future. As a result, more and more trucks will negotiate HRGCs, thereby increasing the chances of truck-train crashes. Multiple publications report on safety systems at rail crossings. Shinar and Raz (1982) studied three different crossing protection systems and found that vehicle speeds reduced significantly when the lights were switched on and the gates were coming down, but reduced only slightly when the lights were switched off and the gates were raised. Gordon et al. (1984) recommended that a perception-reaction time of 3.5 seconds, which is one second longer than the standard 2.5 seconds. Hauer and Persaud (1987) showed that the safety of a rail-highway crossing could be estimated by factors such as train and traffic flows, types of warning measures, geometry, and the accident history of sites. Meeker and Barr (1989) observed that two-thirds of 57 drivers crossed the crossing in front of oncoming trains and only four drivers slowed or stopped; they concluded that drivers made their decision to cross based on their perception of the distance of trains and the time needed to cross.

Publications were reviewed that involved driver characteristics that are prominent factors in HRGC safety. For example, Klein et al. (1994) investigated factors involved in rail crossing fatalities by analyzing FARS data from 1975 to 1992. They reported that frequency of fatal crashes at rail crossings was positively related to: roads with posted speed limits of 55 mph; rural areas; Midwestern states; mostly passenger cars; male drivers; Caucasian drivers between ages of 25 and 34; alcohol involvement; and drivers with relatively less education. Jutaek et al. (2006) examined factors associated with rail crossing crashes. They reported that crash rates increased with greater total traffic volume and average daily train volumes. Davey et al. (2008) reported that risky driving behaviors were mainly caused by misjudgment, drivers trying to save time, higher levels of crossing familiarity, poor sight distances, and inadequate warnings.

2.2 Unsafe Driver Actions at HRGCs

Most crashes at HRGCs are the result of a combination of factors including drivers' failed judgments, HRGC geometric characteristics, traffic control characteristics, and environmental factors. However, gate violations by motor vehicle drivers at HRGCs are also major contributing factors. A study by Sabey and Taylor (1980) showed that human factors contributed to about 95% of all crashes, either singularly or in combination with other factors. Human factors, in combination with roadway and environmental factors, contributed to 28% of all reported crashes.

Leibowitz (1985) showed that inaccurate judgments of train size and speed by motor vehicle drivers frequently made drivers cross hazardously. Tenkink and Van der Horst (1990) observed driver behavior at two Dutch rail crossings with automatic flashing warning lights. The authors reported overall good compliance by drivers; however, some drivers were noted for proceeding immediately after the passage of a train instead of waiting for the end of flashing/warning signs.

A study by Meeker et al. (1997) showed that 67% of drivers crossed rail crossings with flashing lights and bells in front of approaching trains, and 38% of drivers still violated after gates were installed. Most of the drivers who violated did not stop or slow down when the crossing was equipped with gates. The hypothesis of the researchers was that drivers felt it was safer to violate the gate without stopping or slowing. Abraham et al. (1998) found that drivers' behavior was relative to their perception of warning signs; decision making; vehicle control; and risk-taking. Longer warning times led to an increase in unsafe crossing behavior. Davey et al. (2008) reported that a common perception of train drivers was that truck drivers often deliberately increased their speed at HRGCs to "beat the oncoming train." The explanation by truck drivers for this willful risk taking was avoiding delays caused by waiting for trains.

Yeh and Multer (2008) provide a comprehensive review of research that addresses driver behavior at grade crossings, in order to better understand the decisions and actions made by drivers so that countermeasure could be developed to discourage dangerous driving behavior at HRGCs. The document updated an earlier report by Lerner et al. (1990).

2.3 Categorization of Unsafe Maneuvers

Fitzpatrick et al. (1997) classified driver violations into three categories according to time of violation occurrence. Flashing light (FL) violations occurred in a time period from the onset of flashing lights to two seconds after the gate arms began to go down. Typically enforced violations (TEV) were in the period beginning two seconds after the gates started going down (the end of FL period) until train arrival at the crossing. The third category of violations, after train (AT), was recorded after the train departure until the end of flashing lights. Goodell-Grivas (2000) classified violations at HRGCs before the arrival of trains as more risky in comparison to violations occurring after train departure. Hellman et al. (2001) used two categories for four-quadrant gated HRGCs. The first consisted of violations characterized by passing through the crossing after activation of the signal but before the gates were fully lowered. The second consisted of violations that occurred after the gates were lowered but before train arrival. Finally, Khattak (2007, 2008, 2009) considered several categories of maneuvers at HRGCs, including passing around lowered gates or gates in motion, making U-turns when gates were fully lowered, and vehicles backing up from the crossing.

2.4 Statistical Models for Count Data

Traditional linear regression models are not suitable for investigating relationships between dependent variables representing counts of events and other independent variables, since one of the requirements is that the dependent variable be continuous. The Poisson model and its variants, e.g., the negative binomial and the gamma models, are frequently used to model a count variable (Joshua and Garber 1990; Miaou and Lum 1993; Mitra et al. 2002; Geedipally and Lord 2008). The Poisson distribution requires that the mean and variance of a count variable be equal; frequently the variance of a count variable is greater than its mean. Observational data, such as the number of traffic crashes in a year, frequently exhibit this property, which is termed overdispersion. Under such circumstances the negative binomial model is used, which relaxes the requirement that a mean and variance of a count variable be equal. The negative binomial model is based on the Poisson model, except that it has an additional parameter alpha (α), called the overdispersion parameter, that is used to decide which model (Poisson versus negative binomial) is more suitable. Statistical significance of the estimated alpha parameter in a negative binomial model shows the appropriateness of the negative binomial compared to the Poisson model. Washington et al. (2003) and Miaou (1994) have illustrated the use of negative binomial models in the highway safety context. A gamma model is suitable when the variance of a count variable is less than its mean, i.e., the data are underdispersed (Greene 2007).

Other variations of the Poisson model are the zero-inflated Poisson (ZIP) and the zero-inflated negative binomial models (ZINP). These models are useful for count variables that contain more zeros than expected under a Poisson or negative binomial distribution. These models may sometimes offer improved statistical fit and better predictive performance compared to traditional Poisson and NB models (Shankar et al. 1997).

2.5 Summary of Literature Review

In brief, a number of researchers have focused on different aspects of HRGCs safety and classified gate violations in different ways. A review of modeling techniques revealed the appropriateness of the Poisson models for count data with several variations, including the negative binomial, gamma, zero-inflated Poisson, and the zero-inflated negative binomial models.

However, the review did not reveal any published documents specifically dealing with truck drivers’ gate related violations at HRGCs.

Chapter 3 Data Collection

Data collection consisted of focusing on different types of gate violations by truck drivers at two HRGCs located in Nebraska. The following four gate violations were taken into account.

1. Trucks crossing the HRGC with gates descending.
2. Trucks crossing with HRGC gates fully lowered.
3. Trucks crossing between successive trains with fully lowered gates.
4. Trucks crossing while the gates were ascending.

Trucks included in this research were SU trucks and trucks with trailer units (semis). Interaction between trucks and trains constituted an observation, along with a list of associated factors that were extracted from recorded video. A spreadsheet including a coding scheme was developed, which was populated with the collected data.

3.1 Study Sites and Field Data Collection

The data were collected at the N141st St. grade crossing in Waverly and the M-St. crossing in Fremont, both located in Nebraska. The Waverly HRGC (US DOT crossing no. 074940T) comprised of four sets of rail tracks crossing two lanes of roadway and protected by dual-quadrant gates, while the Fremont crossing (US DOT crossing 074662E) consisted of two sets of tracks crossing two lanes of a roadway and protected by dual quadrant gates. Both crossings were equipped with flashing lights, crossbuck signs, and audible bells. Figures 3.1 and 3.2 show the two study sites.

Figure 3.1 HRGC at N 141st street in Waverly, NE (source: Google, Inc.)

Figure 3.2 HRGC at M St. crossing in Fremont, NE (source: Google, Inc.)

A noticeable aspect of the Waverly HRGC was the short distance between the highway traffic signal (on Highway 6 and 141st St.) and the rail crossing. Additionally, a grain elevator in close proximity to the crossing attracted a considerable number of trucks. Day- and night-vision cameras and DVR were installed at both locations to record train crossings. The camera at Waverly was installed on top of a fire station located in the southeast corner of the crossing to capture video footage of train crossings; the camera in Fremont was installed on a utility pole.

Video was recorded during the month of November, 2008, and was later observed in the office. Instances of train crossings with trucks present at the crossing were extracted from the video footage. These video clips were then used for pertinent data extraction and population in a spreadsheet.

A total of 29 variables representing traffic control characteristics, roadway characteristics, temporal characteristics, and environmental characteristics of the HRGC were recorded for each observation. Table 3.1 presents a complete list of those variables and their respective coding.

Table 3.1 Variables and coding scheme

VARIABLE	LABEL	CODING/UNITS
S_NO	Serial number	
DATE	Date of observation	
DAY	Day of week	Mon=1, Tue=2, ..., Sun=7
G_DOWN	Gate down time from start to end of flashing lights	Seconds
T_ARRIVAL	Time between light flashing and train arrival	Seconds
TRAINS	Number of crossing trains	
SIMULTANEOUS	Dummy for simultaneous train crossings	1 if simultaneous, 0 otherwise
STOP	Dummy for train stopped at crossing	1 if stopped, 0 otherwise
CLEAR	Dummy for clear weather	1 if clear, 0 otherwise
RAIN	Dummy for rain	1 if raining, 0 otherwise
WET	Dummy for wet pavement	1 if pavement is wet, 0 otherwise
SNOW	Dummy for snow	1 if snowing, 0 otherwise
SNOW_PVT	Dummy for snow on pavement	1 if snow on pavement, 0 otherwise
FOG	Dummy for fog	1 if fog, 0 otherwise
DAYTIME	Light condition	0 if nighttime, 1 if daytime, 2 if dawn or dusk, 3 if dark or cloudy, 4 if other

Table 3.1 (cont'd.) Variables and coding scheme

N_SU_TRUCKS	Total number of SU trucks observed (includes queue+unsafe maneuvers)	Integer
N_SEMIS	Total number of semis observed (includes queue+unsafe maneuvers)	Integer
SU_GR1	Number of SU trucks crossing with descending gates	Integer
SU_GR2	Number of SU trucks crossing with gates fully lowered	Integer
SU_GR3	Number of SU trucks crossing with gates ascending	Integer
SU_GR4	Number of SU trucks crossing between successive trains	Integer
SEMI_GR1	Number of semis crossing with gates descending	Integer
SEMI_GR2	Number of semis crossing with gates fully lowered	Integer
SEMI_GR3	Number of semis crossing with gates ascending	Integer
SEMI_GR4	Number of semis crossing between successive trains	Integer
SU_UTURN	Number of SU trucks making U-turns	Integer
SU_B_UP	Numbers of SU trucks backing up	Integer
SEMI_UTURN	Number of semis making U-turns	Integer
SEMI_B_UP	Numbers of semis backing up	Integer

An example of data extraction is aided by figures 3.3 and 3.4, and table 3.2. In figure 3.3, time and date information for the observation is displayed at the bottom-left of the screen. Using the controls visible to the right of the screen, the video clip was played and observed for gate violations by trucks. Weather conditions from the video clip were observed by data collectors. Figure 3.4 shows the onset of a gate activation due to an oncoming train. The total time of the train crossing event was calculated by noting the times of flashing light activation and de-activation. The time interval between flashing light activation and train arrival at the crossing was calculated in a similar manner. Other variables, such as number of trains, stoppage of trains, violations of truck drivers, and truck traffic, were observed by data collectors and populated in a spreadsheet with pre-defined variables and values (given in table 3.1). Table 3.2 shows a sample of observation data populated from the captured video. A total of 476 train crossing observations with trucks were collected.

Figure 3.3 Interface of DVR software

Figure 3.4 Onset of HRGC gate activation

Table 3.2 Example of data extraction for a single observation

S_NO	DATE	DAY	G_DOWN	T_ARRIVAL	TRAINS
51	12/10/2008	1	150	33	1
SIMULTANEOUS	STOP	CLEAR	RAIN	WET	SNOW
0	0	1	0	0	0
SNOW_PVT	FOG	DAYTIME	N_SU_TRUCKS	N_SEMIS	SU_GR1
0	0	1	1	1	0
SU_GR2	SU_GR3	SU_GR4	SEMI_GR1	SEMI_GR2	SEMI_GR3
0	0	0	1	0	0
SEMI_GR4	SU_UTURN	SU_B_UP	SEMI_UTURN	SEMI_B_UP	
0	0	0	0	0	

Chapter 4 Data Analysis

Data analysis began with a preliminary and was followed by a more detailed analysis of gate violations by truck drivers. The preliminary analysis consisted of calculating frequencies, means, and variances for different variables. The preliminary analysis was performed mainly using SPSS (version 18); this analysis is subsequently described.

4.1 Preliminary Data Analysis

As previously stated, four different types of gate violations were monitored during data collection. These included passing under descending gates, passing around fully lowered gates, passing under ascending gates, and passing around fully lowered gates between successive trains. Figure 4.1 shows the number of observations with zero, one, or two gate violations. No gate violation was observed in 78.2% of the observations, while a single violation was observed in 21.6% of the observations. Only in a single observation were two trucks involved in gate-related violations. Figure 4.2 shows the frequency of different types of observed gate violations; the most frequent was passing under ascending gates (19.7%), followed by passing under descending gates (1.7%), while 0.6% of the violations involved SU trucks passing around fully lowered gates. No trucks were observed passing around gates between successive trains at the two observed HRGCs.

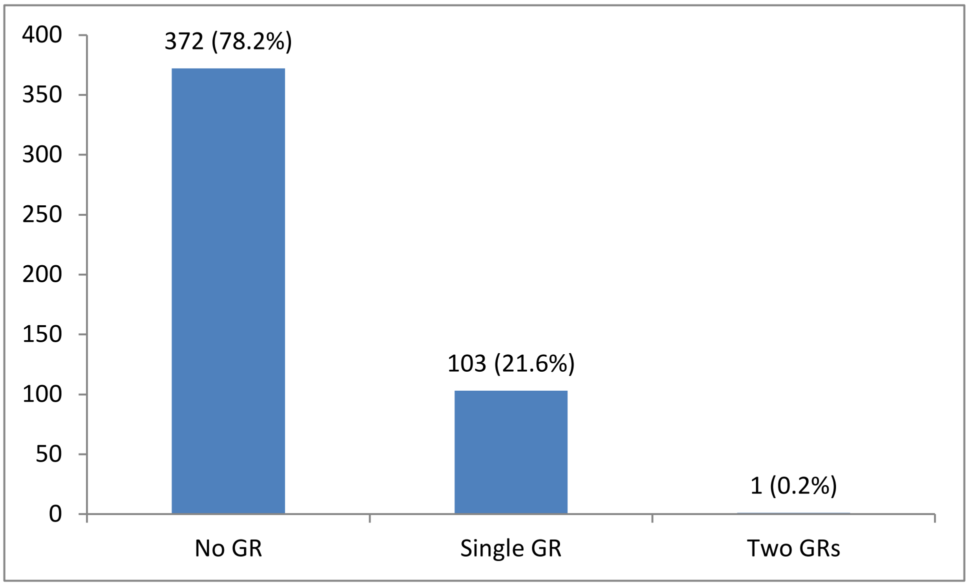

Figure 4.1 Observations with different number of gate violations

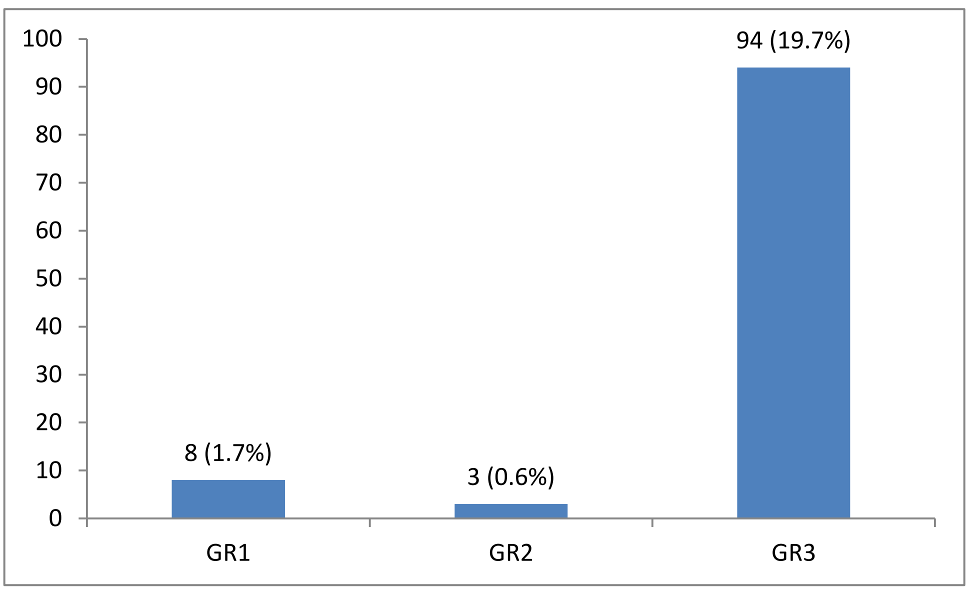

Figure 4.2 Frequency of different types of gate violations

Figure 4.3 shows the distribution of observations on different days of the week. Most (22.3%) of the observations were made on Tuesday, with somewhat equal observations made on

Monday, Wednesday, Thursday, and Friday. Fewer observations were collected on Saturday and Sunday. Figure 4.4 presents the distribution of observations across different times of the day. The majority (69.1%) of observations were collected during daytime, while somewhat equivalent observations were collected under dark or cloudy, dawn or dusk, and nighttime conditions, respectively.

Table 4.1 presents descriptive statistics for the collected data. The average event time was 363.5 seconds (about 6 minutes). The mean time between the start of flashing lights and train arrival at the crossing was 46.1 seconds (provision of 20 seconds as a minimum is mandated). The following section presents a more detailed analysis that includes the testing of the hypotheses listed in table 1.1.

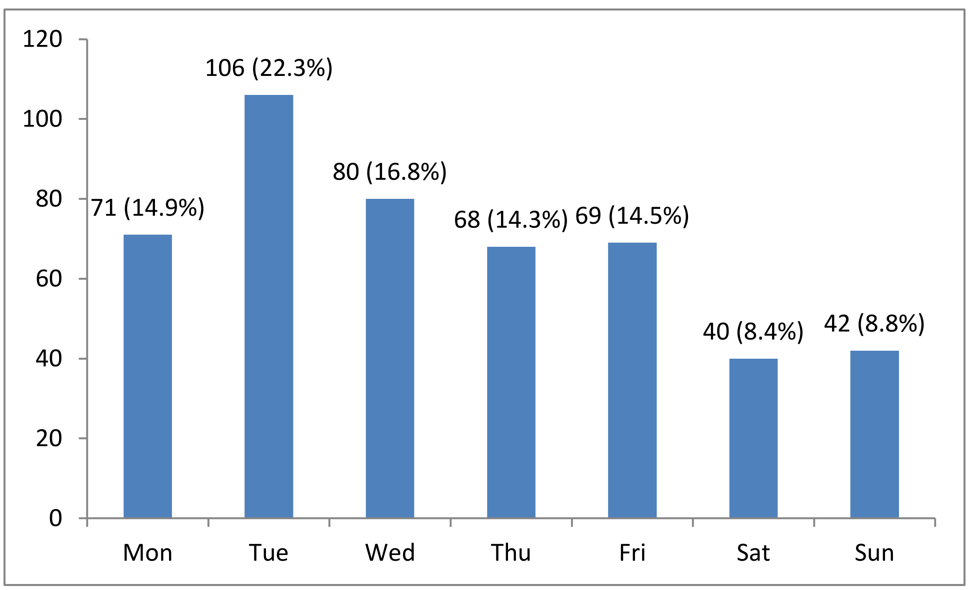

Figure 4.3 Collection of observations on different days of the week

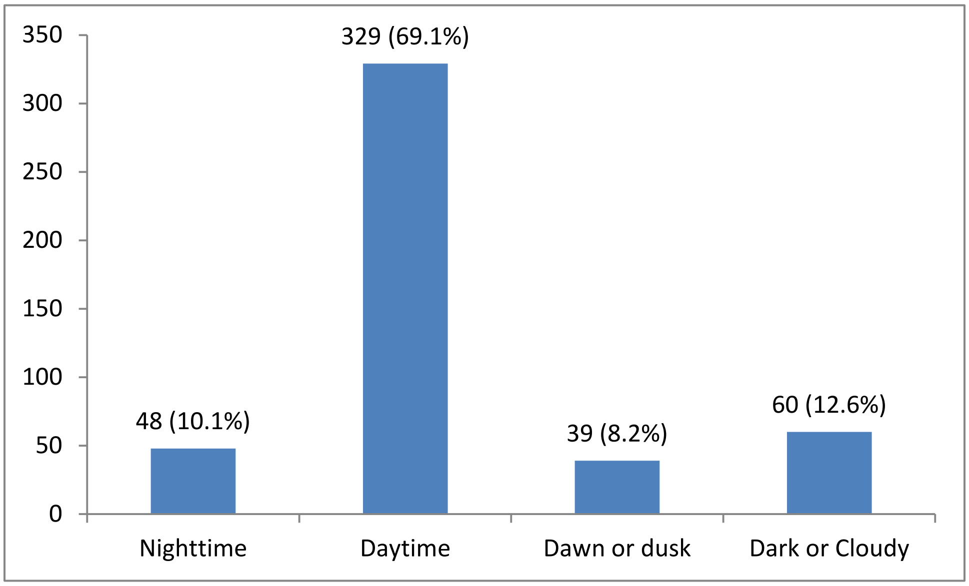

Figure 4.4 Time of day distribution of observations

Table 4.1 Descriptive statistics for the collected data

Variable	Description	Missing Values	Mean	Std. Deviation	Minimum	Maximum
GR_TOTAL	Total truck (su+semi) gate rushes	0	0.221	0.420	0	2
DAY	Day of week, Mon=1,..Sun=7	0	3.517	1.857	1	7
G_DOWN	Gate down time from start to end of flashing lights (seconds)	2	363.568	309.960	43	3019
T_ARRIVAL	Time between light flashing and train arrival (seconds)	3	46.106	40.598	0	859
TRAINS	Number of crossing trains	0	1.143	0.401	0	3
SIMULTANEOUS	Dummy for simultaneous train crossings	0	0.139	0.346	0	1
STOP	Dummy for train stopped at crossings	0	0.193	0.395	0	1
CLEAR	Dummy for clear weather	0	0.893	0.310	0	1
RAIN	Dummy for rain	0	0.032	0.175	0	1
WET	Dummy for wet pavement	0	0.084	0.278	0	1
SNOW	Dummy for snow	0	0.019	0.136	0	1
SNOW_PVT	Dummy for snow pavement	0	0.080	0.271	0	1
FOG	Dummy for fog	0	0.004	0.065	0	1

Table 4.1 (cont'd.) Descriptive statistics for the collected data

DAYTIME	Light condition, 0=nighttime,1=daytime,2=dawn or dusk,3=dark or cloudy,4=other	0	1.233	0.796	0	3
N_SU_TRUCKS	Total number of single unit trucks observed (includes queue+unsafe maneuvers)	0	0.708	0.559	0	3
N_SEMIS	Total number of semis observed (includes queue+unsafe maneuvers)	0	0.309	0.485	0	2
SU_GR1	Number of single unit trucks crossing with gates descending	0	0.008	0.091	0	1
SU_GR2	Number of single unit trucks crossing with gates fully lowered	0	0.006	0.079	0	1
SU_GR3	Number of single unit trucks crossing with gates ascending	0	0.147	0.355	0	1
SU_GR4	Number of single unit trucks crossing between successive trains	0	0.000	0.000	0	0
SEMI_GR1	Number of semis crossing with gates descending	0	0.008	0.091	0	1
SEMI_GR2	Number of large semis crossing with gates fully lowered	0	0.000	0.000	0	0
SEMI_GR3	Number of semis crossing with gates ascending	0	0.050	0.219	0	1
SEMI_GR4	Number of semis crossing between successive trains	0	0.000	0.000	0	0
LOCATION	Fremont or Waverly	0	1.534	0.499	1	2
TRUCK QUEUE	Number of trucks in queue	0	1.126	0.391	1	4
WEEKEND	Dummy for weekend	0	0.172	0.378	0	1
DAY	Dummy for daytime (daytime=1)	0	0.691	0.462	0	1

4.2 Detailed Data Analysis

Detailed data analysis involved analyzing the frequency of gate related violations by truck drivers and statistically testing the hypotheses listed in table 1.1 The Poisson model or its variations were appropriate for use, as the variable of interest consisted of gate violation counts during train crossing events. The Poisson model allows the establishment of a relationship between a dependent (count) variable and a number of independent variables. For a discrete random variable Y, such as number of gate violations, with observed frequencies y_i = 1, 2, …,N (where $y_i \geq 0$), the probability that the observed frequencies are the real frequencies is:

$$prob(Y = y_i) = (e^{-\lambda_i}\lambda_i^{y_i})/(y_i!) \tag{4.1}$$

$$ln\lambda_i = \beta' X_i \tag{4.2}$$

where,

β'= estimated vector of parameters

X_i= vector of gate rush relevant characterizes for observation i, and

λ_i= mean and the variance of the observed gate rush frequency

The Poisson model requires that the mean and variance of the count variable be the same. Many times this requirement is not met, and an alternative model is needed. The negative binomial model relaxes this requirement and serves as an alternate model. The resulting probability distribution is:

$$prob[Y = y_i|\epsilon] = \exp[-\lambda_i \exp(\epsilon)]\lambda_i^{y_i}/y_i! \qquad (4.3)$$

where,

ϵ= error term, (1, α^2). Integrating ϵ out of the above equation produces the unconditional distribution of y_i. The equation for this distribution is:

$$prob[Y = y_i] = \Gamma(\theta + y_i)/[\Gamma(\theta)y_i!]\mu_i^{\theta}(1 - \mu_i)^{y_i} \qquad (4.4)$$

where,

$prob[Y = y_i] =$ probability of the *i*th gate violation,

$\mu_i = \theta/(\theta + \lambda_i)$, and

$\theta = 1/\alpha$

Both the Poisson and the negative binomial models can be estimated by the standard maximum-likelihood methods. A measure of the goodness-of-fit for an estimated model is the fraction of a restricted log-likelihood:

$$\rho^2 = 1 - [\frac{L(\beta)}{L(0)}] \quad (4.5)$$

where,

$L(\beta)$= log likelihood and $L(0)$= restricted log likelihood.

The value of ρ for an estimated model is between 0 and 1; a greater value of ρ indicates a better fitting model compared to models with lower values of ρ. A chi square test is used to judge the overall usefulness of the model, which measures the sum of the differences between observed and expected outcome frequencies; therefore the statistical significance of chi square indicates that the model is providing useful information. The equation is:

$$\chi^2 = \sum_{i=1}^{n} \frac{(y_i - Y_i)^2}{Y_i} \quad (4.6)$$

NLOGIT 4.0 was used for model estimation. Estimated coefficients in the model were statistically tested using a student's t-test to assess if they were different than zero at 95% or 90% confidence levels. Absolute t-statistic values of 1.96 or greater and 1.64 or greater indicated statistical significance at the 95% and 90% confidence levels, respectively.

Table 4.2 shows the estimated model with relevant summary statistics. Overall, the estimated model provided useful information even though the overall model fit was not very good. A positive estimated coefficient shows that the frequency of gate violations by trucks increased with increasing values of the variable, while a negative estimated coefficient indicates that gate violations decreased with increasing values of the variable.

Table 4.2 Estimated model for gate violations by trucks at HRGCs

Variable	Description	Est. Coeff.	Std. error	t-statistic	Mean
N_SU_TRUCK	Total number of SU trucks	0.709	0.212	3.345	0.706
N_SEMIS	Total number of semis	0.586	0.254	2.308	0.309
T_ARRIVAL	Time between lights flashing and train arrival (sec)	0.003	0.002	1.989	46.106
NIGHT	Dummy variable for nighttime	0.477	0.273	1.750	0.101
RAIN	Dummy variable for rain	-1.221	0.958	-1.275	0.032
Constant	Constant in the model	-2.424	0.275	-8.808	-
	Model summary statistics				
	Number of observations	473			
	Log likelihood	-255.821			
	Restricted Log likelihood	-263.732			
	Rho-squared	0.030			
	Chi squared	15.822			
	P-value for chi squared	0.007			

Two variables indicating the number of SU trucks (N_SU_TRUCKS) and semis (N_SEMIS) encountered during train crossing events were included in the model specification to test Hypothesis 1 (listed in table 1.1). Together, the variables represent truck exposure to involvement in gate violations. Both variables were statistically significant at the 95% confidence level, indicating that gate violations increased with greater numbers of SU trucks and semis arriving at HRGCs, thus confirming Hypothesis 1. The greater value of the estimated coefficient for SU trucks compared to the coefficient for semis showed that SU truck drivers were more prone to gate violations, in comparison to drivers of semis.

The variable T_ARRIVAL represented the time between the start of flashing lights and train arrival at the crossings. This time depends on the speed of approaching trains, and a minimum stipulated value of 20 seconds must be provided. The estimated coefficient was positive and statistically significant at the 95% confidence level, showing that longer values of T_ARRIVAL were associated with greater gate violations at the HRGCs. This result confirms Hypothesis 2 listed in Table 1.

To test Hypothesis 3, the model specification included a dummy variable for nighttime. The estimated coefficient for this variable was positive and statistically significant at the 90% confidence level (t-statistic >1.64), thus confirming Hypothesis 3. The finding regarding nighttime was that it was associated with a greater frequency of gate related violations in comparison to daylight, dawn, and dusk, etc. Finally, a dummy variable for rain was included in the model to explore its association with the frequency of gate related violations by trucks (i.e., Hypothesis 4). The estimated coefficient was negative, indicating that gate violations occurred less frequently during conditions of rain; however, the estimate was not statistically significant at the 90% confidence level, and therefore the collected data did not provide enough evidence to make a conclusive statement regarding the effect of rain on gate violations by truck drivers. Hypotheses 5 (duration of gate closure) and 6 (weekends versus weekdays) were tested and found to not be substantiated by the model. These two variables were then removed from the model specification.

Other variables available in the database were also tested in the model specification, but were found not to be statistically significant. These included: the number of crossing trains, train stoppage on the crossing, and a dummy variable for crossing location (Waverly or Fremont). These variables were excluded from the model specification for parsimony.

Chapter 5 Conclusions and Recommendations

The objectives of this research were to report on the frequency and type of gate violations by truck drivers and to empirically identify factors associated with such gate violations. Four types of violations were monitored: trucks passing under descending gates, trucks passing around fully lowered gates, trucks passing under ascending gates, and trucks passing around fully lowered gates between successive trains. Data were collected at two HRGCs and analyzed; no trucks were observed passing around gates between successive trains at the two observed HRGCs. Analysis indicated that about 20% of the observations involved trucks passing under ascending gates, with relatively few trucks passing under descending gates, and even fewer trucks passing around fully lowered gates. Results of a Poisson model confirmed the hypotheses that a greater frequency of violations was associated with the variables of greater truck traffic at the HRGCs; longer durations between the onset of flashing lights and train arrival at the crossing; and nighttime. Based on these findings, the following conclusions were reached.

- Gate related violations at HRGCs by truck drivers mainly included passing under descending or ascending gates.
- Longer times between the onset of flashing lights and train arrivals at HRGCs contributed to greater frequencies of gate violations.
- Nighttime was associated with greater frequencies of gate violations by truck drivers.

To improve safety at HRGCs the following recommendations were offered:

- The time interval between the onset of flashing lights and actual train arrival at HRGCs should not be excessively large beyond the minimum 20 seconds required.
- Countermeasures aimed at reducing gate violations at nighttime should be investigated, including driver education and enforcement of motor vehicle laws at HRGCs.

Certain aspects of truck safety at HRGCs need further investigation. These include the collection and analysis of data on characteristics of drivers involved in gate violations; wider geographic and temporal coverage of HRGCs in the analysis; and implementation and assessment of countermeasures for reducing gate violations by truck drivers. Moreover, though this research did not find statistically significant evidence regarding the effect of rain on gate violations by truck drivers, the effects of weather on HRGC safety warrant future study.

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