Study of Driver's Behavior at Passive Railroad-Highway Grade Crossings

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Railway highway grade crossing safety has always been a concern for railroads, state DOTs, and the driving population. This paper presents an overview of drivers' behavior at different passive warning sign systems present at a selected number of Kansas railroad-highway grade crossings. Emphasis in this study was on drivers' stopping behavior at the STOP signs, as that has been a major concern of Kansas DOT (KDOT). A field study was conducted on nine grade crossings with selected warning devices to determine driver's approach behavior, particularly stopping behavior at STOP signs. Various statistical analysis and comparisons are done for stopping of heavy trucks, school buses and other vehicles at crossings with both poor and good sight distance on their approaches. Based on the field tests conducted it was found that the majority of drivers did not stop at the STOP signs at the grade crossings. A higher percentage of drivers actually stopped at crossings with poor sight distance on the approach than on approaches with good sight distance. The use of the STOP sign at passive grade crossings has been controversial for several decades. This paper presents a brief history of their use and the controversy. Based on this limited study, the authors recommended that a STOP sign should not be used at grade crossings without a valid engineering study that includes an evaluation of the sight distance.

INTRODUCTION

Approximately every 90 minutes a crash occurs on a railroad-highway grade crossing in the U.S. The Association of American Railroads (AAR) has estimated that vehicle-train collisions cost the railroad industry nearly one billion dollars a year (Highway-Rail Grade Crossing Safety 2006). According to the Federal Railroad Administration (FRA)(2005), there were 145,608 public grade crossings in the U.S., out of which 55.7% (81,052) were passive grade crossings. About 44% of fatalities from public grade crossing accidents in 2005 (143 out of 325) occurred at passive grade crossings (National Transportation Safety Board Most Wanted 2005). The Federal Highway Administration (FHWA) has reported that the fatal and nonfatal injury crash rates have been decreasing, but daily vehicle trip miles and train traffic are growing, increasing the potential for crashes at grade crossings (Fambro et al. 1994).

The annual number of vehicle-train crashes decreased by 75% between 1975 and 2001, with deaths in these crashes decreasing 68% from near 1,000 in 1975 to 315 in 2001 (Mok and Savage 2005). This decrease is generally attributed to the Federal Aid Highway Act of 1973, which authorized the Federal-Aid Highway Crossing Program – commonly referred to as the Section 130 Program. This program for states amounted to capital expenditures of approximately $8.5 billion (at current prices) from 1975 to 2001 for grade crossing improvements (Mok and Savage 2005). Using negative binomial regressions on pooled data from 49 states, Mok and Savage (2005) disaggregated all improvements into constituent causes of crash reduction and concluded two-fifths were due to factors such as reduced drunk driving and improved emergency response, about one-seventh each from Operation Lifesaver and ditch lights on locomotives, about one-tenth from crossing closure and only about one-fifth from the installation of lights and gates. However, when estimating costs and benefits, Mok and Savage (2005) came up with a benefit-cost ratio of 2.07 for the Section 130 program and concluded: *"The Section 130 program can be regarded as remarkably successful and has led to real savings of life and serious injury at a relatively modest cost."*

According to the latest statistics on the Federal Railroad Administration (FRA) website (accessed May 2009), railroads have made great strides in reducing collisions at railroad-highway grade crossings. From 1980 to 2008, the number of grade crossing collisions fell 78%, grade crossing injuries fell 76%, and grade crossing fatalities fell 66%, even though highway and train traffic are much higher today than they were in 1980. In 2008, according to the preliminary data from FRA, 286 fatalities occurred at the railroad-highway grade crossings.

Active grade crossings have automatic, train-activated warning devices like flashing lights, gates and bells (Russell and Cathcart 1998). A passive grade crossing does not have any train-activated warning devices but has only signs like a STOP sign, a CROSSBUCK sign or a YIELD sign (Russell and Cathcart 1998). Generally, it is believed that active grade crossings are safer than passive grade crossings. However, it is not economical to convert all passive grade crossings to active grade crossings, as the approximate cost is \$200,000 to \$400,000 per crossing (Burr 2005). About 67% of grade crossings are on low-volume roads (Average Daily Traffic below 400), where upgrading them to active grade crossings is not cost-effective, but they still account for a high percentage of the grade crossing deaths in the U.S. (Russell and Cathcart 1998).

The use of STOP or YIELD signs has been promoted for a low-cost safety measure. Their use is currently permissible, and it is expected that either a STOP sign or YIELD sign will be mandatory at all passive grade crossings when the next edition of the Manual on Uniform Traffic Control Devices (MUTCD) is published. However, the effectiveness of the STOP sign, based on drivers' stopping behavior (generally assumed to be a surrogate for safety), has been controversial for several years. The Kansas Department of Transportation (KDOT) sponsored this study to get data on drivers' behavior at specific passive grade crossing situations, primarily their observance of the STOP sign. Again, the use of the STOP sign at passive grade crossings has been controversial for several years. A summary of their use is presented below.

LITERATURE REVIEW

Since 1970 there have been numerous studies conducted to understand drivers' behavior towards different warning sign systems, including the Rumble strips and STOP sign installation study in Kentucky (Sanders et al. 1978), the Alabama study comparing STOP signs vs. CROSSBUCK signs (Sanders et al. 1978), the Headlight luminance study (Russell et al. 1999), the Indiana study (Russell 1979) of roughness of the road approaching the grade crossings, and the crash rates study for seven Midwestern states (Raub 2007).

The MUTCD guidelines had a lot of changes over the years regarding use of the STOP sign at railroad-highway grade crossings. In the 1961 MUTCD guidelines, seven conditions were set forth warranting a STOP sign. The No. 6 condition stated: *"Railroad crossings where a stop is required by law or by other of the appropriate public authority."* During the period of 1961 to 1971, there was a lot of controversy and debate on this warrant. Subsequently, when the 1971 edition of the MUTCD was written, the "railroad warrant" was removed. The only warrant that could be applied was (MUTCD 1971): *"Other intersections where a combination of high speed, restricted view, and serious accident record indicates a need for control by the stop sign."* It was never made clear whether this warrant could be applied to railroad-highway grade crossings or not. The State of Florida asked for an "interpretation" through the normal manual interpretation process, and in reply the FHWA stated that the STOP sign could be used after an engineering study, which shows a specific need, but only as an interim measure (Russell and Burnham 1999).

Until 1975, the Uniform Vehicle Code and Model Traffic Ordinance (UVCMTO) authorized the use of a STOP sign at particularly dangerous railroad-highway grade crossings (Russell and Burnham 1999). The interpretation for the State of Florida on the use of STOP signs at railroad grade crossings was incorporated into section 2B-5 "Warrants for Stop sign" (i.e., STOP signs could be used after an engineering study showed a specific need, but only as an interim measure) (MUTCD

1978) (Russell and Burnham 1999).

In 1976 the railroad grade crossing subcommittee of the National Advisory Committee for Uniform Traffic Control Devices (NACUTCD) formed a task force to review a 1978 FHWA study, and in a report it was concluded that the STOP sign could be effective under certain conditions. The task force was formed to determine if new language should be proposed for the MUTCD and to draft appropriate new language. Language suggested by the subcommittee subsequently became a part of the 1988 MUTCD guidelines. The language is as follows (Russell and Burnham 1999): 8B-7 STOP SIGN AT GRADE CROSSING (R1-1, W3-1). The use of STOP signs at railroad highway grade crossings shall be limited to those grade crossings selected by a detailed traffic engineering study and should also meet the following four elements:

1. Highways should be secondary in character with low traffic counts.
2. Train traffic should be substantial.
3. Line of sight to an approaching train is restricted by physical features; such that approaching traffic is required to reduce speed to 10 mph or less in order to STOP safely.
4. At the STOP bar, there must be sufficient sight distance down the track to afford ample time for a vehicle to cross the tracks before the arrival of a train.

The U.S. congress passed a law under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) authorizing the use of STOP signs and YIELD signs at railroad-highway grade crossings with two or more trains per day. FHWA issued Final Rule 92-11,which was published in the Federal Register on November 6, 1992 (57FR 53029). A FHWA interpretation defined "two or more trains per day" as meaning two or more on average per day for one full year prior to sign installation, i.e., 365 * 2 = 730 trains. MUTCD section VIII-32 (C) was then revised (Russell and Burnham 1999).

When it comes to the use of the STOP sign at the grade crossings, mixed reactions and different concerns were observed over the years. In the 1960s the concern was whether the STOP sign was effective or not; in the 1970s it was indiscriminate overuse; in the 1980s it was determining appropriate use; and in the 1990s the controversy was with the passage of Federal legislation, which some believed to be politics vs. traffic engineering judgment (Lerner et al. 2001). Most of the traffic engineers were against its use, but most railroad officials and public attorneys were in favor of using the STOP sign at grade crossings (Russell 1979).

Russell and Burnham (1999) believe that the STOP sign at grade crossings can be effective when used where certain specified conditions exist. These conditions were very well specified in the 1988 edition of the MUTCD guidelines (U.S. Department of Transportation 1988). Indiscriminate use of the STOP sign at grade crossings could lead to disrespect for both the sign and also grade crossings, which can be more dangerous (Lerner et al. 2001). The "classic" 1966 Bezkorovainy-Holsinger study (cited in Russell 1979) found that 84% of Lincoln, Nebraska, drivers violated the rules and did not STOP at STOP signs at grade crossings. During that time, too many STOP signs were in use on Lincoln's local streets, and that may have contributed to the lack of respect for the STOP sign (Russell 1979). One of the studies from the American Railway Engineering Association (AREA) showed that 74% of auto drivers did comply with the STOP sign, and if five mph or less is accepted as a safe action, the figure went up to 96.8% (Russell 1979). The authors of this paper believe that this is the only study of dozens in the available literature that has ever reported a majority of drivers complying with the STOP sign at grade crossings.

FIELD STUDY

A field study was conducted to determine how drivers react to passive signs at a selected group of grade crossings in Kansas. With input from the Kansas Department of Transportation (KDOT), nine grade crossings (Table 1) with different warning devices were selected. All but two locations were at locations where the railroad tracks closely parallel a state highway, because driver stopping/ slowing behavior at these types of locations was of concern to them. The original plan was to

Table 1: Grade Crossings Data

DOT #[1]	County	Location	AADT[2]	Main Tracks	Other Tracks	Trains per day	Sign System
605343F/UP	Wabaunsee	Hays (7th) Rd, North edge of Alma	61	1	0	23	STOP X-BUCK
818393Y/UP	Saline	Halstead, near K-140	261	1	0	8	X-BUCK YIELD
818399P/UP	Saline	Muir, near K-140	133	1	0	8	X-BUCK
818613S/UP	Shawnee	Arn Rd, near US 24	116	1	0	10	X-BUCK STOP
818604T/UP	Shawnee	Carter Rd , near US 24	88	1	0	10	X-BUCK STOP
602966E/UP	Reno	108th St., near K-61	88	1	0	15	X-BUCK STOP
814413U/UP	Nemaha	236 St.	227	1	1	23	STOP
602960N/UP	Reno	69th St., near K-61	383	1	0	15	Lights Gates STOP X-BUCK
813912G/UP	Shawnee	Walnut St., Rossville	84	1	0	10	Lights Gates STOP X-BUCK

[1]Department of Transportation Number
[2]Annual Average Daily Traffic

include two crossings with CROSSBUCK signs only, two with CROSSBUCK and STOP signs, two with CROSSBUCK and YIELD signs, two with STOP signs at the grade crossings and YIELD signs at a nearby parallel highway, and two where STOP signs were placed at active grade crossings. Only one site with CROSSBUCK and YIELD signs could be located, thus nine grade crossings were included. Of the nine, seven grade crossings were passive grade crossings and two were active grade crossings that also had a STOP sign. The driver reaction of interest to KDOT was the rate of compliance to the STOP sign and any noticeable stopping at a YIELD sign or CROSSBUCK only. All STOP signs and the only YIELD sign were installed on separate posts, with placement in accordance with the 2003 MUTCD sections 2B.06 and 2B.10. All locations had a STOP AHEAD or YIELD AHEAD sign.

The two sites with a STOP sign used at active grade crossings are special cases explained below. This situation is generally contrary to MUTCD guidelines, but these are special cases. In these cases, the crossing is near a highway that is parallel to the railroad tracks. The STOP signs' main purpose is to stop vehicles from crossing the track if there is insufficient space between the crossing and highway. KDOT wanted to know what drivers' compliance was in these cases. KDOT supplied the details of the grade crossings required for the study. It should be noted that resources were not available to determine vehicle speeds, except subjectively, or drivers' "looking behavior." There was no way to determine if a driver coming to a full stop or a rolling stop looked for a train. Also, since the main objective of the study was to determine driver stopping or slowing behavior due to the signs, this was not considered a problem. Crash data were not obtained, because no meaningful comparisons of the few selected crossings would have been possible for transferable conclusions. Figure 1 shows pictures of a few grade crossings.

In the cases of three STOP sign locations at passive grade crossings (108th Street, Carter road, and Arn road), the railroad track is parallel to a state highway within 30.5 meters (100 feet). In these cases, it is KDOT policy to place a STOP sign at the grade crossing and a YIELD sign at the nearby highway. This practice ensures that a driver stopped at the track can determine if there is enough space for his/her vehicle between the tracks and highway or another vehicle stopped for highway traffic. Also, once the driver starts up and crosses the tracks, many times another stop at the highway is not necessary. In the cases where this system is used, there is good sight distance from a vehicle stopped at the tracks and vehicles approaching the intersection on the highway. On the approach away from the highway, there is only a CROSSBUCK.

In the two cases where a STOP sign is used in conjunction with flashing lights and gates (Walnut Street and 69th Street), the reasoning is similar to that described in the above paragraph. In other words, the STOP sign is not used to enhance or supplement the active devices (flashing lights and gates) but rather to better control vehicle flow and possible queuing between the tracks and the highway at all times and lessens the risk of a vehicle being on the tracks when an approaching train presents a danger. As is the case with passive grade crossings with similar geometry, there is a YIELD sign at the highway. However, on the approaches away from the highways, there is only a CROSSBUCK.

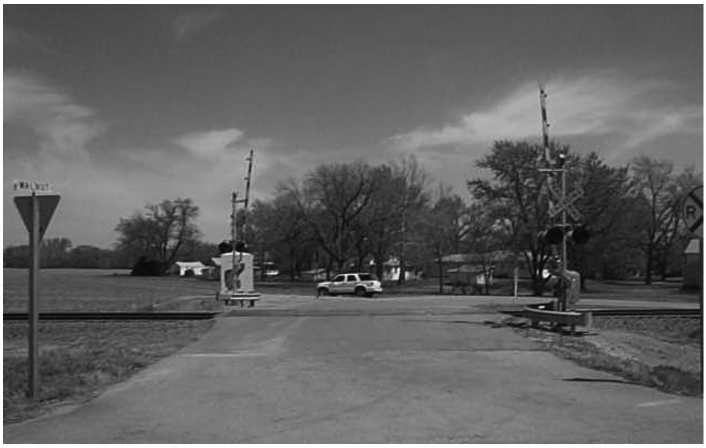
The next phase started with going to each grade crossing and installing a video camera. Two types of video cameras were used. One was a fisheye camera and the other was a small security camera. The small security camera had infrared function and was used to capture the action at night. At most of the grade crossings, video cameras were installed on wooden telephone poles. A DVD player, small television and disks or TV/VCR were kept at ground level in a metal locked box. Figure 2 shows the setup of both types of video cameras. Figure 3 shows the setup of other instruments.

At every grade crossing the study was carried out for six to seven days. About 14 hours per day were recorded (usually between 7 a.m. and 10 p.m.) with either the DVD recorder or VCR recorder. With the video cameras setup for this experiment, it was not possible to measure drivers' head movement, thus "looking behavior" could not be recorded. Only the vehicles' motion was captured by the cameras. At most of the grade crossings some of the DVDs or VCRs recorded during nighttime. In the next phase, all the recorded DVDs and video-tapes were watched and analyzed. Drivers' reactions to the grade crossing were manually recorded, forming three categories: full stop, rolling stop and no stop. The three categories that are mentioned above were given a specific definition. Full stop means a complete stop, where the vehicle is at 0 mph. A rolling stop is where the driver significantly reduces the speed of the vehicle and "rolls" across at an estimated speed of less than 10 mph. No stop is the case where drivers continue crossing the grade crossings at about the same speed as he/she approached the camera range. The categories mentioned here were determined subjectively.

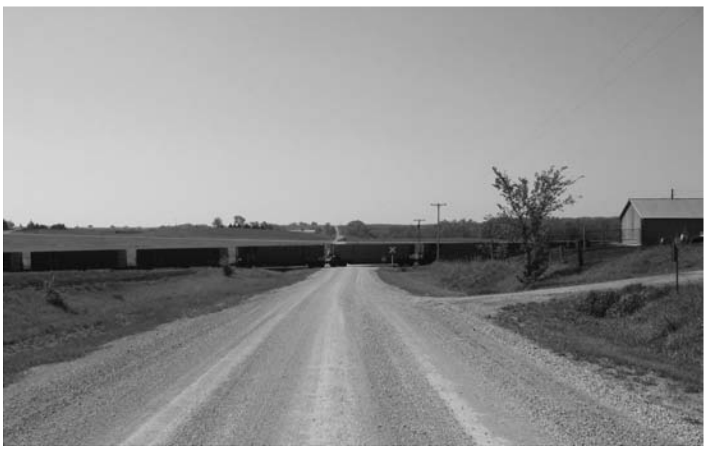
RESULTS

A total of 4,318 vehicles passed through all nine grade crossings used in the study. Out of 4,318 vehicles, 4,088 vehicles were recorded during daytime and 230 vehicles were recorded during nighttime. Overall, 9% (398) of the vehicles stopped completely, 15% (651) did a rolling stop, and 76% (3,269) did not stop at all. During daytime, 9% (372) of the vehicles stopped completely, 15% (612) did a rolling stop, and 76% (3,104) did not stop at all. During nighttime, 11% (26) of the vehicles stopped completely, 17% (39) did a rolling stop, and 72% (165) did not stop at all. During nighttime, 2% more drivers stopped completely at grade crossings as compared to daytime. The

Figure 1: Pictures of Grade Crossings



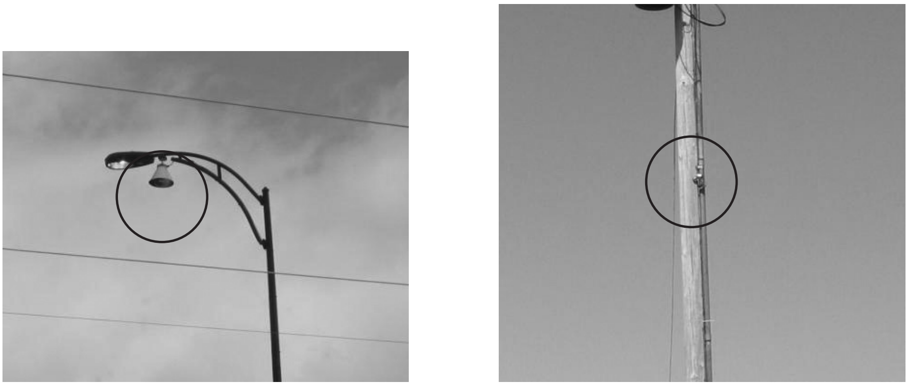
(a) Dot # 813912G/UP @ Walnut Street, Rossville, Shawnee County



(b) Dot # 814413U/UP @ Street 236, Nemaha County

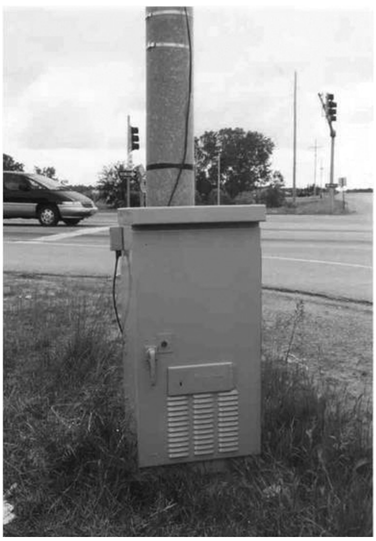
(c) Dot # 818604T/UP Carter road near US-24, Shawnee County

Figure 2: Setup of Two Types of Video Cameras



(a) Fisheye video camera (b) Small security camera

Figure 3: Cabinet for TV/VCR or DVD Recorder



percentage of drivers not stopping at the grade crossings is 4% higher during daytime.

It is very important to know how school bus drivers and heavy truck drivers react to different signs at grade crossings. According to law, school bus drivers are required to stop fully at all grade crossings in all conditions. School buses carry children, and risking their life at grade crossings is not acceptable. Heavy trucks are huge vehicles and drivers' viewing angle, sight distance and turning capacity are very different than normal vehicles. Also, heavy trucks sometimes contain flammable items or other hazardous materials, which can create disastrous accidents if drivers don't take safe action at the grade crossings. Heavy trucks with certain cargo are required to stop at all grade crossings.

Comparisons between stopping behaviors of school buses, heavy trucks and other vehicles at grade crossings (Table 2) showed that at all grade crossings, 81% (98) of heavy truck drivers, 11% (1) of school bus drivers, and 78% (3,160) of other vehicle drivers did not stop at all. Overall, at all grade crossings, 10% (12) of heavy truck drivers, 11% (1) of school bus drivers, and 15% (638) of other vehicle drivers did a rolling stop. A total of 9% (11) of heavy truck drivers, 78% (7) of school bus drivers, and 7% (390) of other vehicle drivers stopped completely. The number of school buses was too small to make any statistically reliable conclusion, but even one school bus not stopping and one doing a rolling stop should be a concern.

Table 2: Results for School Buses, Heavy Trucks and Other Vehicles at All Grade Crossings

Day	**No. of Heavy Trucks**	**%**	**No. of School Buses**	**%**	**No. of Other Vehicles**	**%**
Full STOP	9	9	7	78	364	7
Rolling STOP	11	11	1	11	590	15
No STOP	80	80	1	11	3025	78
Total	**100**	**100**	**9**	**100**	**3,979**	**100**
Night	**No. of Heavy Trucks**	**%**	**No. of School Buses**	**%**	**No. of Other Vehicles**	**%**
Full STOP	2	10	0	0	26	12
Rolling STOP	1	5	0	0	48	23
No STOP	18	85	0	0	135	65
Total	**21**	**100**	**0**	**0**	**209**	**100**
Day + Night Combined	**No. of Heavy Trucks**	**%**	**No. of School Buses**	**%**	**No. of Other Vehicles**	**%**
Full STOP	11	9	7	78	390	7
Rolling STOP	12	10	1	11	638	15
No STOP	98	81	1	11	3,160	78
Total	**121**	**100**	**9**	**100**	**4,188**	**100**

Statistical Tests and Comparisons

Statistical tests were conducted to find out if there is any statistically significant difference in mean/variance between different populations/samples. A normal "t" test could have been possible, but in our study the sample sizes in categories compared were very small and not equal, which meant that the best method to perform the statistical test was "pooled estimate" of population variance (Miller and Freund 1977). The assumption in this method is that the population variances are equal in different categories. The null hypothesis can be stated, as there is no statistically significant difference in mean/variance between different populations/samples.

Comparisons of Active versus Passive Grade Crossings

Comparison between STOP signs at active grade crossings and passive grade crossings showed that at active grade crossings with STOP signs, 3% more drivers stopped completely than at passive grade crossings. At active grade crossings with STOP signs, 5% more drivers did a rolling stop than at passive grade crossings. And at active grade crossings with STOP signs, 8% fewer drivers did not stop at all compared to passive grade crossings. Statistical test results showed:

1. There was no statistically significant difference between the drivers stopping completely at active grade crossings and passive grade crossings with STOP signs ($t = 1.445 < t_{0.025} = 2.571$).

2. There was a statistically significant difference between the drivers doing rolling stops at active grade crossings and passive grade crossings with STOP signs ($t = 2.78 > t_{0.025} = 2.571$).
3. There was no statistically significant difference between the drivers not stopping at all at active grade crossings and passive grade crossings with STOP signs ($t = 1.7 < t_{0.025} = 2.571$).

The results of comparison between STOP signs at active grade crossings and passive grade crossings with school buses, heavy trucks and other vehicles separated are shown in Table 3. The numbers were too small to conduct a statistical test and draw any reliable conclusions.

Table 3: Comparisons Between STOP Signs at Active Grade Crossings and Passive Grade Crossings with School Buses, Heavy Trucks and Other Vehicles Separated

Types of Vehicles	Full STOP	Rolling STOP	No STOP
Heavy Trucks at passive grade crossings with STOP sign	10%	10%	80%
Heavy Trucks at active grade crossings with STOP sign	0%	33%	67%
School buses at passive grade crossings with STOP sign	75%	25%	0%
School buses at active grade crossings with STOP sign	80%	0%	20%
Other vehicles at passive grade crossings with STOP sign	8%	12%	80%
Other vehicles at active grade crossings with STOP sign	10%	18%	72%

Comparisons of Poor versus Good Sight Distance

Sight distance was estimated by the research team along the tracks in either direction from various approach distances. Out of the passive grade crossings with STOP signs, two had poor sight distance on one approach. Nemaha County (southbound) and Carter road (southbound) had restricted sight distances. Nemaha County (southbound) has a hill to the right, while Carter road has a hill, a curve and bushes blocking the view of the eastbound trains, resulting in poor sight distance on the south approach of each grade crossing.

Arn road and Carter road both are passive grade crossings with CROSSBUCK signs and STOP signs, with a parallel state highway US-24 within 100 feet. Arn road has good sight distance on the southbound approach and Carter road has poor sight distance on the southbound approach. Comparison of Arn road and Carter road southbound approaches showed that a higher percentage of drivers stopped fully at Carter road (southbound approach) than at Arn road (southbound approach); a higher percentage of drivers did a rolling stop at Carter road (southbound approach) than at Arn road (southbound approach); and a lower percentage of drivers did not stop at Carter road (southbound approach) than at Arn road (southbound approach).

Comparisons of approaches with poor sight distances at grade crossings with a STOP sign showed that a higher percentage of drivers stopped completely at Carter road than Nemaha Street 236; a lower percentage of drivers did not stop at all at Carter road than Nemaha Street 236; and a higher percentage of drivers did a rolling stop at Carter road than Nemaha Street 236.

Comparisons of southbound and northbound approaches of Nemaha Street 236 and Carter road showed that a higher percentage of the drivers stopped fully at the southbound approach than at the northbound approach of both Nemaha County and Carter road grade crossings; a lower percentage of drivers on the southbound approach did not stop compared to the northbound approach of both of these passive grade crossings; and a higher percentage of the drivers did a rolling stop at the southbound approach than at the northbound approach of Carter road grade crossings. At Nemaha Street 236 the numbers were the same.

Comparisons of the southbound approach on Carter road and other STOP sign locations (all approaches) showed that on the southbound approach of the Carter road grade crossings, 24% (33) of the drivers stopped completely, 25% (35) did a rolling stop, and 51% (72) did not stop. At all STOP sign location grade crossings with good sight distances on the approaches (Arn road, Alma, and 108th Street), 12% (136) of the drivers stopped completely, 16% (187) did a rolling stop, and 72% (844) of the drivers did not stop at all.

Comparisons of Grade Crossings With versus Without Parallel Highways

Comparisons of grade crossings with parallel highway vs. grade crossings with no parallel highway (all STOP signs with CROSSBUCK locations) showed that a higher percentage of the drivers stopped completely at the passive grade crossings with no parallel highway (Nemaha Street 236, Alma) compared to passive grade crossings with parallel highways (Carter road, Arn road, 108th Street). The percentage of the drivers doing rolling stops is almost equal in both cases, and a lower percentage of the drivers did not stop at the passive grade crossings without a parallel highway compared to passive grade crossings with a parallel highway. Statistical tests showed that there is no significant statistical difference between the drivers stopping completely, ($t = -0.62 < t_{0.025} = 3.182$), drivers doing a rolling stop ($t = 0.015 < t_{0.025} = 3.182$), and drivers not stopping at all ($t = 0.25 < t_{0.025} = 3.182$) at passive grade crossings with STOP signs and a parallel highway vs. passive grade crossings with STOP signs and no parallel highway.

CONCLUSIONS

Because of the limited nature of the numbers of grade crossings and selection of specific grade crossings, general transferable conclusions are limited. However, conclusions specific to the types of Kansas locations studied are valid.

A majority of the drivers did not stop at the STOP signs at the grade crossings. At the STOP signs at all passive grade crossings, 79% of drivers did not stop, 13% did a rolling stop and only 8% stopped completely. During nighttime, drivers' reactions were safer than they were at daytime. A majority of drivers were ignoring the STOP signs where they were present. Heavy trucks had a poorer compliance percentage than any other vehicles (not including school buses). The number of school buses was too small to make any statistically reliable conclusions. However, one did a rolling stop and one did not stop, which is a point of concern. Poor sight distances at the grade crossings leads to higher stopping percentages. Stopping behavior appears to be proportional to the severity of the sight distance restriction. A higher percentage of drivers stopped completely and did a rolling stop at the STOP signs at the active grade crossings compared to passive grade crossings with a STOP sign. There was no statistically significant difference between the categories of full stop and no stop for active or passive crossings, but there was a statistically significant difference between the two types of crossings for the rolling stop category. A higher percentage of drivers (21%) stopped at the grade crossings with no parallel highway than did so at the grade crossings with a parallel highway (10%). A "pooled deviation" of population variance test showed that there were no significant differences between any of the categories (full stop, rolling stop and no stop) for parallel highway or no parallel highway crossings. A relatively higher percentage of heavy trucks stopped completely at the passive grade crossings with STOP signs, and a relatively higher percentage of school buses stopped completely at active grade crossings with STOP signs. But the numbers of heavy trucks and school buses were too small to draw any conclusions. At grade crossings with only CROSSBUCK signs and CROSSBUCK with YIELD signs, the least percentage

(1%) of drivers stopped completely, and the highest percentages (93% and 90%, respectively) of drivers did not stop.

In general, based on this limited study, it can be stated that the drivers do not respect the STOP sign (albeit, more drivers slow down compared with a YIELD sign), and the nature of the crossing, specifically sight distance, has an important effect on behavior irrespective of the signs deployed. It is recommended that a STOP sign should not be used at grade crossings without a valid engineering study that includes an evaluation of need based on limited sight distance.

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