Examination of Vehicle Crashes Nationally at Highway-Rail Grade Crossings

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Collisions between trains and vehicles remain an important highway safety issue. Not only do such collisions often result in severe injuries and death to vehicle occupants, they also create a source of tort claims especially against the railroads. The United States Department of Transportation (USDOT), especially through the Federal Railroad Administration (FRA) continues to address measures to reduce or eliminate these crashes. Individual components related to safety including education, enforcement, and improvements in crossing warning systems frequently appear in the literature. Some examples from a very large body of the literature include education (Savage 2006 and Stagl 2006), enforcement (Carroll and Warren 2002), and improvement in grade crossing systems (Heathington 1996). Liability issues also have received specific attention (Glennon 1997).

The literature which addresses characteristics of collisions between trains and vehicles is not as extensive. Klein, *et al*. (1994) concentrated on fatal crashes at grade crossings. The National Transportation Safety Board (NTSB) using case studies tried to identify critical factors in highway-rail crossing fatal crashes (NTSB 1998). Raub (2007) examined crash rates for seven Midwestern states. One important finding from this paper was substantial differences in the rates dependent upon the class of warning systems in place. Articles also have addressed contribution of human factors (Richards and Heathington, 1988, and Meshkati, *et al.,* 2006.

Finally, a body of work has attempted to model and prediction grade crossing collisions. Much of the effort has originated with the Federal Highway Administration (FHWA) and a number of individual states. The most comprehensive review appears in Elzohairy and Benekohal (2000) and a more recent effort deriving from the research of Oh, *et al.* (2006).

This paper derives from current work to tabulate and analyze highway-rail grade crossing crashes and inventory. The work should provide a comprehensive, national analysis. Data come from the FRA Office of Safety Web site (FRA Office of Safety). Crash data are available from 1988 to present. Inventory data cover only the most current inventory records for the crossings. Historic inventory were provided by the FRA. The Web site, in addition to making available data for downloading can produce tables for individual states and periods, but not comprehensive tables covering all reported elements, and not for the U.S. as a whole. Moreover, the tabulations do not combine crash and inventory records..

For the purposes of this paper, analyses are limited to collisions between a trains and vehicles at a public highway, at-grade crossing. The term “crossing” will be used. There also are crossings of private roads and for only pedestrians. A private crossing can be a driveway, entrance to a commercial or industrial site, or farm, but in any case it usually is maintained by the entity which needs to be served by crossing the tracks. These crossings may, or may not, be marked with specific warning devices; however, it is the responsibility of the user to be aware of the crossing and to take due care. Analysis of crashes at private crossings will appear in the longer work.

Most public crossings have combinations of warning devices; however, a few have none. Table 1 lists the primary warning device used for the FRA crash report. The ordering of the devices effectively is from active systems or those most restrictive to vehicular movement (gates) to no warning systems. Moreover, at most crossings, the engineer is required to sound the train horn up to 0.25 miles from the crossing. Quiet zones are allowed under precise conditions (FRA Train Horn Rules URL). Although the crash report provides only for the codes shown in the Table, three other important classes of warning devices are appearing: yield signs, four-quadrant gates (placing gates across all lanes of the crossing roadway), and experiments with devices which attempt to stop a vehicle from entering the tracks. Devices to alert train engineers of obstacles on the track are still in testing. The use of yield signs or four-quad gates appears only on the inventory.

Table 1

Warning Devices

Coded on Crash Reports

FRA Code	Device	FRA Code	Device
1	Gates	7	Crossbucks
2	Cantilever Flashing Lights	8	Stop Signs
3	Standard Flashing Lights	9	Watchman
4	Wig wags	10	Flagged by Crew
5	Highway Traffic Signals	11	Other
6	Audible Devices	12	None

This paper will concentrate on the two most frequently used active warning systems, i.e., a system triggered by the presence of a train, gates and flashing lights, and the two most frequently employed passive systems, crossbucks alone and crossbucks with a stop sign. Tables and statistics will include presence of yield signs which is available from the inventory narrative, and no signs or signals. The number of other lesser used devices, e.g., wig wags and crew flagging, is so limited nationally, that computing rates or comparing them with other devices is not practical from a statistical perspective.

Crash Data

Issues with the Data

All records came from the FRA, both through their online download, and directly from the Office of Safety. Each crash appears as a single record. Unlike crashes, multiple inventory records may exist for each crossing. Whenever a change occurs to field of data, the FRA generates a new record. As a result, 1.3 million records were made available. The latest record for any currently active crossing has an “end date” of 999999, Data for both crashes and inventory covers a ten-year period from January 1, 1996 through December 31, 2005.

Several adjustments were made in the crash and inventory records, including;

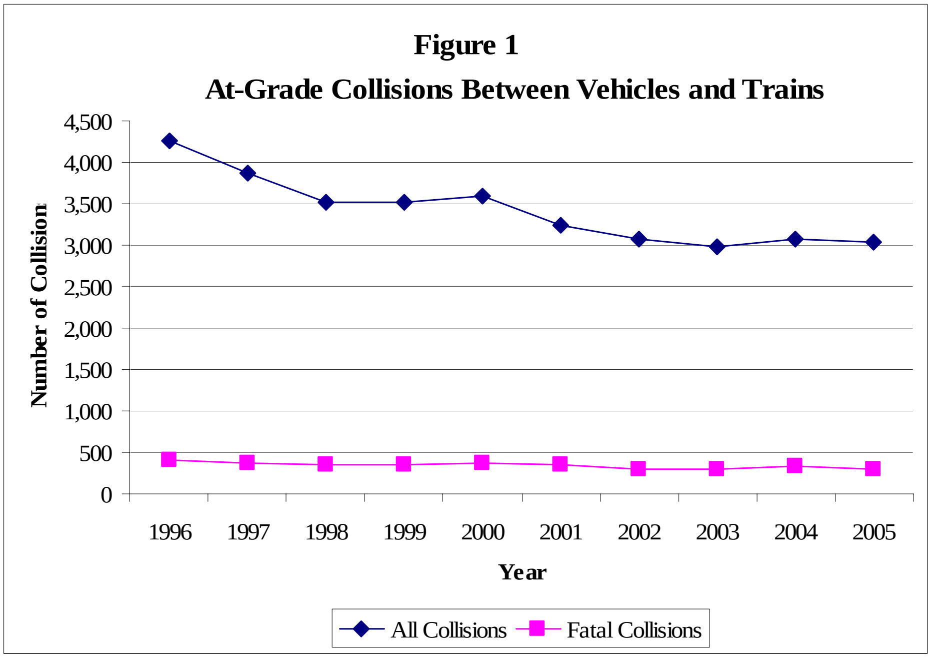
- determining where yield signs are used from a narrative section of the inventory,

- converting the warning device codes to a common system (crash and inventory use a different coding sequence),
- adjusting the crash report warning device when the device coded for the inventory appears to be correct (mainly for crossings that had gates in the inventory, but crash records did not), and
- substituting a yield sign for crash records where the coded device showed only crossbucks.

Data in both the crash reports and inventory records have some issues which require caveats. First, problems in quality arise (for a seminal report regarding the quality of crash report, see O'Day 1993). Most issues in crash reporting are coverage (reporting all crashes), completeness, and accuracy. Both the railroad report and a police crash report can reflect these problems. The inventory suffers more from timeliness and coverage. Although both state transportation agencies and railroads should be reporting all changes to crossings, there is no penalty attached for failure to report.

National Perspective

From 1996 to 2005, 34,166 grade crossing crashes were reported to the FRA. As shown in Table 2, crashes at public crossings have been decreasing both in frequency and as a percent of all reported crashes. In 1996, there were 4,268 reported public crossing crashes. The 3,043 crashes in 2005 represents a 28% decrease over the ten years. Figure 1 clearly shows the gradually descending numbers.



Fatal crashes at public crossings have decreased more than 25% from 410 in 1996 to 304 in 2005. Fatalities continue to occur in 10% of the collisions. This percentage is much higher than for fatal vehicular crashes which represent 0.6% of all highway crashes (Safety Facts, FHWA

Table 2
At-Grade Collisions Between Trains and Vehicles, 1996 to 2005
From Federal Railroad Administration Crash Reports

Crossing	Year										10-Year
Classification	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**
Private/Other[1]	457	463	416	396	474	394	366	389	434	429	4,218
Public	3,811	3,404	3,105	3,116	3,115	2,843	2,711	2,588	2,641	2,614	29,948
All Crashes	4,268	3,867	3,521	3,512	3,589	3,237	3,077	2,977	3,075	3,043	34,166
Pct. Public	89.3%	88.0%	88.2%	88.7%	86.8%	87.8%	88.1%	86.9%	85.9%	85.9%	87.7%

Collisions Resulting in One or More Fatalities

											10-Year
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**
Private/Other	31	30	35	31	47	33	34	27	30	25	323
Public	379	341	325	312	322	316	264	271	296	279	3,105
Total	410	371	360	343	369	349	298	298	326	304	3,428
Fatal as % of All Crashes	9.6%	9.6%	10.2%	9.8%	10.3%	10.8%	9.7%	10.0%	10.6%	10.0%	10.0%

Table 3
National Vehicle Crashes, 1996 to 2005
From National Highway Traffic Safety Administration

	Year										10-Year
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**
All Crashes	6,842,000	6,865,000	6,335,000	3,279,000	6,394,000	6,323,000	6,181,000	6,328,000	6,181,000	6,159,000	60,887,000
Fatal Crashes	37,351	37,280	37,081	37,043	37,409	37,795	38,253	38,252	38,253	39,189	377,906
Fatal as % of All Crashes	0.55%	0.54%	0.59%	1.13%	0.59%	0.60%	0.62%	0.60%	0.62%	0.64%	0.62%
Grade Crossing as % of All Crashes	0.06%	0.06%	0.06%	0.11%	0.06%	0.05%	0.05%	0.05%	0.05%	0.05%	0.06%

URL). In other words, a collision between a vehicle and train is 16 times more likely to result in a fatality than collisions not involving a train. This substantial over-representation helps drive the continued attention to highway-rail crashes from traffic safety organizations, e.g., Operation Lifesaver, the United States Department of Transportation (USDOT), and safety professionals

Table 3 shows the distribution by severity of crashes at public crossings. Since 1996, the 29,948 collisions at public crossings resulted in 7,783 injuries in addition to the 3,105 with fatalities or in 36% of the collisions. Approximately 32% of all highway collisions nationally had injuries or fatalities. Except for the very high death rate, grade crossing collisions overall are not significantly more likely to be injury producing.

Selected Characteristics of Grade Crossing Crashes

Each of the 50 states and Washington, DC have reported at least one crash during the past ten years. Rhode Island, Hawaii, and DC have had five or fewer. Texas, with 3,072 has led the nation. Illinois was second with 1,738. Table 4 displays the ten states with the highest numbers of crashes. Together they account for approximately 50% of the crashes reported during the period. However, these same states do not also represent the ten highest in fatalities. Only Texas and Illinois retain their respective ranking with 288 and 256 fatal crashes each. Third in ranking was California with 230. The percent of collisions with a fatality in Illinois and California, 14.7% and 16.0% of the total respectively, were significantly higher than the nationwide average of 10.0%.

The Table also shows crashes and rankings for eight states in the Institute of Transportation Engineers, District VI. All District VI states combined excluding CA have approximately as many grade crossing crashes as Michigan. Fatal collisions follow similar rankings except for Nevada. While it is 47th in number of crashes, it is 24th in those with a fatality.

Trains struck vehicles in 76% of the crashes; the remaining times a driver collided with the train. Although 10% of the collisions produce a fatality, a train striking the vehicle was significantly more likely to do so. However, the overall severity of crashes was similar regardless of type of collision. These results appear as Table 5.

Other characteristics of interest from the crash reports included the weather, light conditions, time, and driver characteristics. Table 6 shows that seven of 10 crashes occurred in clear weather with a slightly higher percentage of the fatal collisions occurring then. Sixty two percent 62% of the collisions occurred in daylight. The percentage of fatal crashes during daylight hours was significantly higher. Drivers were more likely to run into trains at night. Finally, the largest percentage of collisions occurred at crossings with no limits to sight distances.

The largest percentage of collisions have occurred in January and December. Crashes occurred more frequently on Friday than any other day of the week with Sunday the lowest. Finally, crashes were fairly evenly distributed from 0800 hours to 1800 hours. The highest percentage occurred at 1500 hours. Differences among the hours were not significant.

Table 7 displays the distribution of crashes by age of the driver. In approximately 25% of the reports, the driver's age was not stated. The percent columns exclude "not stated." An additional

Table 4
Severity Level of Crashes at Public Grade Crossings

	Year											10-Year
Severity Level	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**Total**	**Total**
Fatal	379	341	325	312	322	316	264	271	296	279	3,105	10.4%
Injury	1,040	944	867	852	774	733	635	629	682	627	7,783	26.0%
None	2,392	2,119	1,913	1,952	2,019	1,794	1,812	1,688	1,663	1,708	19,060	63.6%
Total	3,811	3,404	3,105	3,116	3,115	2,843	2,711	2,588	2,641	2,614	29,948	

Table 5
States with the Most Crashes

Nationally				ITE Region VI			
		Crash Ranking				**Crash Ranking**	
State	**10 Years**	**All**	**Fatal**	**State**	**10 Years**	**All**	**Fatal**
TX	3,072	1	1	AK	32	44	45
IL	1,738	2	2	CA	1,437	5	3
IN	1,737	3	4	HI	0	50	47
LA	1,587	4	5	ID	235	31	29
CA	1,437	5	3	MT	175	36	35
GA	1,243	7	14	NV	21	47	24
AL	1,101	8	12	OR	234	32	34
MI	1,081	9	13	WA	388	25	26
MS	1,037	10	8	Total	2,522	9	13

note: Other ten highest states in fatal crashes: FL, 7th; AR, 9th, OK, 10th

Table 6
Severity of Crashes Showing Weather and Light Conditions

							Type of Collision	
	Severity			**All Crashes**				
Weather	**Fatal**	**Injury**	**None**	**Total**	**Percent**	**% Fatal**	**Train Into Vehicle**	**Vehicle Into Train**
Clear	2,252	5,431	12,860	20,543	68.6%	72.5%	15,901	4,642
Cloudy	632	1,597	3,835	6,064	20.2%	20.4%	4,663	1,401
Fog	37	137	340	514	1.7%	1.2%	294	220
Rain	139	452	1,405	1,996	6.7%	4.5%	1,424	572
Sleet	6	17	55	78	0.3%	0.2%	52	26
Snow	39	149	565	753	2.5%	1.3%	494	259
Total	3,105	7,783	19,060	29,948			22,828	7,120

	Severity			All Crashes			Train Into Vehicle	Vehicle Into Train
Light	**Fatal**	**Injury**	**None**	**Total**	**Percent**	**% Fatal**		
Dark	844	2,131	6,585	9,560	31.9%	27.2%	6,465	3,095
Dawn	73	189	479	741	2.5%	2.4%	577	164
Day	2,075	5,199	11,397	18,671	62.3%	66.8%	15,016	3,655
Dusk	113	264	599	976	3.3%	3.6%	770	206
Total	3,105	7,783	19,060	29,948				

two columns display the 2000 census population distribution of age groups in the United States. Comparing the percent of crashes by age and census group shows that drivers from ages 20 through 39 appear over-represented. Those ages 20 to24 years are significantly over-represented. Drivers ages 50 and older are substantially under-represented, although by age 70, the under-representation is disappearing. Unlike other vehicle collisions, it is not the youngest driver most frequently involved at grade crossings. On the other hand, drivers from ages 15 to 19 years and older than 55 years are more likely to suffer a fatal injury than for other age groups.

Males are significantly more likely to have a vehicle-train collision. Only 25% of the crashes involved females; 75% involved males. Given that males represent 48% of the U.S. population, they are 1.55 times more likely to be involved in a grade crossing crash.

One final tabulation examined the severity and type of collision and whether or not there was a whistle ban in place. Approximately 3.7% of all crashes occurred at crossings where a whistle ban was in place. There were no real differences in the severity of the collision dependent upon the presence of a ban. However, a train was significantly more likely to strike the vehicle when the ban was in place.

Approximately 3 of every four crashes this was the manner of collision. The class of warning device makes a difference. Where gates and stop signs are present, a train is even more likely to strike a vehicle than with at crossings with other warning devices.

Table 7
Severity of Crashes Showing Age Grouping of Driver
Including U. S. Census (2000) Distribution of Population by Age Grouping

	Severity				**Percent***		**2005 Population**	
Age Group	**Fatal**	**Injury**	**None**	**Total**	**Total**	**Fatal**	**(000)**	**Percent**
15-19 yrs	283	695	1168	2,146	9.8%	11.6%	21,039.0	9.3%
20-24 yrs	286	928	2133	3,347	15.2%	11.7%	21,037.9	9.3%
25-29 yrs	195	627	1477	2,299	10.4%	8.0%	20,065.7	8.8%
30-34 yrs	217	697	1601	2,515	11.4%	8.9%	20,077.2	8.8%
35-39 yrs	229	655	1471	2,355	10.7%	9.4%	21,002.0	9.2%
40-44 yrs	212	569	1364	2,145	9.7%	8.7%	22,860.5	10.1%
45-49 yrs	176	451	1078	1,705	7.7%	7.2%	22,484.5	9.9%
50-54 yrs	148	405	896	1,449	6.6%	6.0%	19,997.7	8.8%
55-59 yrs	128	260	636	1,024	4.7%	5.2%	17,353.7	7.6%
60-64 yrs	130	217	482	829	3.8%	5.3%	13,001.9	5.7%
65-69 yrs	86	165	349	600	2.7%	3.5%	10,131.4	4.5%
70+ yrs	358	388	844	1,590	7.2%	14.6%	18,150.3	8.0%
Not Stated	657	1726	5561	7,944			0.0	
Total	3,105	7,783	19,060	29,948			227,201.8	

* Excluding "not stated"

Crossing Inventory

Crossing inventory data derive from the FRA inventory records. These records were used to compute crash rates based on crossing vehicles and trains. They also provide some information about warning devices that are not available on the crash report. For analytical purposes, the characteristics of the crossing on July 1 are presumed to be representative of the year. However, for computation of rates, the average annual daily travel (AADT) and train movements on that date are used and annualized.

Table 8 shows the number of crossings each year and the 10-year average. The latter is used as a convenience for discussion. Data for private crossings from 1996 through 1999 were not available at the time of this paper. Approximately 92% of crossings are public at-grade. Most of the remainder are private. The remaining discussion in this paper uses data for the 134,000 public at-grade crossings.

Appendix 1 displays a table showing the number of crossings by state for each year from 1996 through 2005. The Table also shows the national rank. Texas has the most crossings, an average of 8,959. Second was California with an average of 7,657, and third Illinois with 6,065. Except for Texas, the ranking in number does not correspond closely to the ranking in crashes and has a substantial effect on crash rates by state.

Two fields from the inventory, AADT and daily trains, provide the bases for computing rates. Each is annualized. For vehicles the term 100 million crossing vehicles” (HMCV is used. Trains are shown as 1,000,000 annual trains, and number of crossings in thousands. Other coded

Table 8
Number of At-Grade Crossings on July 1 of Each Year

Class of Crossing	**Year**				
	1996	**1997**	**1998**	**1999**	**2000**
Pedestrian	692	589	422	295	2,125
Private*	0	0	0	0	5,837
Public	129,743	127,534	123,134	117,536	118,332
All Crossings	130,435	128,123	123,556	117,831	126,294

Class of Crossing	**Year**					**Average per Year**
	2001	**2002**	**2003**	**2004**	**2005**	
Pedestrian	250	298	323	318	266	558
Private*	10,131	12,470	13,622	15,002	12,933	11,666
Public	131,978	138,339	144,827	151,879	157,513	134,082
All Crossings	142,359	151,107	158,772	167,199	170,712	146,305

* note: Inventory records for private crossings available from 2000 to 2005

characteristics such as crossing angle, road surface, number of tracks, and development are briefly addressed.

Because the likelihood of an at-grade crash likely depends upon the type of warning device present, discussion will center on warning devices. The classification of these devices appeared in Table 1. Although the inventory shows the presence of four-quad gates, they are not widely used except in a few states. Crossings with four-quad gates are then treated as active crossings with gates.

Table 9 displays summary statistics for the crossings. Discussion will exclude special active devices and traffic signals because the crash report does not always reflects the these devices, and their use is so infrequent that statistical analysis would not provide useful answers. Columns in the Table show number of crashes, crossings, C and trains for the 10-year period. Daily averages for vehicles and trains also appear. Although crossings with gates have the most vehicles, an average of 438 HMCV annually, fewer vehicles cross daily than at locations with flashing lights. However, crossings with flashing lights have approximately 60% fewer trains passing daily than at gates. Warning devices shown in Table 9 are present for 98% of the collisions, at 98% of the crossings, and serve more than 95% of train and vehicle movements.

Crash Rates

Table 10 shows the crash rates based on numbers of crossings, vehicles, and trains. In the 10-year period from 1996 through 2005, 29,407 crashes (an average of 2,941 per year) occurred at the six selected warning device classes. Based on the number of crossings operating annually, the crash rate per 1,000 crossings was 22.5. The overall rate based on crossing vehicles was 3.25 per HMCV, and for trains, 6.83 per million trains.

Table 9

10-Year Summary of Crashes, Crossings, Annual HMCV, and Annual Trains

	Annual Occurrences				**Average Daily**	
Warning Device	**Crashes**	**Crossings (000)**	**100 MCV (HMCV)**	**1,000,000 Trains**	**Vehicles**	**Trains**
Crossbucks	9,626	63.03	1,679.91	1,347.42	730.2	5.9
Flashing lights	6,704	20.27	2,836.15	584.56	3,833.3	7.9
Gates	9,539	39.49	4,382.61	2,133.71	3,040.5	14.8
Other Signs or No signs	115	1.56	16.97	26.23	299.1	4.6
Stop signs	3,262	6.01	136.96	197.25	624.6	9.0
Yield signs	161	0.45	8.85	15.42	541.0	9.4
Total*	29,407	130.80	9,061.45	4,304.60	1,898.0	9.0

* Excluded are 541 crashes with flagging, special devices, and traffic signals

Table 10

10-Year Summary of Crashes, Crossings, Annual HMCV, and Annual Trains

	Average Annual				**Crash Rates**		
Warning Device	**Crashes**	**Crossings (000)**	**100 MCV**	**1,000,000 Trains**	**per 1,000 Crossings**	**per HMCV**	**per 1M Trains**
Crossbucks	962.6	63.0	168.0	134.7	15.3	5.73	7.14
Flashing lights	670.4	20.3	283.6	58.5	33.1	2.36	11.47
Gates	953.9	39.5	438.3	213.4	24.2	2.18	4.47
Other Signs or No signs	11.5	1.6	1.7	2.6	7.4	6.78	4.38
Stop signs	326.2	6.0	13.7	19.7	54.3	23.82	16.54
Yield signs	16.1	0.4	0.9	1.5	35.9	18.20	10.44
Total	2,940.7	130.8	906.1	430.5	22.5	3.25	6.83

When examining individual classes of device, gates would appear to provide the most protection from vehicle-train collisions. The other active device, flashing lights, should provide the second highest level of safety in that they signal the presence of a train.

With passive devices (excluding no signs or signals), the crossbucks could be considered at the lowest level of warning. As discussed by Richards and Heathington (1988), many motorists either did not recognize the presence of crossbucks or know what the law required. Additional pressure has been placed on adding stop signs, or more recently to yield signs along with the crossbucks. In some states, a large percentage of passive crossings now have stop signs.

Differences in Crash Rates Based on Warning Device

Number of crossings. The rates per 1,000 crossings are best used for comparing a specific class of crossings within a given state. However, because the rates do not reflect exposure, they could be misleading. For example, crashes occurred at 1 of every 54,000 crossings with stop signs. The rate for crossings with gates was one in 24,000. However, crossings with stop signs often have very few vehicles and train movements; whereas, gates are used at crossings with heavy vehicle and train movements.

<u>Vehicle crossings</u>. Gates, because they close the crossing to traffic should have the lowest crash rates. Locations with these devices have a rate of 2.18 per HMCV. Slightly higher with a rate of 2.36 per HMCV are crossings with flashing lights. Most of the collisions occurring at gated crossings result from persons driving around the gates. The remainder generally occur when drivers fail to stop at gates or become stranded. In rare instances, especially with trucks, the drivers do not clear the descending gates in a timely manner or the gates malfunction.

Locations with only crossbucks had a rate of 5.73 per HMCV, more than twice the rate of active devices. The highest rate was at crossings controlled with stop signs. The rate of 23.82 is approximately 10 times that for active devices and four times that of crossbucks alone. This national finding closely echoes an earlier finding by Raub (2006) based on examining seven Midwestern states.

Close to the stop-sign rate is that for yield signs. However, there are too few installations of yield signs. Only 8 states reported any crashes, with Michigan and Ohio reporting 70% of the installations. Where the number of crossings with yield signs has been increasing, the rates have been dropping.

<u>Train movements.</u> Using 1,000,000 trains as a basis provides a slightly different overall perspective. Crossings with gates and no signs share the lowest rates of 4.5 and 4.4 respectively. The low rate for where no signs are present from the probably derives from the few locations and crashes.

Yield signs have a rate of 10.4 and flashing lights have a much higher rate than gates of 11.5 per million trains. Stop signs remain at the top of the rates with 16.5 crashes per million trains. Although the range in rates between crossings with gates and with stop signs is not as large as for vehicle movements, crossings with stop signs are almost four times more likely to have a collision than those with gates. They also are more than double the rate of 7.14 per million trains for crossbucks only.

<u>Type of collision.</u> The single-most distinguishing characteristic which differs significantly among the devices is the type of collision. The frequencies and percentages appear in Table 11. With stop signs and gates, the vehicle was significantly more likely to struck by a train based on a test of proportions. On the other hand, where crossbucks only or flashing lights exist, the driver was more likely to strike the train. The z-scores exceeded the 0.01 level in all cases. That a train is more likely to strike a vehicle is logical in that most of the collisions at gated crossings occur when drivers ignore the gates. For stop signs, the drivers may be slowing, assume that no train is present (because the average driver rarely if ever will see a train at the crossing), and proceed without looking. A now dated study from Texas (Lumm and Stockton 1982) done at low-volume rural roads showed that drivers appeared to be the most careful when there were no signs or yields signs as opposed to stop signs. The same type of study has not been done for rail crossings.

Table 11
Type of Collision by Category of Warning Device

	Train Into Vehicle		Vehicle Into Train		All Crashes	
Warning Device	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Crossbucks	7,116	31.2%	2,510	35.3%	9,626	32.1%
Flagging	38	0.2%	22	0.3%	60	0.2%
Flashing lights	4,564	20.0%	2,140	30.1%	6,704	22.4%
Gates	7,866	34.5%	1,673	23.5%	9,539	31.9%
Other Signs or No signs	96	0.4%	19	0.3%	115	0.4%
Special Devices	112	0.5%	58	0.8%	170	0.6%
Stop signs	2,700	11.8%	562	7.9%	3,262	10.9%
Traffic signals	233	1.0%	78	1.1%	311	1.0%
Yield signs	103	0.5%	58	0.8%	161	0.5%
Total	22,828		7,120		29,948	

The higher rates of drivers running into trains at crossbucks and flashing lights may derive from incorrect driving assumptions. Studies such as by Heathington (1996) showed that subjects who drove across a railroad crossing and then were asked to describe what they had seen, missed seeing warning signs and devices. With flashing lights, the reasons are not so clear. It would warrant a separate research study, but perhaps the expectations of the human factors people and of drivers are not the same.

Other Characteristics of Crashes and Rates

Table 12 shows the states with the highest crash rates for each of the four major warning devices: crossbucks, stop signs, flashing lights, and gates. Only states with at least 10 crashes per year were included in the rankings. An important observation is that states with the greatest number of crashes are necessarily those with the highest rates.

Other inventory elements available for crossings include the number of crossing lanes, type of development at the crossing, angle of road and crossing, presence of a nearby (paralleling) highway, and whether or not the road is paved. Significant differences appear in the number of crashes based on the following factors:

- Highway is paved.
- Type of development at the crossing - fewer crashes than expected where commercial, industrial, and residential development nearby, and approximately twice as many where the crossing has no nearby development.
- Crossings with four or more lanes of travel.

On the other hand, the angle of the crossing, and whether or not a highway is nearby plays no apparent role.

Table 12
States With Ten Highest Crash Rates
Showing Four Major Warning Devices

Crossbucks		Stop Signs		Flashing Lights		Gates	
State	**Per Annual 100MCV**	**State**	**Per Annual 100MCV**	**State**	**Per Annual 100MCV**	**State**	**Per Annual 100MCV**
IA	23.52	ID	212.17	IN	7.11	NE	5.22
IN	18.35	NE	144.82	AR	5.95	LA	4.44
WI	15.53	WI	94.75	IA	5.74	AR	4.09
NM	12.81	TX	88.06	KY	5.27	MS	4.09
LA	11.70	MA	84.95	MS	5.26	MO	3.65
NE	11.08	LA	66.45	LA	4.85	TN	3.37
IL	10.97	IN	54.74	GA	4.51	ND	3.30
MS	10.56	IA	53.81	AZ	3.87	IA	3.16
OK	10.30	UT	51.62	MA	3.54	KY	3.12
KS	9.80	NM	46.98	WI	3.31	NM	3.06
Avg	5.74		23.82		2.36		1.74

Examination of fatal crashes presents slightly differing findings. Fatal crashes were more likely to occur when the road was not paved, which is opposite the finding for all crashes. Most important is that 62% of crashes that occurred where no development is present were fatal. This rate is six times the percentage of fatal crashes at all locations.

Because vehicular crashes often are attributable to the younger drivers, a tabulation was done using age of the driver and the AADT present at the crossing on the day of the crash. Although that AADT is annualized, it is limited to those crossings where a crash occurred. Although, drivers ages 20 to 44 are more likely to be involved in a crash than others, drivers from 16 to 19 years have a higher crash rate per HMCV.

Commentary on the Analyses

The class of warning device present at a highway-rail grade crossing plays a critical role in the likelihood of a vehicle-train collision. Based on vehicles using the crossing, the presence of gates or flashing lights generate very low rates. These are active devices and normally signal the presence of a train (although false activations occur frequently). The passive devices which include crossbucks only or those augmented by stop or yield signs, at a minimum, more than double the rate. Where only crossbucks are in place, a crash is 2.5 times more likely. What remains surprising is the high rates when stop signs and yield signs are used in addition.

Stop signs, especially, would be assumed to make the crossing safer. However, this does not appear to be the case. The same finding appeared when examining a smaller sample of states. The possibility that stop signs would not reduce crashes had appeared elsewhere including the NTSB (1998), Lumm and Stockton (1982) and Mounce (1981).

While crash rates where yield signs are present are slightly lower than for stop signs, they do not approach the rates for crossbucks only. One problem that remains with examining the yield signs is that they have not been installed at enough locations.

Until some form of observational research is conducted which examines driver behavior under each of the three passive devices, reasons for the differences. The use of four-quad gates should yield the lowest crash rates, but their installation is expensive. Otherwise, those warning devices currently in use are likely to continue. Rather than continuing study of the construction of devices, more research on how motorists respond and behave may prove useful. What also is important is examining what other lower-cost devices may be of value. Traffic signals might serve as another class of warning device, and to a large extent already are in use for intersections a nearby paralleling highways. They might substitute for flashing lights. Finally, train presence indicators might also prove valuable.

Overall, the FRA data can be a valuable tool for study. Currently, there are weaknesses that should be addressed. First, the range and classification of devices needs to be standardized for both crashes and inventory, and must be extended to cover the newer applications. Most importantly, both the crash report and inventory should show a “primary” warning device, and then secondary ones as necessary. More emphasis also should be given to simpler crash reports, encouraging their submission. Furthermore, more timely inventory records should prove valuable in helping identify locations which are more dangerous and in need of further review of the warning devices.

This paper has addressed some of the characteristics of highway-rail grade crossing crashes. It shows that there are a number of important issues related to these collisions. Moreover, it also shows that the continued attention to this form of collision remains important.

References

Carroll, A. A. and J. D. Warren. “Photo Enforcement at Highway-Rail Grade Crossings in the United States: July 200 - July 2001.” *Transportation Research Record* 1801 (2002), p. 46-53.

Elzohairy, Yossary and Rahim F. Benekohal. *Evaluation of Accident Prediction and Hazard Index Formulas for Railroad Highway Crossings*. Springfield, IL: Illinois Department of Transportation, 2000.

Federal Railroad Administration, Office of Safety. **http://safetydata.fra.dot.gov/officeofsafety/**. Accessed April 2007.

FRA Train Horn Rules.
http://www.fra.dot.gov/downloads/safety/trainhorn_2005/amended_final_rule_081706.pdf.
Accessed January 2007.

Glennon, J. C. "Highway Grade Crossings." *Accident Reconstruction Journal*, v. 9, no. 4 (July/August 1997), p. 27-44.

Heathington, K. W., "Railroad Grade Crossing Accident Behavior and Countermeasures." *Infrastructure*, v. 2, no. 1 (Fall 1996) p. 10-16.

Klein, Terry M., Tina Morgan, and Adrienne Weiner. *Rail-Highway Crossing Safety: Fatal Collision and Demographic Descriptors*. NHSTA Technical Report 808 196, Washington, DC: November 1994.

Lumm, Harry S. and William R. Stockton. "Stop Signs or Yield Signs." *Transportation Research Record* 881 (1982), p. 29-33.

Manual on Uniform Traffic Control Devices for Streets and Highways. Washington, DC: United States Department of Transportation, 2003.

Meshkati, N, M. Rahimi, and M. J. Driver. "Investigating the Role of Driver Decision Styles in Highway-Rail Crossing Accidents." *Accident Reconstruction Journal*, v. 16, no. 3 (May/June 2006), p. 51-57.

Mounce, John M. "Driver Compliance with Stop-Sign Control at Low Volume Intersections." *Transportation Research Record* 808 (1981), p. 30-37.

National Transportation Safety Board. *Safety at Passive Grade Crossings, Volume I: Analysis*. Washington, DC: National Transportation Safety Board, 1998.

O'Day, James. *Accident Data Quality*. *Synthesis of Highway Practice*. National Cooperative Highway Research Program, Transportation Research Board, Washington, DC: 1993.
Oh, J., S. P. Washington, and D. Nam. "Accident Prediction Model for Railway-Highway Interfaces." *Accident Analysis and Prevention*, v. 38, no. 2 (March 2006), p. 346-356.

Raub, R. A., "Examination of Highway-Rail Grade Crossing Collisions Over 10 Years in Seven Midwestern States," *ITE Journal*, v. 76, no. 4, (April 2006), p. 16-22. (see also Raub, R. A. and R. E. Lucke. "Examination of Highway-Rail Grade Crossing Collisions Over 10 Years in Seven Midwestern States," Paper Prepared for 84th Annual Meeting, Transportation Research Board, Washington, DC, January 2005.)

Richards, S. H. and K. W. Heathington. "Motorist Understanding of Railroad-Highway Grade Crossing Traffic Control Devices and Associated Traffic Laws." *Transportation Research Record*, 1160 (1988), p. 52-59.

Safety Facts. Federal Highway Administration. http://safety.fhwa.dot.gov/facts_data.htm/. Accessed April 2007.

Savage, I. “does Public Education Improve Rail-Highway Crossing Safety?” *Accident Analysis and Prevention,* v. 38, no. 2 (March 2006), p 310-316.

Stagl, J. “Taking Aim from an Array of Angles.” *Progressive Railroading*, v. 49, no. 1 (January 2006), p. 27-41.