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Driver Behavior Analysis at Highway-Rail Grade Crossings using Field Operational Test Data – Heavy Trucks

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13. ABSTRACT (Maximum 200 words) The United States Department of Transportation's (U.S. DOT) Research and Innovative Technology Administration's (RITA) John A. Volpe National Transportation Systems Center (Volpe Center), under the direction of the U.S. DOT Federal Railroad Administration (FRA) Office of Research and Development (R&D), conducted a research study focused on collecting and analyzing data related to driver characteristics at or on approach to highway-rail grade crossings. Volpe Center reviewed and coded 3,171 grade crossing events involving heavy vehicle drivers collected during a recent field operational test of vehicle safety systems. The data collected for each grade crossing included data about drivers' activities, driver and vehicle performance, driving environment, and vehicle location at or on approach to highway-rail grade crossings. One of the findings of the data analysis was that, on average, drivers were likely to engage in secondary tasks, an indicator of distraction, about 21 percent of the time while traversing a highway-rail grade crossing. Additionally, results showed that drivers failed to look either left or right on approach to passive grade crossings about 41 percent of the time. The ultimate objective of the research is to provide the basic driver behavior research needed to identify potential driver education/awareness strategies that would best mitigate risky driver behavior at grade crossings.			
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

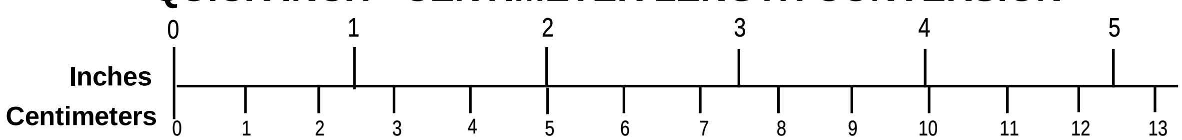
VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

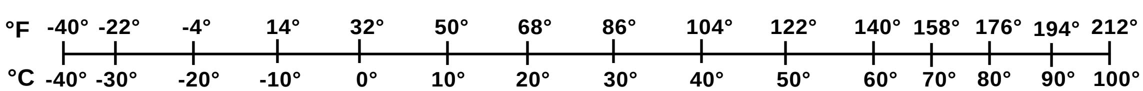
TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIC



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Executive Summary

In order to improve safe driving behavior at highway-rail grade crossings, it is important to understand driver actions at or on approach to highway-rail grade crossings. Thus, in order to gain better understating of the problem, the U.S. Department of Transportation's (U.S. DOT) Federal Railroad Administration's (FRA) Office of Research and Development (R&D) funded a project to review and analyze driver's activities at or on approach to highway-rail grade crossings. This effort was conducted under the auspices of the Highway-Rail Grade Crossing Safety and Trespass Prevention Research Program at the John A. Volpe National Transportation Systems Center (Volpe Center). The research team used data recently obtained from the Integrated Vehicle Based Safety System (IVBSS) Field Operational Test (FOT) sponsored by the U.S. DOT National Highway Traffic Safety Administration (NHTSA) for analysis of driver behavior at or on approach to highway-rail grade crossings. This report presents the findings related to heavy-truck driver behavior at and on approach to highway-rail grade crossings as analyzed from the IVBSS Heavy Truck (HT) FOT data.

Analysis of the IVBSS HT FOT data yielded a subset of 3,171 grade crossing events, or instances, where the IVBSS HT research vehicle traversed a grade crossing. The research team then reviewed and coded the 3,171 grade crossing events. The data collected for each grade crossing event included data about drivers' activities, driver and vehicle performance, driving environment, and vehicle location at or on approach to highway-rail grade crossings.

The results of the data analysis revealed that, on average, commercial drivers in the study were likely to engage in secondary tasks, an indicator of driver distraction, about 20.8 percent of the time. The data also indicated that pickup and delivery drivers, as well as drivers with a Commercial Driver's License (CDL) for less than 22 years, were more likely to be engaged in secondary tasks compared to line-haul drivers and drivers who had a CDL for 22 years or more. The average length of CDL experience was 22 years for the study sample.

Analysis of looking behavior on approach to grade crossings showed that drivers looked at least one way at or on approach to highway-rail grade crossings about 60.5 percent of the time. When analyzed by age group, the data revealed that younger drivers (less than the study average of 47 years old) were more likely to look at least one way at or on approach to highway-rail grade crossings than older drivers (47 years old or older). Roughly 64.1 percent of younger drivers looked at least one way compared to 51.1 percent for older drivers. The data also indicated that at or on approach to highway-rail grade crossings, drivers with a CDL for 22 years or more looked at least one way 69.2 percent compared to 56.8 percent for drivers with a CDL for less than 22 years.

Evaluating the effectiveness of motorist and pedestrian signs and treatment is a top research priority. The authors hope the results presented in this report provide the basic driver behavior research needed to identify and guide potential driver education/awareness strategies that would best mitigate risky driver behavior at grade crossings.

1 Introduction

In 1994, the U.S. Department of Transportation (U.S. DOT) *Rail-Highway Crossing Safety Action Plan* [1] set a goal to reduce grade crossing collisions and fatalities nationwide by 50 percent over 10 years. The U.S. DOT came close to meeting its goal. From 1994 to 2003, incidents between trains and highway users were reduced by 40.4 percent, from 4,999 to 2,977. Over that same period, fatalities were reduced by 45.9 percent from 617 to 334 [2]. In 2006, the U.S. DOT Research and Innovative Technology Administration's John A. Volpe National Transportation Systems Center (Volpe Center) completed a study to identify factors that aided in the successful reduction of these incidents. The study identified Commercial Driver Safety as the factor responsible for the largest reductions in incidents from 1994 to 2003 [3]. One of the major commercial driver safety components was the creation in 1999 of the Federal Motor Carrier Safety Administration (FMCSA), whose major purpose is to reduce the number and severity of large-truck crashes by emphasizing commercial vehicle safety. One of the FMCSA's most significant accomplishments to date has been the passage of the Commercial Driver Disqualification law (CFR 383.51) in October 1999, which states that commercial drivers convicted of violating the highway-rail grade crossing warning devices will have their CDL suspended.

Figure 1 shows the incident rate per one billion Vehicle Miles Travelled (VMT) for commercial vehicles (Truck and Truck-trailer), and all other vehicle types over the past decade. As can be seen from the chart, commercial vehicles have the highest rate of incident per VMT, but they also have the largest reduction over that period. The incident rate decreased by 60.8 percent for commercial vehicles compared to 36.9 percent for all other vehicle types from 2001 to 2010. However, in 2010, the commercial vehicle incident rate was still almost three times greater than the incident rate for all other vehicle types.

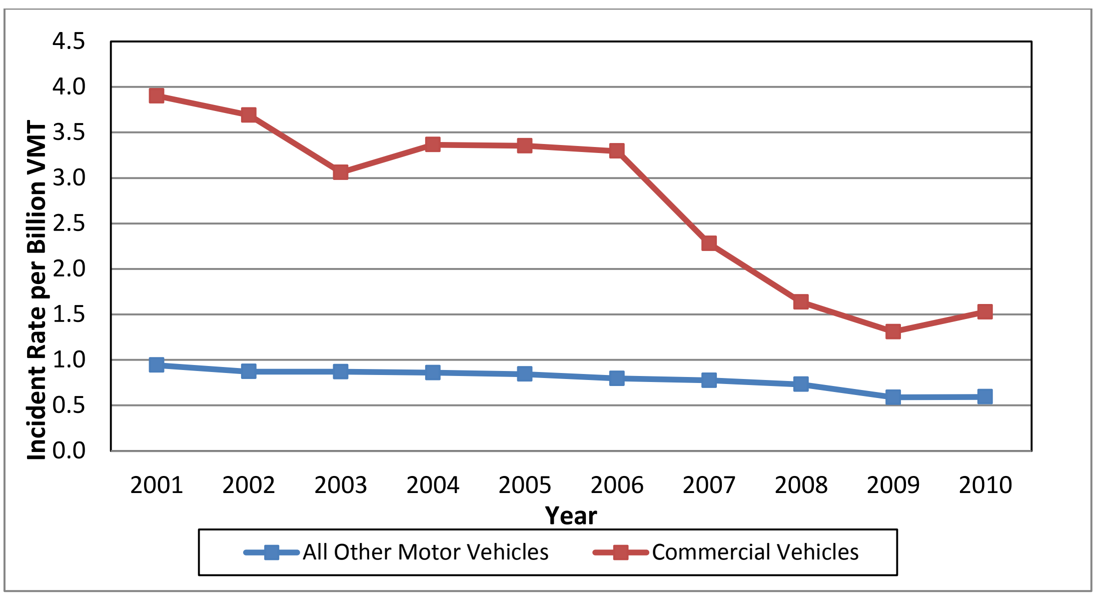

Figure 1. Incident Rate per Billon VMT for Commercial Vehicles and All Other Vehicle Types

The need to conduct research on driver behavior issues at grade crossings was highlighted in the 2009 *US DOT Federal Railroad Administration's Third Research Needs Workshop on Highway-Rail Grade Crossing and Trespass Prevention* sponsored by the Federal Railroad Administration (FRA) [4]. That workshop, held as a forum to exchange ideas, concepts, and strategic planning, resulted in the identification of high-priority research needs. Evaluating the effectiveness of motorist and pedestrian signs and treatment, as well as researching driver behavior, were classified as top priorities.

In order to improve driver behavior at highway-rail grade crossings, it is important to understand driver actions at or on approach to grade crossings. Thus, to gain a better understating of the problem, the U.S. DOT FRA Office of Research and Development (R&D) funded a project to review and analyze driver activity at or on approach to highway-rail grade crossings. Volpe Center used data obtained in 2010 from the Integrated Vehicle Based Safety System (IVBSS) Heavy Truck Field Operational Test (FOT) sponsored by the U.S. DOT National Highway Traffic Safety Administration (NHTSA) for this effort focused on studying heavy-truck driver behavior at and on approach to highway-rail grade crossings.

The IVBSS program was established in November of 2005 to develop and test an integrated, vehicle-based, crash warning system that would help reduce rear-end lane change and roadway departure crashes for light vehicles and heavy commercial trucks. It was a cooperative research agreement between the U.S. DOT and an industry team led by the University of Michigan Transportation Research Institute (UMTRI) to assess the potential safety benefits and drivers' acceptance of an integrated crash warning system [5].

The Volpe Center's Advanced Vehicle Technology Division had performed an independent evaluation of the IVBSS program (in support of the NHTSA) which included analysis of video and numerical data collected during the IVBSS FOT. The Volpe Center's Highway-Rail Grade Crossing Safety and Trespass Prevention Research Program leveraged the NHTSA-sponsored evaluation program to perform research into driver behavior at or on approach to highway-rail grade crossings.

1.1 Project Objectives

The main objectives of this project were:

- To conduct a feasibility assessment of using the IVBSS Heavy Truck FOT data to perform highway-rail grade crossing driver behavior analyses
- To collect and analyze driver activity at or on approach to highway-rail grade crossing

These objectives were achieved through the analysis of video and numerical data gathered from the IVBSS HT FOT. The data collection and analysis focused on events where the test vehicles were on approach and traveled over grade crossings. The ultimate objective of the research was to provide the basic driver behavior information needed to identify potential driver education/awareness strategies that would best mitigate risky driver behavior at grade crossings.

2 Overview of the IVBSS Heavy Truck FOT Data

The majority of the background information presented in this section was obtained from the reports titled "Integrated Vehicle-Based Safety Systems Heavy-Truck Field Operational Test Independent Evaluation" [6] and "Integrated Vehicle-Based Safety Systems Heavy-Truck Field Operational Test Key Finding Report" [7].

The IVBSS HT FOT was conducted over a period of 10 months (mo) from February 2009 to December 2009. It included 20 commercial truck drivers from Con-way Freight, Inc. and 10 research vehicles. Each research vehicle was assigned to one pickup and delivery (P&D) and one line-haul (LH) driver. P&D drivers worked during day time, and LH drivers worked the night shift. Each driver drove a research vehicle for a period of 10 months.

2.1.1 Characterization of the IVBSS HT FOT Fleet

The research vehicles were comprised of 10 single International ProStar 8600-series tractors. The heavy truck platform provided the following crash warning functions:

- Forward crash warning (FCW)—warns drivers of the potential for a rear-end crash with another vehicle;
- Lateral drift warning (LDW)—warns drivers that they may be drifting inadvertently from their lane or departing the roadway; and
- Lane-change/merge warning (LCM)—warns drivers of possible unsafe lateral maneuvers based on adjacent vehicles or vehicles approaching in adjacent lanes, and includes full-time side-object-presence indicators. LCM also includes a blind-spot detection (BSD) component that provides drivers with information about vehicles in their blind spot [7].

2.1.2 Participants

The 20 participants from Con-way Freight, Inc. were comprised of 10 P&D drivers and 10 LH drivers. These driver categories were defined as follows:

> *Pickup and delivery drivers worked during the day, making many short trips throughout the metropolitan Detroit area to pick up and deliver goods. Line-haul drivers worked the night shifts, generally making one long round-trip delivery* [6].

Although 20 drivers were recruited for the FOT, data from only 18 drivers was included in the analysis. As noted in the IVBSS report, two P&D drivers did not accumulate sufficient mileage during the test and therefore were not included for final analysis [6]. The 18 participants ranged in age from 32 to 63 years old, with an average age of 47 years. On average, LH drivers tended to be older and had held CDLs for longer than P&D drivers, as shown in Table 1. Data for number of years with CDL was not available for driver number 29 and therefore that driver was not included in any analysis related to years with CDL.

Table 1. **Demographic of the Field Test Participants**

	Driver Number	Age	Years with CDL	Years Employed by Con-way	Education Level
Pickup and delivery	1	46	22	15	High School
	2	46	13	10	High School
	4	32	10	10	High School
	5	43	21	10	High School
	6	44	12	9	High School
	7	52	33	8	High School
	8	38	14	11	High School
	10	63	15	14	High School
Line-haul	21	51	30	25	High School
	22	48	27	24	High School
	23	54	35	21	High School
	24	48	25	20	High School
	25	45	21	15	Some College
	26	52	23	18	High School
	27	49	25	19	High School
	28	46	25	12	Some College
	29	53	?	9	11th Grade
	30	40	18	10	High School
Average P&D		45.5	17.5	10.9	
Average LH		48.6	25.4	17.3	
Average All		47.2	21.7	14.4	

2.1.3 IVBSS HT FOT Data

A wide range of video and numerical data was collected during the IVBSS HT FOT. The data were collected and stored in a Data Acquisition System (DAS) installed in each research vehicle. Both video and numerical data were collected continuously throughout a trip. A trip was defined by the vehicle ignition cycle (i.e., from the time the vehicle ignition was turned on until it was turned off) [7]. Data was retrieved from the DAS at the end of the testing period when a participant returned the research vehicle to UMTRI.

The numerical data were collected using the integrated system that was installed in each research vehicle. The system collected data related to vehicle performance, driver performance, vehicle location, and driving environment. The raw numerical data was stored in a Structured Query Language (SQL) database format. The complete list of numerical data collected for the analysis of grade crossing events is provided in Appendices A, B, and C.

The video data was collected from five cameras that were installed inside each research vehicle. The cameras were placed strategically to capture the forward view, driver's face, cabin/instrument panel, exterior left side of the vehicle, and exterior right side of the vehicle.

For the IVBSS Heavy Truck FOT, the overall data set consisted of 21,289 trips covering a total of 497,385 miles (mi). Figure 2 and Figure 3 show the geographical range of FOT travel by the P&D and LH drivers, respectively, based on destination points [6]. Most driving, relative to mileage, took place in the lower peninsula of Michigan (63 percent) and in Ohio (33 percent), with a small portion taking place in northern Indiana (4 percent) [6]. Travel ranged as far north as Gaylord, Michigan, south to Cincinnati, Ohio, east to Lordstown, Ohio, and west to Gary, Indiana. Based on drivers' end destination, the study area selected for this research consisted of highway-rail grade crossings in Michigan, Ohio, and Indiana. Grade crossings in these three States, where most of the travel took place, were selected to cross-reference with routes traveled by each research vehicle to determine vehicle presence at highway-rail grade crossings.

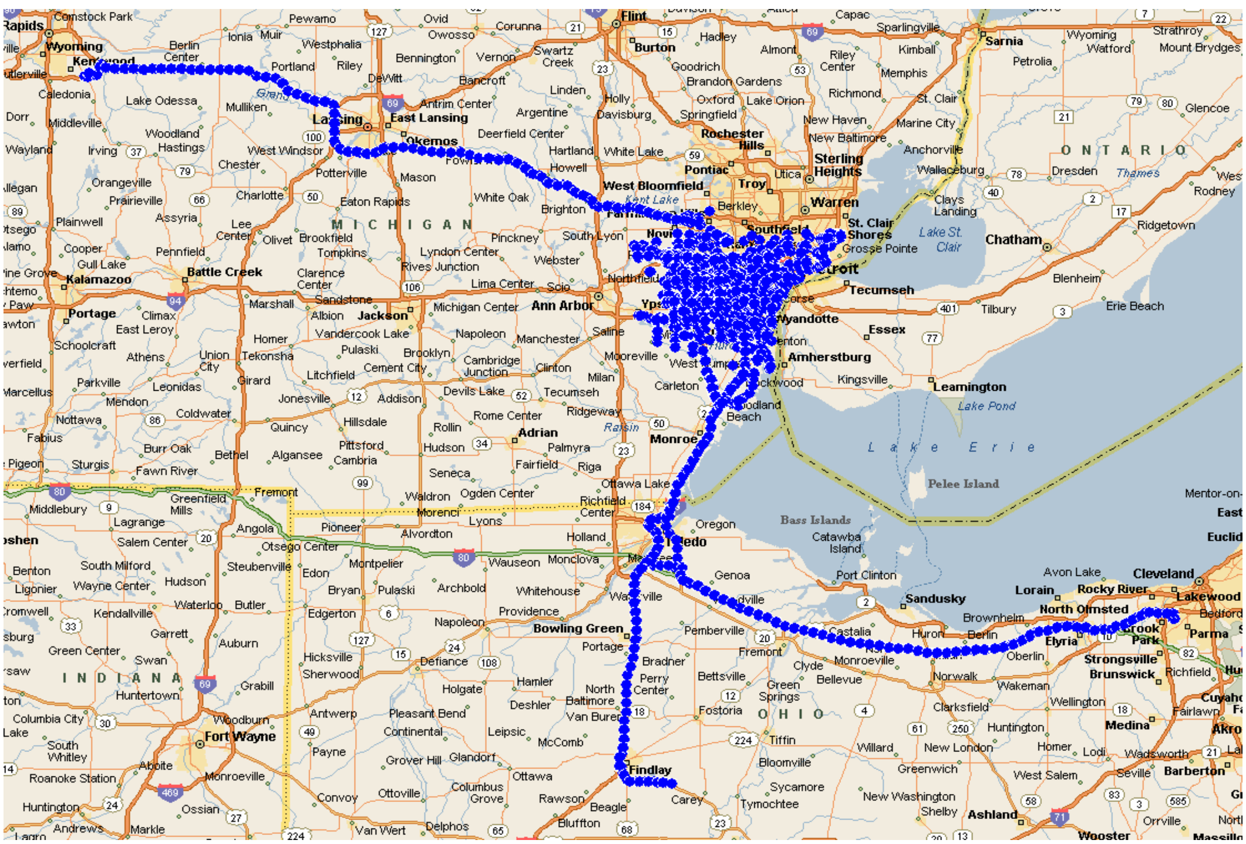

Figure 2. Geographical Range of Driving by P&D Drivers

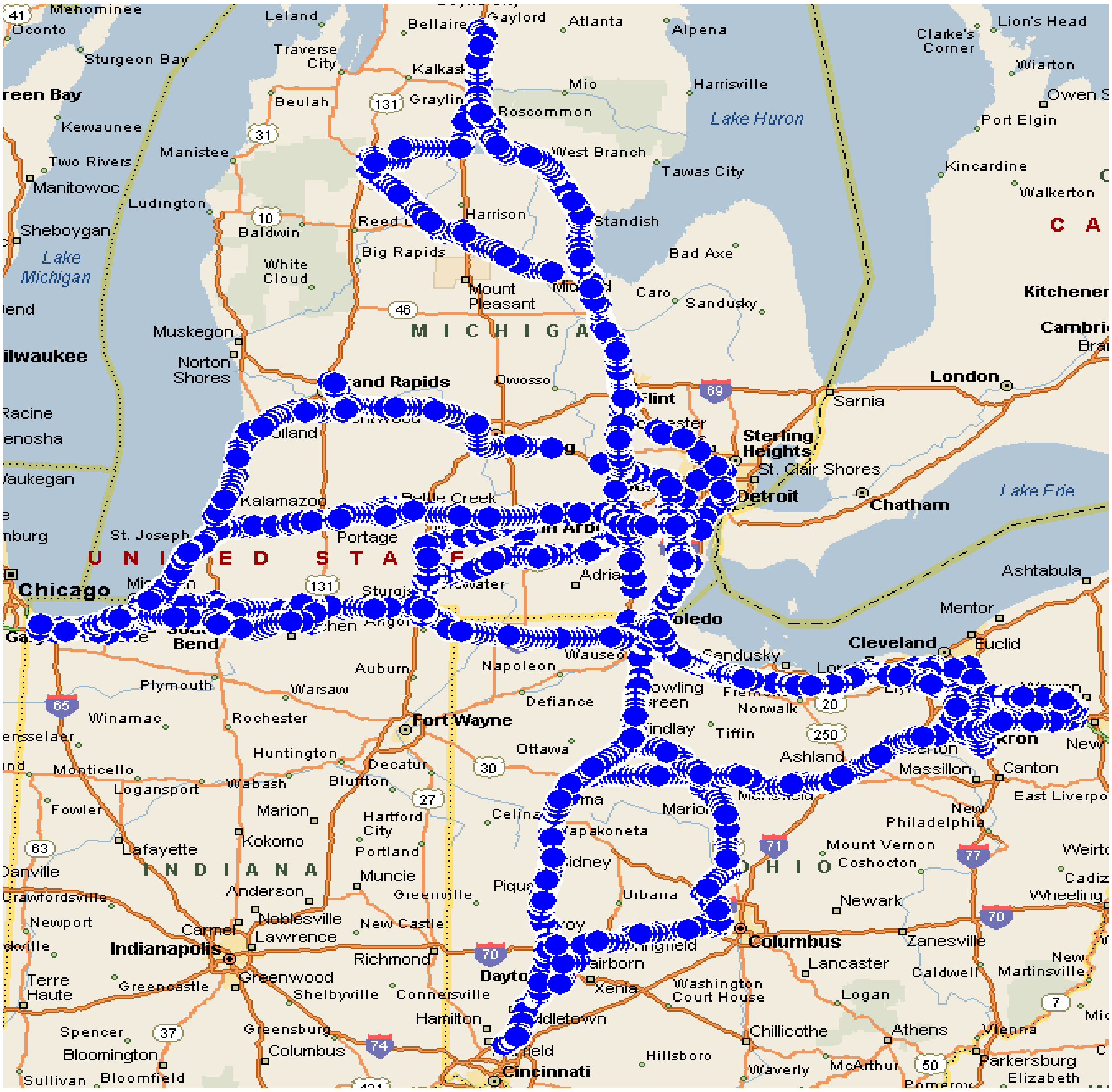

Figure 3. Geographical Range of Driving by LH Drivers

3 Grade Crossing Data Collection

The first step to analyzing driver behavior at highway-rail grade crossings was collecting data on driver activity at or on approach to such grade crossings. To perform this data collection, the Volpe Center research team developed four customized data collection tools to interface with and query the IVBSS FOT data. These tools are:

- Grade Crossing Locator
- Video Data Viewer
- Grade Crossing Coder
- Data Exporter

3.1 Grade Crossing Locator

The Grade Crossing Locator tool cross-referenced each grade crossing's geo-location with the research vehicle geo-location to calculate if and when a vehicle was present at a crossing. Samples of driver's end destinations were mapped to determine the participant travel destination. Based on this result, grade crossings in Michigan, Indiana, and Ohio were selected and cross-referenced with routes traveled by each research vehicle to determine vehicle presence at highway-rail grade crossings. The latitude (lat.) and longitude (long.) coordinates of each highway-rail grade crossing within those three States was obtained from the Bureau of Transportation Statistics National Transportation Atlas Database 2008. The geo-location of each research vehicle was obtained from the lat./long. coordinates recorded by an onboard Global Positioning System (GPS). Due to geo-location accuracy limitations inherent in both data sets, a radius of 100 feet (ft) around each grade crossing was used in querying the vehicle data in order to capture the events accompanying a research vehicle's movement over a highway-rail grade crossing. The tool generated a list of possible trips with crossing ID and the estimated time that a research vehicle was present at a crossing. Figure 4 provides a snapshot of the Grade Crossing Locator tool.

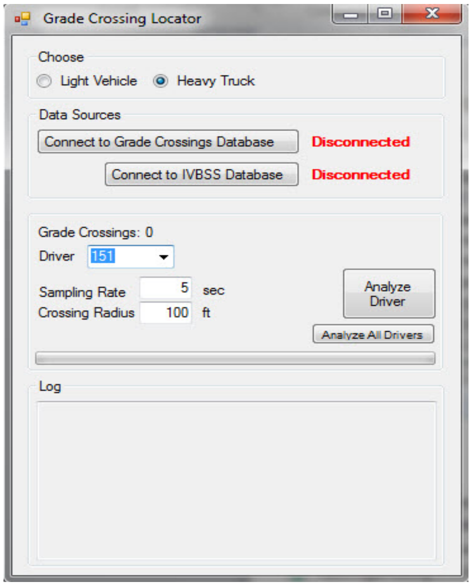

Figure 4. Grade Crossing Locator Tool

3.2 Video Data Viewer

Driver activity at or on approach to a highway-rail grade crossing was collected (from the five video cameras installed in each research vehicle) and subsequently analyzed. The Video Data Viewer tool was developed to combine all five camera views and play them simultaneously so that the driver's activity and the surrounding scene from different angles could be viewed concurrently.

Figure 5 provides a snapshot of the Video Data Viewer as the research vehicle approached a crossing that is occupied by a train. A drop down menu on the top left corner of the screen provided an option to select driver and trip for possible grade crossing events. All grade crossing events for the selected driver and trip were displayed on the bottom right corner of the screen with Crossing ID and the time the research vehicle was present at that crossing.

Figure 5. Video Data Viewer

3.3 Grade Crossing Coder

Figure 6 provides a snapshot of the Grade Crossing Coder. This tool was developed and used to record driver activity observed through the Video Data Viewer. The data collection of driver activity for a grade crossing event started at the moment a research vehicle arrived at the grade crossing pavement marking (this is designated in the Grade Crossing Coder as t1) and ended when it cleared the crossing (this is designated in the Grade Crossing Coder as t3). For any grade crossing event during which a research vehicle did not encounter the pavement marking, data collection started eight seconds before the research vehicle arrived at the crossing (this is designated in the Grade Crossing Coder as t2). This 8 second (s) value was calculated based on the average time it took a research vehicle to cover the distance from a pavement marking to a crossing, as observed during the study. The data collected from the video scene included information about crossing inventory, driving conditions, driver activities, and crossing violations.

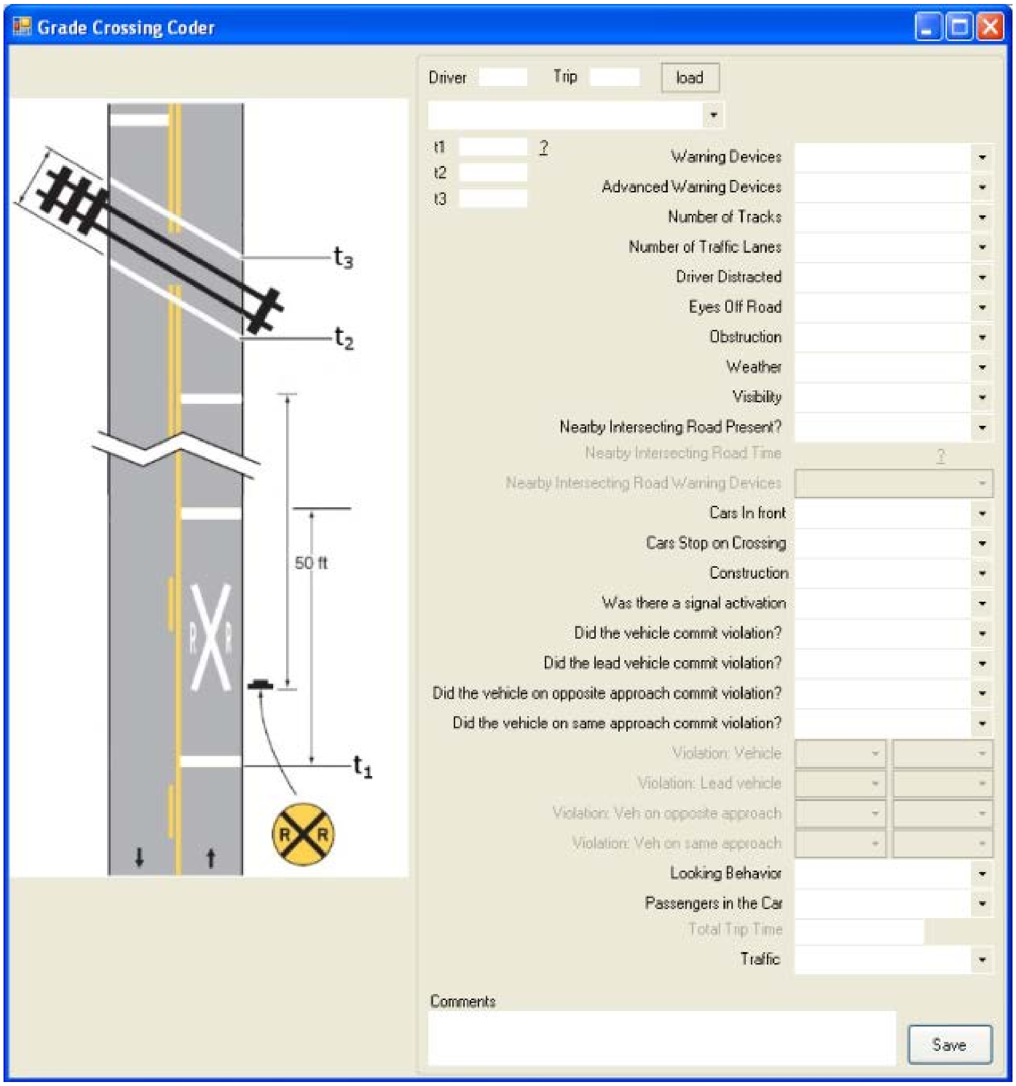

Figure 6. Grade Crossing Coder

The left side of the screen in Figure 6 shows a schematic of a typical single track highway-rail grade crossing with the locations of t1, t2, and t3. The menus on the right were used to enter driver characteristics and surrounding scene information for a grade crossing event. The first step in entering the data was inputting the driver and trip ID, and then selecting the crossing ID for which the data was collected. Once the information was entered, the save button on the bottom right corner of the screen was used to save the coded information as a data table. Table 2 provides a list of the data gathered from analysis by the Grade Crossing Coder of the video data for each grade crossing event. Appendix D provides the data dictionary and information about how the video was coded.

Table 2. Data Dictionary for Grade Crossing Events

Driver ID	Driver ID
Trip ID	Trip ID
crossing_event_id	Crossing ID for which the data is collected
t1_time	Time a research vehicle arrives at the crossing pavement marking
t2_time	Time a research vehicle arrives at the crossing (used the stop line at the crossing as a reference for arriving at the crossing)
t3_time	Time a research vehicle exits the crossing
warning devices	Lists highest warning device at a crossing
adv_warning_devices	Identifies whether advanced warning is present for a crossing
num_tracks	Number of tracks
num_traffic_lanes	Number of traffic lanes that intersect with a crossing
driver_distracted	Secondary task that driver was involved in
eyes_off_road	Identifies whether driver's eyes were off road
obstruction	Identifies whether a crossing was obstructed
weather	Provides weather condition
visibility	Provides visibility measure?
nearby_intersecting_road	Identifies whether intersecting road is present within 10 s of a crossing
nearby_intersecting_road_time	Time research vehicle arrives at an intersecting road
nearby_intersecting_road_warning_devices	Warning devices at the intersecting road
cars_in_front	Identifies whether cars are present in front of the research vehicle
cars_stop_on_crossing	Identifies whether any car is stopped on a crossing
construction	Identifies whether construction work is performed at or on approach to the crossing
signal_activation	Identifies whether crossing was activated for the grade crossing event
veh_commit_violation	Identifies whether research vehicle committed violation
lead_veh_commit_violation	Identifies whether lead vehicle committed violation
veh_opposite_approach_commit_violation	Identifies whether vehicle in opposite direction committed violation
veh_same_approach_commit_violation	Identifies whether vehicle on same approach committed violation
violation_veh_type	Research vehicle violation type
violation_veh_when	Violation before or after a train for research vehicle
violation_leadveh_type	Lead vehicle violation type
violation_leadveh_when	Violation before or after a train for lead vehicle
violation_oppoapproachveh_type	Opposite approach vehicle violation type
violation_oppoapproachveh_when	Violation before or after a train for vehicle from opposite approach
violation_sameapproachveh_type	Same approach vehicle violation type
violation_sameapproachveh_when	Violation before or after a train for vehicle from same approach
looking_behavior	Looking behavior as driver approached the crossing
passengers_in_car	Number of passengers in the car
total_trip_time	Total trip time
traffic	Traffic conditions on approach to a crossing
comments	Comments

3.4 Data Exporter

Figure 7 shows a screenshot of the Grade Crossing Exporter tool. This tool was used to export both video and numerical data collected for each grade crossing event. The top section titled "Available Grade Crossings" exported a list of possible grade crossing events per driver that was identified with the Grade Crossing Locator tool. The file was exported in a spreadsheet format with a list of possible trips, crossing IDs, and the time a research vehicle was present at a crossing for that trip.

The middle section titled "Grade Crossing Responses" exported all the user generated grade crossing responses for the selected driver as inputted in the Grade Crossing Coder. This data was also exported in a spreadsheet format.

The last section titled "Numerical Data" was used to export both video and numerical data for a single grade crossing event. The data was exported in a spreadsheet format with three different tabs. The first tab included numerical data collected at 10 Hz during the IVBSS FOT; the second tab included data collected at 5 Hz; and the final tab included summary data of the trip and the video data that was collected for its grade crossing events. Refer to Appendices A, B, and C for the complete list of both numerical and video data that was collected for each grade crossing event.

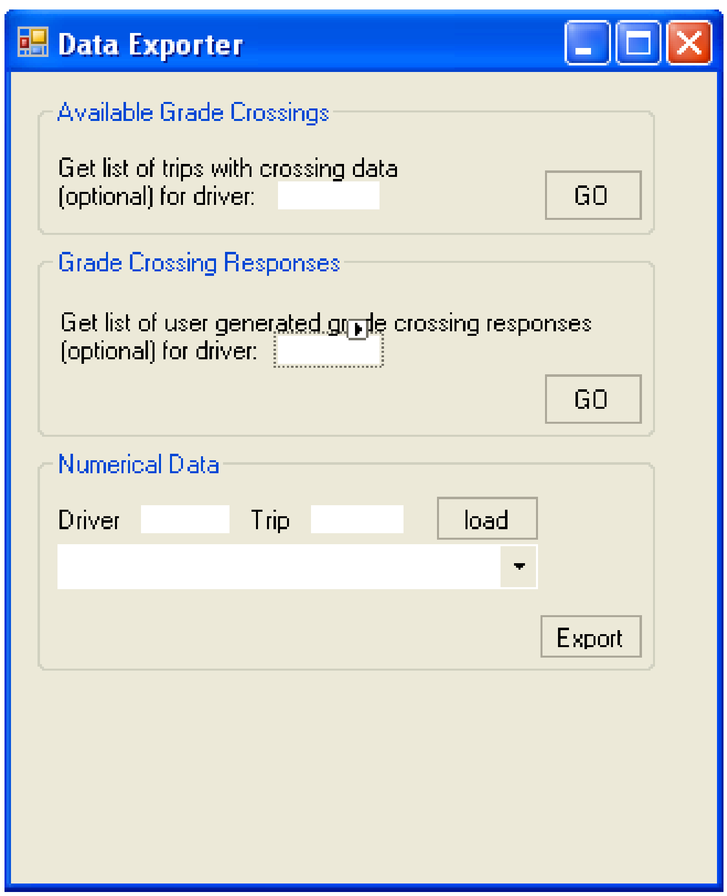

Figure 7. Data Exporter

4 Data Analysis

The analysis presented in this section concentrates on the heavy-truck part of the IVBSS FOT. Analysis of the heavy-truck driver behavior data at grade crossings focused on identification of patterns of driver behavior, and on distribution of crossing events by warning devices, vehicle exposure, and grade crossing violation. Examples of driver behavior characteristics include looking behavior (looked one way, looked both ways, or neither) and the presence of distractions (phone, eating, talking to passenger, etc.).

4.1 Vehicle Exposure

The IVBSS HT FOT spanned approximately 10 months from February 2009 to December 2009. During this period, the 18 participants drove research vehicles a total of 497,385 miles during a total of 21,289 trips. On average, P&D drivers each drove about 8,955 miles and LH drivers each drove about 42,574 miles during the test period. Additionally, P&D drivers encountered an average of 347 grade crossings and LH drivers, who drove most of the time on highways, encountered a much lower average of 39 grade crossings during the test period. Table 3 presents statistics on mileage for all 18 P&D and LH drivers.

Table 3. Participant Exposure by Driver Group

	Driver	Number of Trips	VMT	Crossing Events
Pickup and Delivery	**1**	1,268	9,263	335
	2	2,459	9,621	607
	4	3,682	10,047	588
	5	2,584	10,981	394
	6	965	4,392	86
	7	3,168	11,230	262
	8	2,011	6,669	250
	10	1,160	9,440	255
Line-Haul	**21**	297	22,522	54
	22	511	68,964	81
	23	427	57,017	110
	24	372	52,126	16
	25	264	20,443	8
	26	662	72,473	8
	27	606	57,475	66
	28	312	28,100	27
	29	275	25,809	13
	30	266	20,813	11
Average P&D		2,162	8,955	347
Average LH		399	42,574	39
Average All		1,183	27,633	176

4.2 Grade Crossing Events

For the IVBSS HT FOT, the 18 participants made a total of 21,289 trips in the research vehicles. Of those trips, the Grade Crossing Locator tool identified 5,744 trips during which there was a possible grade crossing event. As previously discussed in Section 3.1, the Grade Crossing Locator tool cross-referenced each grade crossing's geo-location with the research vehicle's geo-location to calculate if and when a vehicle was present at a crossing. Due to accuracy limitations in both data sets, a radius of 100 ft around each grade crossing was used in querying the vehicle data in order to capture the events occurring while a research vehicle traveled over a highway-rail grade crossing. The tool generated a list of possible grade crossing events within the previously identified 5,744 trips. The number of possible grade crossing events amounted to 10,911 when the 100-ft zone around the crossing GPS coordinates was used. The research team reviewed the video from all of these potential grade crossing events and identified 2,891 trips with a total of 3,171 grade crossing events. A total of 2,575 of the 10,911 possible events (23.6 percent) were missing video data, which was an issue related to the IVBSS FOT itself. The remaining potential events identified by the tool turned out to be false positives. Many of those were grade-separated grade crossing events, which were identified since the grade crossing GPS data set used for the study contained GPS information for both at-grade and grade-separated grade crossings. Many others contained events at which the vehicle's direction of travel was parallel to the railroad and any grade crossing at cross-streets within the 100-ft buffer zone would classify it as a grade crossing event.

The 3,171 valid grade crossing events selected for analysis occurred at 158 unique grade crossings. The results of this report are based on the analysis of that data set. Table 4 shows the breakdown of the grade crossing events by route type, age group, and years with a CDL. Overall, about 88 percent of the events occurred on P&D routes; drivers were younger than 47 years old in approximately 73 percent of the events, and drivers had less than 22 years with a CDL in approximately 69 percent of the events.

Table 4. Grade Crossing Events by Driver Demographic

Demographic	Group	Number of Grade Crossing Events
Route Type	Pickup and delivery	2,777
	Line-haul	394
Age	Greater than 47 years old	865
	Less than 47 years old	2,306
Years with CDL	Greater than or equal to 22	959
	Less than 22	2,199
	Unknown (Driver # 29)	13

4.3 Summary of Grade Crossing Event Data

The identification of warning devices present at each grade crossing was one of the data elements coded during the analysis of the video data for each grade crossing event. The analyst was instructed to select the highest level of warning devices present at the crossing. Figure 8, Figure 9, and Figure 10 show some examples of warning devices identified at selected grade crossings. A drop down menu, arranged in descending order with highest level of warning devices at the top, was used for this data element. The drop down menu contained the following devices:

- Four Quadrant Gate
- Gate
- Flashing Lights
- STOP sign
- Crossbucks
- Other
- Unknown

Figure 8. Snapshot of an Event at a Highway-Rail Crossing Equipped with Gates

Figure 9. Snapshot of an Event at a Highway-Rail Crossing Equipped with Flashing Lights

Figure 10. Snapshot of an Event at a Highway-Rail Crossing Equipped with only Crossbucks

Figure 11 shows the distribution of the 3,171 grade crossing events by warning device present at the crossing. As can be seen, a majority of the grade crossing events (91 percent or 2,891) occurred at crossings equipped with active warning devices. The active warning devices for this data set included gates and flashing lights. Most of the remaining grade crossing events (9 percent or 275) occurred at passive crossings. Passive crossings in this data set consisted of those equipped with crossbucks. An additional five events occurred at crossings where the warning device was not identifiable from the video data due to poor video quality or environmental factors. Although three other warning device categories, "Four Quadrant Gate," "STOP sign," and "Other," were listed in the study's coding drop down menu, none of the 3,171 grade crossing events were coded under those categories.

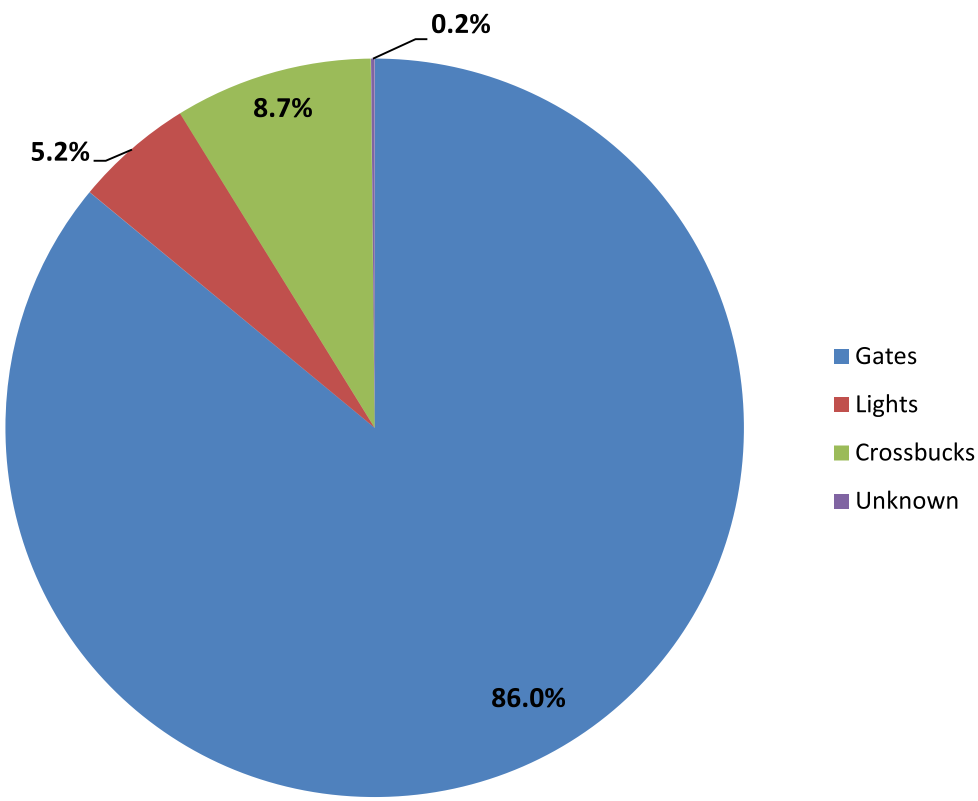

Figure 11. Distribution of Grade Crossing Events by Warning Device

Figure 12 shows the distribution of grade crossing events by the number of tracks at the crossing. As shown in Figure 12, 38.3 percent (1,216) of the grade crossing events occurred at double track highway-rail grade crossings.

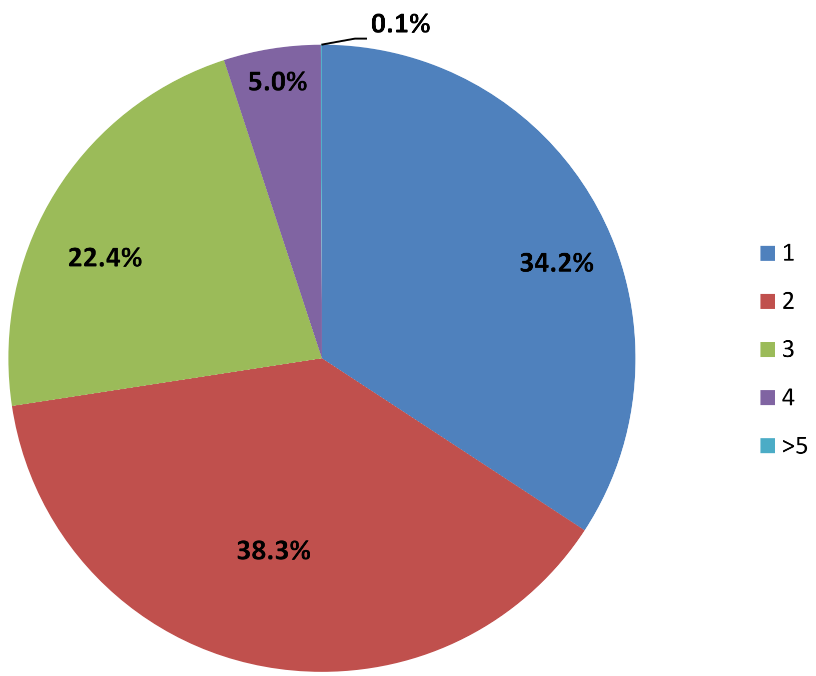

Figure 12. **Distribution of Grade Crossing Events by Number of Tracks**

Figure 13 shows the distribution of grade crossing events by number of traffic lanes in each direction traversing the crossing. As shown, about 55 percent (1,749) of the grade crossing events occurred at highway-rail grade crossings on single lane roadways. Approximately 44 percent of the events occurred on two-lane roadways.

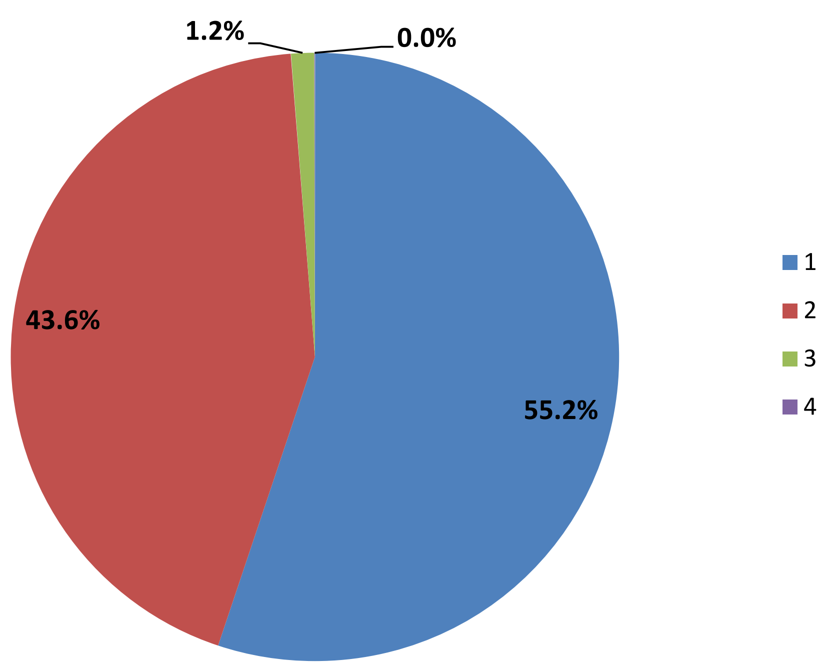

Figure 13. Distribution of Grade Crossing Events by Number of Road Traffic Lanes

4.4 Distraction

For the purpose of this analysis, drivers were identified as being distracted if they were engaged in any secondary tasks that may have prevented them from safely operating the vehicle any time between departing from the location of pavement marking (t1) and exiting the crossing (t3). The secondary task categories for this project were developed based on the set used for the IVBSS project. The secondary tasks were identified by viewing face and cabin shots captured by = video data of two sides of grade crossing events. Out of a possible 3,171 grade crossing events, 660 (or 20.8 percent) involved the driver performing a secondary task. The most frequently observed secondary task involved drivers talking on/listening to phone (205 or 6.5 percent), an example of which is shown in Figure 14. The next most common distraction was smoking/lighting cigarettes (156 or 4.9 percent). Figure 15 and Figure 16 show some other examples of drivers distracted on their approach to a highway-rail grade crossing. Table 5 lists all possible secondary tasks along with their frequency.

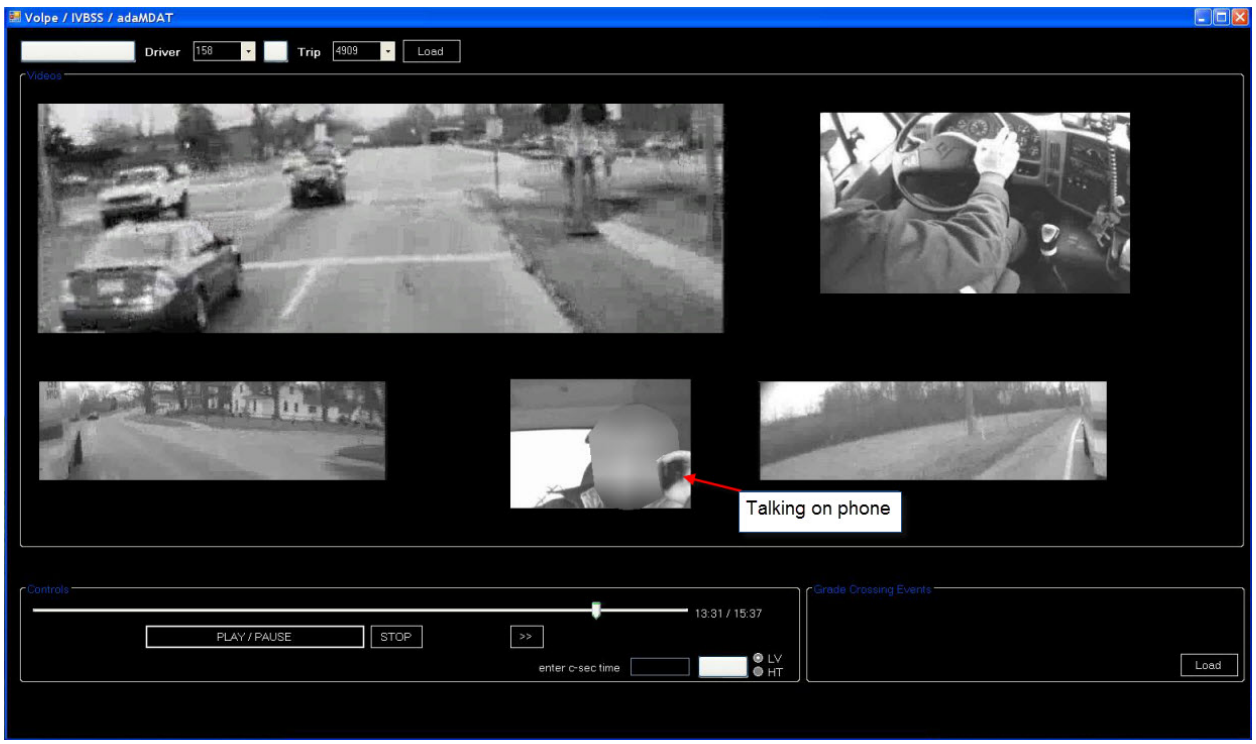

Figure 14. Snapshot of a Driver Talking on Phone on an Approach to a Highway-Rail Grade Crossing

Figure 15. Snapshot of a Driver Text Messaging on an Approach to a Highway-Rail Grade Crossing

Figure 16. Snapshot of a Driver Eating on an Approach to a Highway-Rail Grade Crossing

Data was analyzed to determine whether the distraction was any different based on route type, age group, or number of years with a CDL. Overall, P&D drivers were engaged in secondary tasks more often than LH drivers (P&D drivers were engaged in secondary tasks in 22.2 percent of grade crossing events compared to 11.2 percent for LH drivers). A paired t-test indicated that the overall change in rate of drivers involved in secondary tasks between P&D and LH drivers was statistically significant (p=0.000). Table 5 offers a comparison of secondary tasks between P&D and LH drivers.

Table 5. Frequency of Secondary Tasks

Secondary Tasks	Number of Grade Crossing Events with Secondary Task		Total	Frequency
	P&D	LH		
None	2,161	350	2,511	79.2%
Talking on/listening to phone	192	13	205	6.5%
Smoking/lighting cigarettes	156	0	156	4.9%
Eating	76	1	77	2.4%
Reaching for object in vehicle	56	14	70	2.2%
Text messaging	46	1	47	1.5%
Drinking	41	2	43	1.4%
Looking to the side/outside car	14	2	16	0.5%
Adjusting controls	11	3	14	0.4%
Other	9	1	10	0.3%
Dialing phone	8	1	9	0.3%
Reading	5	2	7	0.2%
Singing/whistling	1	3	4	0.1%
Eyes closed > 1s	1	1	2	0.1%
Total	2,777	394	3,171	

Secondary task frequency was also analyzed based on participants' age and number of years with a CDL. Drivers were divided into two age groups (less than the study average of 47 years old and greater than that average). Data indicated that drivers in the younger group were engaged in secondary tasks in about 20.5 percent of grade crossing events compared to 21.6 percent for drivers in the older group. Based on paired t-test, the change in rate of secondary task frequency between the two age groups was not statistically significant (p=0.494). Table 6 shows the distraction rate by age group.

Table 6. Distraction Rate by Age Group

	Age Group	
	Younger than 47 years old	Older than 47 years old
Grade Crossing Events with Driver Distraction	473	187
Total Grade Crossing Events	2,306	865
Distraction Rate	0.205	0.216

Analysis of secondary task frequency based on number of years with a CDL (less than the study average of 22 years, or 22 years and greater) indicated that drivers with a CDL for at least 22 years were less likely to engage in secondary tasks during a grade crossing event than drivers with a CDL for less than 22 years. About 15.4 percent of drivers with a CDL for at least 22 years were engaged in a secondary task during a grade crossing event compared to 23.2 percent for drivers with a CDL for less than 22 years. A paired t-test indicated that the overall difference in rate of secondary tasks between these two driver groups was statistically significant (p=0.000). Table 7 shows the distraction rate by number of years with CDL.

Table 7. Distraction Rate by Number of Years with CDL

	Age Group	
	Less than 22 years with CDL	22 years or more with CDL
Grade Crossing Events with Distraction	511	148
Total Grade Crossing Events	2,199	959
Distraction Rate	0.232	0.154

4.5 Looking Behavior

Looking behavior was measured by amount of head movement as the driver approached the crossing from the pavement marking (t1) until the research vehicle cleared the crossing (t3). The research team viewed the face video data of all grade crossing events to determine whether drivers looked one way (to the left or to the right), both ways, or straight ahead. It is important to note that the focus was on head movement because no eye tracking data was collected. Analysis of the data collected suggests that drivers did not move their heads 39.5 percent of the time as they approached a highway-rail grade crossing. About 29.7 percent of head movements were in both directions, and 30.8 percent of head movement was in one direction (looked left or looked right). Figure 17 shows the distribution of grade crossing events by looking behavior.

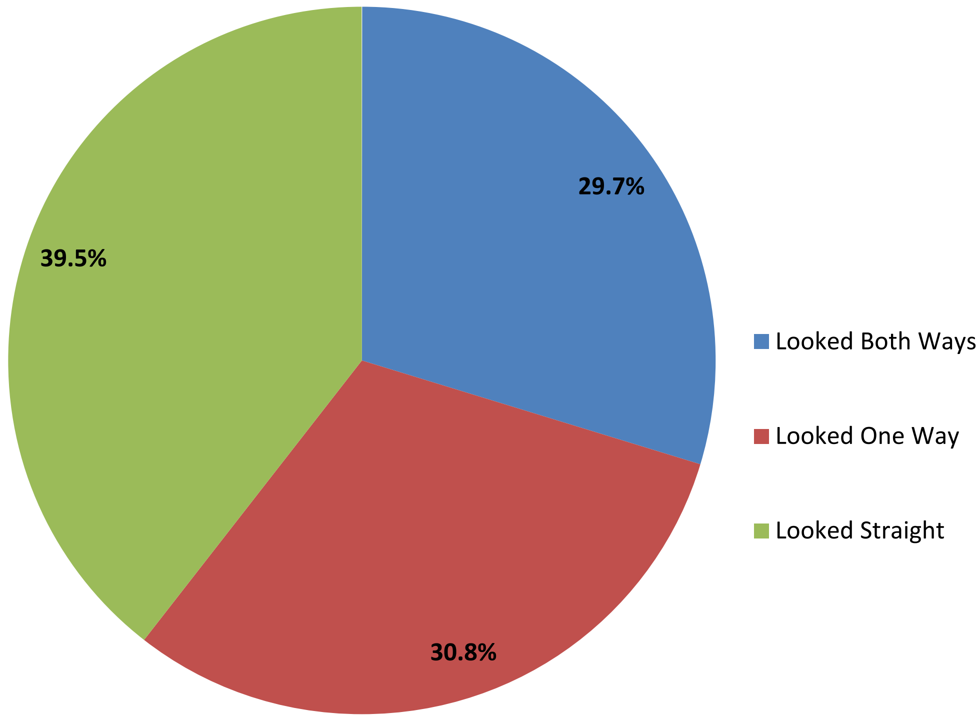

Figure 17. Distribution of Grade Crossing Events by Looking Behavior

The data was analyzed to determine whether the looking behavior was any different based on route type, age group, and number of years with a CDL. Looking behavior was further categorized into either "looked straight" or "looked at least one way." P&D drivers looked at least one way 60.5 percent of the time and LH drivers looked at least one way 61.2 percent of the time at or on an approach to a grade crossing. This observed difference in driver looking behavior was not statistically significant based on a pair t-test (p=0.788). Table 8 shows looking behavior rate by route type.

Table 8. Looking Behavior Rate by Route Type

	Route Type	
	P&D	LH
Grade Crossing Events where drivers looked at least one way	1,679	241
Total Grade Crossing Events	2,777	394
Looking Behavior Rate	0.605	0.612

Grade Crossing events where drivers looked at least one way on their approach to grade crossings were analyzed per age group (younger than 47 years old and older than 47 years old). The data analysis of the looking behavior indicated that at or on an approach to a grade crossing drivers younger than 47 years old were 64.1 percent likely to look at least one way compared to

51.1 percent for drivers older than 47 years. Based on the paired t-test, the observed difference between drivers younger than 47 years old and drivers older than 47 years was statistically significant (p=0.000). It should be noted that seven out of the nine drivers older than 47 years in the study group were assigned to LH routes, where the frequency of encounters with grade crossings was much lower than those for the P&D routes. Table 9 shows looking behavior rate by age group.

Table 9. Looking Behavior Rate by Age Group

	Age Group	
	Less than 47 years old	Greater than 47 years old
Grade Crossing Events where drivers looked at least one way	1,478	442
Total Grade Crossing Events	2,306	865
Looking Behavior Rate	0.641	0.511

Analysis of looking behavior based on number of years with a CDL (less than 22 years, and 22 years or more) indicated that drivers with a CDL for at least 22 years were more likely to look at least one way at or on approach to a grade crossing than drivers with a CDL for less than 22 years. About 69.2 percent of drivers with a CDL for 22 years or more looked at least one way at or on approach to a grade crossing compared to 56.8 percent for drivers with a CDL for less than 22 years. A paired t-test indicated that the overall difference in rate of looking behavior between these two groups of drivers was statistically significant (p=0.000). It should be noted that seven out of the nine drivers with a CDL for at least 22 years in the study group were assigned to LH routes, where the frequency of encounters with grade crossings was much lower than for the P&D routes. Table 10 shows the looking behavior rate by number of years with CDL.

Table 10. Looking Behavior Rate by Number of Years with CDL

	Age Group	
	Less than 22 years with CDL	22 years or more with CDL
Grade Crossing Events where drivers looked at least one way	1,250	664
Total Grade Crossing Events	2,199	959
Looking Behavior Rate	0.568	0.692

Data was further analyzed to determine whether warning devices had any effect on drivers' looking behavior at or on approach to highway-rail grade crossings. The data analysis of the looking behavior indicated that drivers were most likely to look at least one way at crossings equipped with gates (this behavior was exhibited at 62.2 percent of those 2,727 events) and least likely to look at least one way at crossings equipped with lights (this behavior was exhibited at 36.0 percent of those 164 events). For crossbuck-equipped crossings only, drivers looked at least one way approximately 59 percent of the time (163 out of 275). Figure 18 illustrates the distribution of looking behavior by warning device, excluding unknown category.

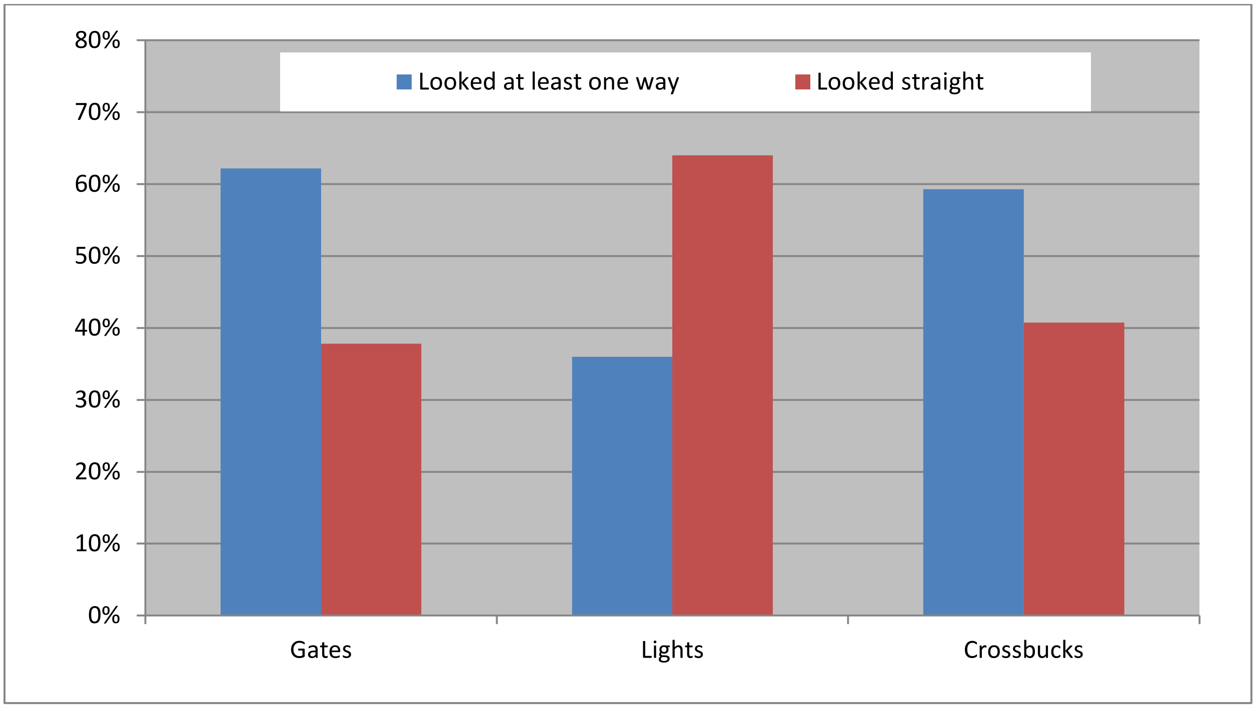

Figure 18. Distribution of Looking Behavior by Warning Devices (excluding Unknown category)

Looking behavior was also analyzed between active and passive crossings in general. For this analysis, active crossings included highway-rail grade crossings equipped with gates and flashing lights, and passive crossings included highway-rail grade crossings equipped with crossbucks. The data analysis of the looking behavior indicated that drivers looked at least one way 59.3 percent of the time at passive crossings (163 of 275 events) compared to 60.7 percent of the time at active crossings (1,755 of 2,891 events). Figure 19 illustrates the distribution of looking behavior between active and passive crossings.

Figure 19. Distribution of Looking Behavior by Type of Crossing (excluding Unknown category)

4.6 Grade Crossing Activation

For an active crossing, grade crossing activation was defined as any time the crossing warning devices were activated, either when a train was on approach or in the event of a false activation [8]. For a passive crossing, grade crossing activation was defined as when a highway-rail crossing was occupied by a train. Out of the possible 3,171 crossing events analyzed in this study, the research team identified 43 events (1.4 percent) involving grade crossing activation. The 43 grade crossing activation events were comprised of 37 at crossings equipped with gates, 4 at crossings equipped with flashing lights, and 2 at crossings equipped with crossbucks. Six out of the 41 activation events at active crossings were identified as false activation events, meaning that the warning devices were activated without a train being present.

Grade crossing violations were collected for the 43 grade crossing activation events. A grade crossing violation occurs when motorists disobey the warning devices at the highway-rail grade crossing. Grade crossing violations were collected for the research vehicle as well as for other vehicles in the vicinity, as captured by the research vehicle's external cameras. These included other vehicles in front of or parallel to the research vehicle traveling in the same direction, and vehicles on opposite approach to the grade crossing. For those 43 grade crossing activation events, the research team identified 38 violations. There were an additional 10 instances for which the reviewer was not able to determine from the video data whether a nearby vehicle commited a violation. Table 11 provides distribution of violations by warning devices and type of vehicle. For the four violations that were commited by research vehicles, the drivers looked at least one way and were not involved in any secondary tasks in all four events. Two of the four violations occurred during false activation events.

Table 11. Distribution of Violations by Warning Devices

Warning Devices	Number of Activation Events	Number of Violations by Research Vehicle	Number of Violations by Other Vehicles	Total Violations
Gates	37	3	31	34
Lights	4	0	3	3
Crossbucks	2	1	0	1
Total	43	4	34	38

Three types of violations were collected for the 37 grade crossing activation events that occurred at crossings equipped with gates. The definition of each type is listed below [8].

- A Type I violation occurs when a violator traverses the crossing while the lights are flashing, the bells are ringing, but before gate descent.
- A Type II violation occurs when a violator traverses the crossing during gate descent or ascent with audible devices sounding.
- A Type III violation occurs when a violator traverses the grade crossing after the gates finish their descent and are fully deployed in a horizontal position.

The research team identified 34 violations for the 37 grade crossing activation events that occurred at crossings equipped with gates, as shown in Table 11. The 34 violations were comprised of 5 Type I violations (3 before and 2 after a train), 24 Type II violations (2 before and 22 after a train), and 5 Type III violations. All Type III violations occurred during three false activation events. One out of the five type III violations was commited by a research vehicle. The driver in that event, which was also determined to be a false activation event, looked both ways before going around gates to traverse the crossing.

The research team identified three violations for the four grade crossing activation events that occurred at crossings equipped with flashing lights. These violations occurred when motorists traversed the crossing while the lights were flashing either before or after a train. The three violations all occurred after a train had cleared the crossing but while lights were still flashing.

The two grade crossing activation events that occurred at crossings equipped with crossbucks included one violation. That violation occurred when a research vehicle traversed the crossing before the train fully cleared the crossing as shown in Figure 20.

On thirteen occasions research vehicles were the lead vehicle at an activated crossing event. The drivers comitted a violation about 23 percent of the time (in 3 out of 13 events where the truck was the lead vehicle). The 13 grade crossing activation events consisted of 9 at crossings equipped with gates, 3 at crossings equipped with flashing lights, and 1 at crossings equipped with crossbucks. For the 9 grade crossing activation events at a gated crossing, research vehicles commited 2 Type I violations (all before a train). The research vehicle did not commit any violations for the three grade crossing activation events that occurred at crossings equipped with flashing lights. For the one grade crossing activation event at a crossing equipped with crossbucks, the research vehicle committed a violation by traversing the crossing before the train fully cleared the crossing, as shown in Figure 20. Figure 21, Figure 22, and Figure 23 show examples of each type of violation at crossings equipped with gates.

Figure 20. Research Vehicle Committing a Violation at a Crossbucks-equipped Crossing

Figure 21. Type I Violation

Figure 22. Type II Violation

Figure 23. Type III Violation

5 Conclusion

Although previously studied and acknowledged to be a key factor in highway-rail grade crossing accidents, little is known about driver behavior and its contribution in such incidents. Thus, in order to gain a better understating of the problem, FRA's Office of R&D funded this study to review and analyze driver activity at or on approach to highway-rail grade crossings. This research had two main goals. The first goal was to conduct a feasibility assessment of using the IVBSS FOT data to perform grade-crossing behavior analyses on heavy-truck vehicle drivers. The second goal was to collect and analyze truck drivers' activities at or on approach to highway-rail grade crossings. Both of these goals were achieved through the research documented herein.

This report reviews truck driver behavior using the IVBSS Heavy Truck FOT data set. The 18 HT IVBSS FOT participants took 21,289 trips over the study period. Out of those trips, the research team identified 2,891 trips containing 3,171 grade crossing events, or instances where the IVBSS research vehicle traversed a grade crossing in the three states selected for this study. The research team then reviewed and coded the 3,171 grade crossing events. The data collected for each grade crossing event included data about drivers' activities, driver and vehicle performance, driving environment, and vehicle location at or on approach to highway-rail grade crossings.

The results of the data analysis revealed that on average drivers were likely to engage in secondary tasks, an indicator of driver distraction, about 20.8 percent of the time while traversing a grade crossing, and were likely to look at least one way at or on approach to grade crossings about 60.5 percent of the time.

The analysis of secondary task by route type, driver's age, and number of years with a CDL revealed that the distraction did not differ significantly based on driver's age. Younger drivers, those under the study average of 47 years old, were engaged in secondary tasks 20.5 percent of the time compared to 21.6 percent for older drivers (those over the study average of 47 years old). The data also indicated that P&D drivers were more likely to be engaged in secondary tasks than LH drivers. P&D drivers were engaged in secondary tasks at or on approach to grade crossings approximately 22 percent of the time, compared to 11 percent of the time for LH drivers. The data further indicated that drivers with a CDL for less than 22 years were more likely than drivers with a CDL for 22 years or more to be engaged in secondary tasks during grade crossing events.

Looking behavior did not differ significantly between P&D and LH drivers. P&D drivers looked at least one way 60.5 percent of the time compared to 61.2 percent for LH drivers. But when analyzed by age group, the data revealed that younger drivers were more likely to look at least one way at or on approach to highway-rail grade crossings than older drivers. Younger drivers looked at least one way approximately 64.1 percent of the time compared to 51.1 percent for older drivers. The data also showed that drivers with a CDL for 22 years or more looked at least one way approximately 69.2 percent of the time compared to 56.8 percent for drivers with a CDL for less than 22 years. It should be noted that this analysis is based on a small number of drivers that participated in the IVBSS FOT. Out of the overall pool of 18 professional truck drivers in the study, 7 out of 9 in the older age group were assigned to LH routes and 7 out of 9 with a CDL for at least 22 years were assigned also to LH routes, where the frequency of encounters with grade crossings was much lower than those for the P&D routes.

Analysis of looking behavior by warning devices suggested that drivers were most likely to look at least one way at crossings equipped with gates, followed very closely by crossings equipped with crossbucks; they were least likely to look at least one way at crossings equipped with lights. The data also indicated that looking behavior did not differ significantly between active and passive crossings. Drivers looked at least one way in 59.3 percent of the events at passive crossings, compared to 60.7 percent of the events at active crossings.

Follow-on research already being conducted by the research team will analyze additional data elements such as vehicle speed profiles on approach to grade crossings; the research will also provide a deeper analysis of the driver behavior elements presented in this report.

Evaluating the effectiveness of motorist and pedestrian signs and treatment—and researching driver behavior—is a top research priority, as identified in the 2009 FRA-sponsored Research Needs Workshop [4]. The authors hope the results presented in this report provide the basic driver behavior research needed to identify and guide potential driver education/awareness strategies, such as Operation Lifesaver's Commercial Drivers e-Learning initiative [9], which would best mitigate risky driver behavior at grade crossings.

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Appendix A.
10 Hz Numerical Data Dictionary

Driver	Driver ID
Trip	Trip ID
Time	Time in centiseconds since DAS started
ImuIndex	
LcmIndex	Lane change merge index
RadarFrontExtendedIndex	Front radar extended scan index
AccelPedal	Accelerator pedal
Brake	Brake active
Distance	Trip distance
Engaged	Cruise control active
Speed	Vehicle speed from transmission
Steer	Steering wheel angle, cw is negative
TurnSignal	Turn signal
Wipers	Wiper switch state
GPSHeading	GPS heading from Ublox GPS
GPSValid	True if GPS data is valid
Latitude	Latitude from Ublox GPS
Longitude	Longitude from Ublox GPS
CswAvailable	Csw availability
CswWarning	Csw warning generated from arbitration
FcwAccel	Fcw target acceleration
FcwAvailable	Fcw availability
FcwAzimuth	Fcw azimuth
FcwRadarIndex	ExtendedBosch radar scan index for fcw target
FcwRange	Fcw range
FcwRangeRate	Fcw range rate
FcwTargetId	Fcw target ID (handle)
FcwTargetType	Fcw target type
FcwValidTarget	Fcw valid target
FcwWarning	Fcw warning generated from arbitration
LcmRearAvailable	Lcm rear availability
LcmTTCAvailable	Lcm TTC availability
LcmWarning	Lcm warning generated from arbitration
Leds	Mirror leds
BoundaryLeft	Lane boundary type, left
BoundaryRight	Lane boundary type, right
DistancePastEdge	#N/A
LaneChange	Lane change
LaneOffset	Vehicle offset from lane center
LaneOffsetConf	Lane offset confidence

LaneWidth	Lane width
LdwAvailableLeft	Ldw left side availability
LdwAvailableRight	Ldw right side availability
LdwCaution	Ldw caution generated from arbitration
LdwLateralSpeed	Vehicle speed lateral to lane direction from ldw
LdwThreatLeft	Ldw left threat type
LdwThreatRight	Ldw right threat type
LdwWarning	Ldw warning generated from arbitration
Time	Time in centiseconds since DAS started
AcPressureSwitch	Ac Pressure Switch
AtmPressure	Atmospheric Pressure
BatteryVoltage	Battery voltage
DasVoltage	DAS input voltage
CoolantTemp	Engine coolant temperature
EngineSpeed	Engine speed
FuelUsed	Fuel used
Gear	Gear actual
GPSSpeed	Speed from GPS
IntakeTemp	Intake temperature
MCPressure	Master cylinder pressure
Odometer	Odometer
OutsideTemperature	Outside temperature (uncalibrated)
PulseActivated	True means brake pulse is activating
PulseRefused	True means brake pulse command is rejected
ReferenceDistance	Reference distance travelled
TargetThrottle	Current target throttle
Throttle	Current throttle
ArbitratedWarning	Arbitrated warning enum
ArbReason	Reason for arbitrated warning bitmap
DviAlert	Dvi alert response flags bit0 = audio , bit1 = haptic, bit2 = lvisual, bit3 = vsa
DviEnable	Dvi enable flags bit0 = audio & haptic, bit1 = led, bit2 = vsa
PulseRequest	Brake pulse request
PulsePressure	Brake pulse pressure request
PulseCalcPressure	Brake pulse pressure calculation
SnoozeTime	Time remaining until snooze expires
CswAlertRequest	Csw imminent warning request
FcwAlertRequest	Fcw alert request
LcmAlertRequest	>0 if lcm is requesting a warning
LdwAlertRequest	Ldw alert request
AdhIndex	Adh index
ArbIndex	Arb transaction index
GwIndex	Gateway index

Appendix B.
5 Hz Numerical Data Dictionary

Driver	Driver ID
Trip	Trip ID
Time	Time in centiseconds since DAS started
Ax	Longitudinal acceleration from InertiaLink IMU
Ay	Lateral acceleration from InertiaLink IMU
Az	Vertical acceleration from InertiaLink IMU
PitchRate	Pitch rate from InertiaLink IMU
RollRate	Roll rate from InertiaLink IMU
YawRate	Yaw rate from InertiaLink IMU
Pitch	Pitch angle from InertiaLink IMU
Roll	Roll angle from InertiaLink IMU
Yaw	Yaw angle from InertiaLink IMU
ImuTime	#N/A

Appendix C.
Summary Numerical Data Dictionary

Driver	Driver ID
Trip	Trip ID
StartTime	First time of test
EndTime	Last time of test
IvbssEnable	HMI (Ivbss functionality) enabled
DAS	DAS number
BrakeCount	Count of brake applications
Distance	Trip distance
LdwDayDistance	#N/A
WiperDistance	#N/A
EmergencyShutDown	Shut down request from Blue Earth micro because of out-of-range
Latitude	Latitude from Ublox GPS
Longitude	Longitude from Ublox GPS
Odometer	Odometer
Prndl	Prndl
Speed	Vehicle speed from transmission
TurnSignalCount	Count of turn signal application
LaneChangeCount	Count of lane change
Vgt25Distance	Distance above 25 mph
VgtRearMinDistance	#N/A
VgtTTCMinDistance	#N/A
CswRequestCount	Count of Csw Alert requests
FcwRequestCount	Count of Fcw Alert requests
LcmRequestCount	Count of Lcm Alert requests
LdwRequestCount	Count of Ldw Alert requests
CswWarningCount	Count of Csw warnings
FcwWarningCount	Count of Fcw warnings
LcmWarningCount	Count of Lcm warnings
LdwCautionCount	Count of Ldw cautions
LdwWarningCount	Count of Ldw warnings
TODTripStart	Absolute date/time corresponding to test time = 0 in access date/time format based on computer clock
TripStart	Absolute date/time corresponding to test time = 0 in access date/time format based on computer clock
Vehicle	Vehicle number
WarmStart	True if ignition happened with the DAS already running

Appendix D.
Grade Crossing Video Data Coding Instructions

1. Enter driver and trip ID for which you are collecting driver information and click “load” button.

2. All the grade crossing associated with that driver and trip will load in the drop down menu.

3. Select the crossing from drop down menu.

4. **T1:** Enter the time (hh:mm:ss) when the test vehicle arrives at the crossing pavement marking. If no pavement markings are present, then subtract 8 seconds (s) from the time found for T2. In this case you would figure out the time for T2 and then go back and enter the time for T1.

5. **T2:** Enter the time (hh:mm:ss) when the test vehicle arrives at the crossing. Use the stop line at the crossing as a reference for arriving at the crossing.

6. **T3:** Enter the time (hh:mm:ss) when the test vehicle exits the crossing. Since there is no rear camera, you can usually tell the test vehicle has exited the crossing when it stops vibrating from going over the tracks.

7. **Warning Devices:** Select the highest level of warning devices present at the crossing. The drop down menu is arranged in descending order with highest level of warning devices at the top. The drop down menu contains the following devices:
    - Four Quadrant Gate
    - Gate
    - Flashing Lights
    - STOP sign
    - Crossbucks
    - Other
    - Unknown

8. **Advanced Warning Devices:** Identify whether advanced warning devices are present at the crossing. Advanced warning devices are usually located before or at the pavement marking.
    - Yes
    - No
    - Unsure

9. **Number of Tracks:** Select number of tracks at the crossing from the drop down menu.
    - 1
    - 2
    - 3

- 4
- >4

10. **Number of Traffic Lanes:** Select the number of traffic lanes approaching the crossing. If the traffic lane merges or expands at the approach of the crossing, select the number of traffic lanes that intersect with the crossing.
    - 1
    - 2
    - 3
    - 4
    - 5

11. **Driver Distracted:** From the drop down menu, select the distraction that the driver experiences anytime between t1 and t3. If the driver was not distracted, then select "None."
    - None
    - Dialing phone
    - Talking on/listening to phone
    - Text messaging
    - Singing/whistling
    - Talking to/looking at passenger
    - Adjusting controls
    - Eyes closed >1s
    - Eating
    - Drinking
    - Grooming
    - Smoking/lighting cigarettes
    - Reading
    - Reaching for object in vehicle
    - Looking to the side/outside
    - Other (please specify in the comment section)

12. **Eyes off Road:** Identify from the drop down menu whether the driver's eyes were off the road anytime between t1 and t3.
    - Yes
    - No
    - Unsure

13. **Obstruction:** From the drop down menu, select the category that best describes the obstruction of the crossing on the approach to the crossing.
    - None
    - Trees/Bushes
    - Other vehicles
    - Building
    - Other train

14. **Weather:** Select from the drop down menu, the weather category that best describes the weather condition.
    - Clear
    - Foggy
    - Rain
    - Snow

15. **Visibility:** Select from the drop down menu, the visibility category that best describes the visibility on approach to the crossing.
    - Dawn
    - Day
    - Dusk
    - Dark

16. **Nearby Intersecting Road Present:** Identify whether there is a crossing intersection (not side street) 10 s after (t2) the test vehicle enters the crossing.
    - Yes
    - No

17. **Nearby Intersecting Road Time:** If there is a nearby intersection present, enter time (hh:mm:ss) the test vehicle arrives at the intersection.

18. **Nearby Intersecting Road Warning Devices:** If there is a nearby intersection present, select the warning device that is present at the intersection.
    - Traffic Lights
    - Stop Sign
    - Yield Sign
    - Rotary

19. **Cars In Front:** Select from drop down menu whether there is a car present in front of the test vehicle in the same lane anytime between t1 and t3.
    - Yes
    - No
    - Unsure

20. **Cars Stop on Crossing:** Select from the drop down menu whether the test vehicle or any other vehicle is stopped on the crossing.
    - Yes
    - No
    - Unsure

21. **Construction:** Identify whether there is construction work being performed anytime between t1 and t3.
    - Yes
    - No
    - Unsure

22. **Was there signal activation:** Identify from the drop down menu whether there was any kind of activation at the crossing. The drop down menu contains the following activation types:
    - **Train activation:** When the train is present at the crossing, the train triggers the track circuitry to activate the safety devices at the crossing. For a passive crossing, if there is a train present at the crossing.
    - **False activation:** When the safety devices at the crossing are activated without a train's presence at the crossing. This choice is only applicable for active crossings, not passive crossings.
    - **No activation:** When the safety devices at the crossing are not activated at the crossing. For a passive crossing, if there is no train present at the crossing.

23. **Did the vehicle commit a violation:** Identify from the drop down menu whether the test vehicle commits any one of the following three violations.
    - **Type I:** A type I violation occurs when a violator traverses the crossing while the lights are flashing, the bells are ringing, but the gate has not descended.
    - **Type II:** A type II violation occurs when a violator traverses the crossing during gate descent or ascent with audible devices sounding.
    - **Type III:** A type III violation occurs when a violator traverses the grade crossing after the gates finish their descent and are fully deployed in a horizontal position.

24. **Did the lead vehicle commit a violation:** Identify from the drop down menu whether the lead vehicle (vehicle in front of the test vehicle) committed any of the above three violations.
    - Yes
    - No
    - Unsure

25. **Did the vehicle on opposite approach commit a violation:** Identify from the drop down menu whether any of the vehicles from the opposite approach committed any of the above three violations.
    - Yes
    - No
    - Unsure

26. **Did the vehicle on same approach commit a violation:** Identify from the drop down menu whether vehicle on same approach committed any of the above three violations.
    - Yes
    - No
    - Unsure

27. **Violation_Vehicle: S**elect the type of violation and identify whether the test vehicle caused a violation before or after the train's arrival at the crossing.
    - Type I
    - Type II
    - Type III
    - Before
    - After

28. **Violation_Lead Vehicle:** Select the type of violation and identify whether it was before or after the train's arrival at the crossing.
    - Type I
    - Type II
    - Type III
    - Before
    - After

29. **Violation_Vehicle on opposite approach:** Select the type of violation and identify whether it was before or after the train's arrival at the crossing.
    - Type I
    - Type II
    - Type III
    - Before
    - After

30. **Violation_Vehicle on same approach:** Select the type of violation and identify whether it was before or after the train's arrival at the crossing.
    - Type I
    - Type II
    - Type III
    - Before
    - After

31. **Looking Behavior:** Select from the drop down menu the description that best fits the driver's looking behavior anytime between t1 and t3. Looking behavior does not necessarily mean that the driver is distracted; it may mean that the driver is looking around to determine if a train is arriving or has left. If the driver only looked straight ahead, then select the "*None of the above*" option.
    - Looked Left
    - Looked Right
    - Looked Both Ways
    - None of the Above

32. **Passengers in the car:** Select from the drop down menu the number of passengers in the car. You can identify whether there are passengers in the car from reviewing the cab and face view.
    - 0
    - 1
    - 2
    - 3
    - N/A

33. **Total Trip Time:** Enter the total trip time in hh:mm:ss format. The total trip time can be found at the top right corner of the navigation control box.

34. **Traffic:** Identify the traffic condition (density) on approach side to crossing between t1 and t3. Please do not consider traffic condition on the opposite approach.
    - **None:** Select this category if there is no traffic (no vehicles) in front of the test vehicle.
    - **Light:** Select this category if there are a few vehicles (2-3 vehicles) in front, and traffic is most likely moving at or near roadway speed limit.
    - **Moderate:** Select this category if there are several vehicles in front (4-6 vehicles), and traffic is most likely significantly slower than the normal roadway speed.
    - **Heavy:** Select this category if the traffic (6+ vehicles) condition is stop and go.

35. **Comment:** Add any comments that describe driver's activities or roadway characteristics that are not collected. This field does not have to be filled out for every trip.

Abbreviations and Acronyms

BSD	Blind Spot Detection
CDL	Commercial Driver's License
DAS	Data Acquisition System
FCW	Forward Crash Warning
FMCSA	Federal Motor Carrier Safety Administration
FOT	Field Operational Test
FRA	Federal Railroad Administration
GPS	Global Positioning System
HT	Heavy Truck
Hz	Hertz
IVBSS	Integrated Vehicle-Based Safety Systems
lat.	Latitude
LCM	Lane-Change/Merge
LDW	Lane-Departure Warning
LH	Line haul
long.	Longitude
NHTSA	National Highway Traffic Safety Administration
P&D	Pickup and Delivery
R&D	Research and Development
RITA	Research and Innovative Technology Administration
SQL	Structured Query Language
UMTRI	University of Michigan Transportation Research Institute
U.S. DOT	United States Department of Transportation
VMT	Vehicle Miles Travelled
Volpe Center	John A. Volpe National Transportation Systems Center