IDAHO TRANSPORTATION DEPARTMENT

RESEARCH REPORT

RP 223

Evaluation of IdaShield Sign Safety Benefits at Highway-Rail Crossing in Idaho

By

Michael P. Dixon, Brian Dyre, J. D. Wulfhorst, Ahmed Abdel-Rahim, Alex Grover, Mark Meyer, Monica A. Reyna, and Barbara E. Foltz

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This report describes findings from a study aimed at assessing the safety impact of IdaShield signs installed at 1,341 highway railroad crossings in Idaho. Specifically, our research assessed the marker's effectiveness using three measures:

• Before-and-after analysis of historical crash data preceding and following installation of the IdaShield marker.
• User assessment survey measuring user understanding of the IdaShield and changes in user response due to the IdaShield.
• Simulated driving test environment that exposed participants to various controlled circumstances related to highway railroad crossings.

The before-and-after analysis of test data showed crashes were significantly decreased by 38.6 percent after the IdaShield installation and these effects were largely attributed to the IdaShield. The user assessment survey found users understood the purpose of the IdaShield, believed it enhanced intersection visibility, and would improve safety. Finally, the driver simulation showed how the IdaShield changed driver responses at highway railroad crossings, but only for conditions in which it was paired with a YIELD sign and a train was approaching. No significant safety benefit was noted when the IdaShield sign was paired with a STOP sign. Because the IdaShield produces positive overall outcomes on driver safety and does not have any apparent negative effects, we recommend the signage should continue to be required to increase visibility and safety at passive at-grade railway crossings in Idaho where a STOP sign is not present.</td></tr>
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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.4		mm	mm	millimeters	0.039	inches	in
ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
		AREA					AREA		
in^2	square inches	645.2	millimeters squared	cm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.0929	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
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ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (°F-32)	Celsius temperature	°C	°C	Celsius temperature	9/5 °C+32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

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Technical Advisory Committee

Each research project has an advisory committee appointed jointly by the ITD Research Manager and ITD Project Manager. The Technical Advisory Committee (TAC) is responsible for assisting the ITD Research Manager and Project Manager in the development of acceptable research problem statements, requests for proposals, review of research proposals, and oversight of the approved research project. ITD's Research Manager appreciates the dedication of the following TAC members in guiding this research study.

Project Manager - Sajonara Tipuric, Idaho Transportation Department

TAC Members

Brent Jennings - Idaho Transportation Department
Greg Laragan - Idaho Transportation Department
Nestor Fernandez - Idaho Transportation Department
Carl Main - Idaho Transportation Department
Bruce Friedman - FHWA - Washington, DC
Ned Parrish -– Idaho Transportation Department

FHWA-Idaho Advisor - Lance Johnson

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Special acknowledgement is given to Dr. Michael Dixon of the University of Idaho, the original investigator and lead researcher on this project, who passed away prior to the completion of this project.

Executive Summary

This report describes the impact of an object marker called the "IdaShield" used in Idaho at passive (non-signalized) railroad crossings to improve crossing visibility and traffic control compliance.

Figure 1. IdaShield

The IdaShield is a highly reflective sign consisting of a diamond grade reflective Crossbuck and a "shield" of red and white diamond grade reflective strips that is mounted below the Crossbuck on the same post. The edges of the shield are bent backwards at a 45^{o} angle to reflect train headlights onto the roadway (Figure 1). In the late 1990s, 1,341 of these signs were installed statewide in Idaho.

Specifically, our study assessed the effectiveness of IdaShield signs using three measures:

1. Before-and-after analysis of historical crash data preceding and following the installation of the IdaShield marker.
2. Usability assessment survey measuring user understanding of the IdaShield and changes in user response due to the IdaShield.
3. Simulated driving test environment that exposed participants to various controlled circumstances related to highway, railroad crossings.

Methodology and Results

Before-and-After Analysis of Historical Crash Data

In this first measure, we developed a statistical model of historical crash data to predict crash frequency during the years before and following the IdaShield installation. These predictions were then compared to the observed crash frequency values to determine the effect of the IdaShield marker. Steps were taken to assess any external effects on crash data. To do this, the crash data for the highway-rail crossings involving the IdaShield were compared to statewide historical crash data. This statewide data did not follow the same trends as the IdaShield intersection crash data, suggesting there were no significant external effects.

Our analysis revealed a significant 38.6 percent improvement in safety after IdaShields were installed statewide (see Figure 2). While installing the IdaShield, ITD also improved the reflectivity of the Crossbucks by placing 2 inches wide reflective tape on the front and back sides. Therefore, some of the crash reduction could be associated with improved sign reflectivity and not the IdaShield per se. A separate analysis using Wilcoxon signed rank tests found a significant 39.5 percent improvement in the daytime and 72.2 percent improvement in the nighttime, suggesting that IdaShield had an effect on improving safety during both daytime, when effects of the reflective tape would be much less, and nighttime conditions. The higher percentage of crash reduction for nighttime crashes indicates that some of the crash reduction of the IdaShield could be associated with improved sign reflectivity.

Figure 2. Comparison of Observed and Predicted (SPF) Crash Frequencies Before-and-After IdaShield Installation

Usability Assessment Survey

For the second measure, we assessed users understanding of and any changes in user responses due to the IdaShield. Idaho drivers were randomly sampled across the entire state and asked to complete an online web-based survey and 265 individuals completed the survey with an overall response rate of 37.5 percent. Comparative demographic analyses found the survey respondents adequately represented the Idaho driving population.

In the survey, participants were given scenarios with accompanying pictures of approaching railroad crossings with just IdaShield signs and also IdaShield signs combined with YIELD or STOP signs. In addition, the scenarios covered both daytime and nighttime conditions as well as with no trains or trains approaching.

When the STOP sign was combined with an IdaShield sign, participants responded to stop. However, during daytime scenarios and with a train approaching, driver response was slightly more variable. These results were not statistically or substantively significant to indicate a problem or barrier caused by the IdaShield signage, but in cases where STOP signs are already present, IdaShield signs may not create additional safety value for drivers. Alternatively, when accompanied by YIELD signs, drivers appear to proceed with caution in ways that indicates the IdaShield adds safety at those railway crossings.

Most significant, a majority of drivers (65 percent) who completed the web survey indicated they felt the IdaShield increased visibility of the railway crossings (see Figure 3) as well as overall safety at the crossing.

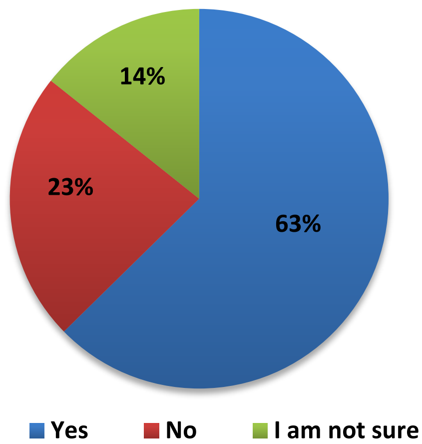

Figure 3. Percentage of Drivers Indicating Increased Visibility

Simulated Driving Test

The third and final measure assessed the effect of IdaShield signs on a sample of 20 drivers in a driving simulation. Participants drove their simulated vehicle along stretches of rural highway containing railroad crossings under both daytime and nighttime conditions. Crossings were passively marked with different combinations of signs, including conditions both with and without IdaShield signs. The presence or absence of an approaching train was also manipulated. The simulator collected measures of vehicular control (e.g., position, acceleration, and speed) and eye movement patterns.

The driver simulation measure showed that IdaShield signs changed driver responses at highway-railroad crossings, but only for conditions in which it was paired with a YIELD sign and a train was approaching. While approaching crossings without an oncoming train, drivers responded to the IdaShield as if it represented a YIELD sign. However, when approaching crossings with an oncoming train, drivers showed greater decreases in speed and increases in transit time for crossings marked by an IdaShield in addition to a YIELD sign.

These IdaShield effects on speed and transit time occurred during both daytime and nighttime conditions. A marked decrease was also observed in drivers dangerously crossing ahead of the approaching train at night, which suggests that the IdaShield may be particularly effective in alerting drivers to an approaching train at night.

Recommendations

The findings from our research show that the IdaShield does positively impact safety. Average crash frequency significantly reduced after IdaShield installation. Users understood the IdaShield’s purpose and most felt it improved the visibility of crossing markings. In addition, the driver simulation test indicated some positive changes in driver behavior at crossings when IdaShields are present. The crash data analysis provided the strongest evidence of the IdaShield’s effect, while the user survey and driver simulation data provided more detailed understanding of this evidence by pointing to IdaShield benefits for YIELD sign traffic control.

Based on our findings, we recommend the following:

- Because the IdaShield produces positive overall outcomes on driver safety and does not have any apparent negative effects, the signage should continue to be required at crossings controlled through a YIELD sign to increase visibility and safety at passive at-grade railway crossings in Idaho.

- When combined with a STOP sign, the safety effect of IdaShield does not seem to be significant. As a result, we recommend that IdaShield signs not be required at passive at-grade railway crossings when a STOP sign is present. Guidelines to use IdaShield at crossings controlled by a STOP sign should be adjusted to reflect this recommendation.

- It is recommended that ITD work with the national committees to amend the national standard for signage at public passive Railroad/Highway Grade Crossings in the MUTCD and to include the IdaShield as an approved object marker.

Chapter 1
Introduction

Background

The IdaShield is a highly reflective warning sign used at passive highway-rail grade crossings in Idaho. These signs were installed statewide in the late 1990s to reduce crashes at highway-rail crossings. The IdaShield concept was inspired by a presentation on the Ohio Buckeye Shield at a national Operation Lifesaver conference in 1992. The Ohio Buckeye was a rectangular red and white colored sign with the text YIELD written vertically on the front of the sign, with the edges of the sign bent backwards at a 45^{o} angle to reflect train headlights onto the roadway (see Figure 4).

The Buckeye Ohio's Crossbuck program was initiated as a pilot program by Ohio with the approval of the FHWA. At the end of the program, a study was conducted to evaluate the effectiveness of the design.(1) The results of that study showed that while the Buckeye Crossbuck improved safety, the level of safety was not statistically significant enough to warrant addition to the MUTCD. Ohio has since replaced all the Buckeye Crossbucks with Crossbuck Assemblies that are MUTCD compliant and incorporate either a YIELD or STOP sign.

The use of the Buckeye design in Idaho required removal of the YIELD text. The resulting design was renamed the IdaShield. The Crossbucks of the IdaShields used diamond grade reflective sheeting. During the installation process 2 inches wide reflective tape was installed on the front and back sides of some IdaShield. The signs indicating the number of tracks were also replaced using high intensity sheeting. Technical drawings with specifications for the IdaShield are included in Appendix A.

Figure 4. IdaShield vs. Ohio Buckeye Shield

IdaShields were initially installed by Idaho Operation Lifesaver (IOL) at 25 passive public highway-rail grade crossings in Idaho. These 25 IdaShield sets were funded by Union Pacific Railroad. After an encouraging 1994/1995 study on these crossings (summarized in Table 1), the Idaho State Legislature provided funding in 1996 to install IdaShields statewide. On August 6, 1996, the Idaho Transportation Department (ITD) requested approval from the Federal Highway Administration (FHWA) for an experimental project to install IdaShields statewide. This FHWA project was requested because the IdaShield was not an approved object marker in the Manual on Uniform Traffic Control Devices (MUTCD). The IdaShield Experimental Project was approved by FHWA on October 3, 1996.

The IdaShield is a highly reflective sign consisting of a diamond grade reflective Crossbuck and a "shield" of red and white diamond grade reflective strips that is mounted below the Crossbuck on the same post. The edges of the shield are bent backwards at a 45^{o} angle to reflect train headlights onto the roadway (Figure 1).

IdaShields were installed at all passive public highway-rail grade crossings in Idaho between May 1997 and August 1998. Posts with diamond grade reflective strips and Crossbucks were also installed at active crossings during this period. Approximately 60 percent of the passive crossings have the Crossbucks, IdaShield, and STOP signs installed. The remaining 40percent of the passive crossings have Crossbucks and IdaShield signs with no STOP sign installed. The specifications for the IdaShield are located in Appendix A. Table 1 provides a breakdown of the installations by crossing type and railroad owner

Table 1. IdaShield Installations by Crossing Type and Railroad Owner

Railroad Owner	Passive Crossings	Active Crossings	Total Crossings
Burlington Northern & Santa Fe Railway Company	63	19	82
Camas Prairie Railroad Company	100	9	109
Eastern Idaho Railroad, Inc.	263	80	343
Idaho Northern & Pacific Railroad Company	57	4	61
Montana Rail Link, Inc.	5	4	9
Palouse River & Coulee City Railroad, Inc.	26	12	38
Saint Maries River Railroad Company	24	3	27
Union Pacific Railroad Company	493	179	672
Total	1,031	310	1,341

Table 2 details the costs for the initial IdaShield installations.

Table 2. IdaShield Project Costs

Materials Costs	$1,071,703.37
Labor Paid	$109,300.00
Subtotal	$1,181,003.37
Labor Donated (estimate)	$603,450.00
Grand Total	$1,784,543.37

Previous IdaShield Studies

Two studies, conducted in 1999/2000 and 2008, investigated IdaShield performance by observing driver stopping compliance and head movements at crossings with:

- Both IdaShields and STOP signs
- STOP signs only.

The results of these studies are shown below in Table 3.

Table 3. Result of Previous IdaShield Studies

Treatment Presence	Driver Stopping Compliance (percentage)		Drivers Looking for Trains (percentage)	
	1999/2000	**2008**	**1999/2000**	**2008**
IdaShields & STOP Signs	60	83	87	91
STOP Signs	52	52	64	64

These results show increases in driver stopping compliance and drivers looking for trains associated with IdaShield presence.

In 2000, Idaho Operation Lifesaver (IOL) also conducted a public opinion poll at both the Eastern and Western Idaho State Fair attendees to rate the usefulness of 6 highway-rail crossing signs. The results are shown in Table 4.

Table 4. Results of 2000 Public Opinion Poll

Sign	Usefulness (percentage)
STOP Sign (R1-1)	78.9
Advanced Warning (W10-1)	77.6
Crossbuck (R15-1)	64.9
Advanced Warning (W10-2)	63.1
STOP Ahead (W3-1)	62.5
IdaShield	42.9

These responses and subsequent interviews with attendees indicate a misunderstanding of or unfamiliarity with the IdaShield in comparison to other signs. Truck and school bus drivers were more familiar with the IdaShield and noted its nighttime effectiveness. Attendees were shown the IdaShield without its usual Crossbuck companion, which may have left participants confused about its meaning.

Crash data analysis included in a previous IdaShield Project report showed that after IdaShields were installed, reported collisions decreased by 50 percent and reported nighttime collisions decreased by 70 percent.[(1)]

The previous studies of the IdaShield signs, however, had a number of limitations. The stopping compliance and head movement measures used in the studies were subjective and data was collected by volunteers with limited training who observed driver behavior at highway-rail crossings. In addition, statistical analyses of driver behavior, survey, and crash data were not performed.

IdaShield Installation Regulations

The following regulations apply to the IdaShield sign assembly and a possible adjacent STOP or YIELD sign. The IdaShield Assembly, consisting of the IdaShield sign, Crossbuck, number of tracks signs (if applicable), and sign post, should be placed on the right side of the roadway 12 and 15 feet before the nearest railroad track. The assembly should also be at least 6 feet from the edge of the shoulder or 12 feet from the edge of the roadway. The bottom of the IdaShield sign should be 2 feet above the nearest railroad track but not more than 3 feet above the ground. The center of the Crossbuck should be 9 feet above the nearest railroad track.[(2)] Adjacent STOP or YIELD signs should be placed at least 6 feet from the edge of the roadway and more than 2 inches away from the signs on the IdaShield Assembly. The bottom of the STOP or YIELD sign should be at least 5 feet above the edge of the road surface.[(3)] Reference Appendix A for dimensions of the IdaShield sign and assembly.[(2,4)]

Highway-Rail Crossing Regulations

Idaho highway-rail crossing sign and pavement marking regulations are summarized below:

- Crossbuck Sign - Required at all highway-rail grade crossings.
- Number of Tracks Sign - Required at passive public highway-rail grade crossings with two or more tracks.
- Exempt Sign - Optional if authorized by local jurisdiction. The exempt sign informs drivers of school buses carrying students, or vehicles carrying hazardous materials that a stop is not required at certain designated highway-rail grade crossings, except when a train, locomotive, or other railroad equipment is approaching or occupying the highway-rail grade crossing, or the driver's view is blocked.

- Advance Warning Sign - Required at all highway-rail grade crossings except for:
    - Low-volume, low-speed roads on minor spurs.
    - Crossings on a minor road less than 100 feet away from a highway running parallel to the railroad tracks.
    - Business or commercial districts with active crossing control devices.
    - Locations that do not permit full visibility of the Advance Warning sign.
- Pavement Markings – Required on road segments with speed limits greater than 40 mph. Pavement markings in advance of a highway-rail grade crossing shall consist of an X, the letters RR, a no-passing marking (two-lane highways where centerline markings are used), and certain transverse lines.
- Lighting - Optional at crossings with high nighttime accident risk.
- STOP Sign - Required at crossings with no active treatment devices unless presence of the STOP sign is determined to cause a greater hazard than its absence.(5)

See Part 8 of the 2009 MUTCD for a complete list of highway-rail crossing regulations.(3) The 2009 MUTCD Crossbuck Assembly with a YIELD or STOP Sign on the Crossbuck Sign Support is shown in Figure 5. To improve the visibility of Crossbuck assembly with a YIELD or STOP sign, MUTCD 2009 regulations included adding a 2-inch white or red retroreflective strip on the supporting post on front and a 2-inch white retroreflective strip on back of the support. Studies are needed to further examine the effectiveness of IdaShield against the MUTCD 2009 Crossbuck assembly, as can be seen in Figure 5.

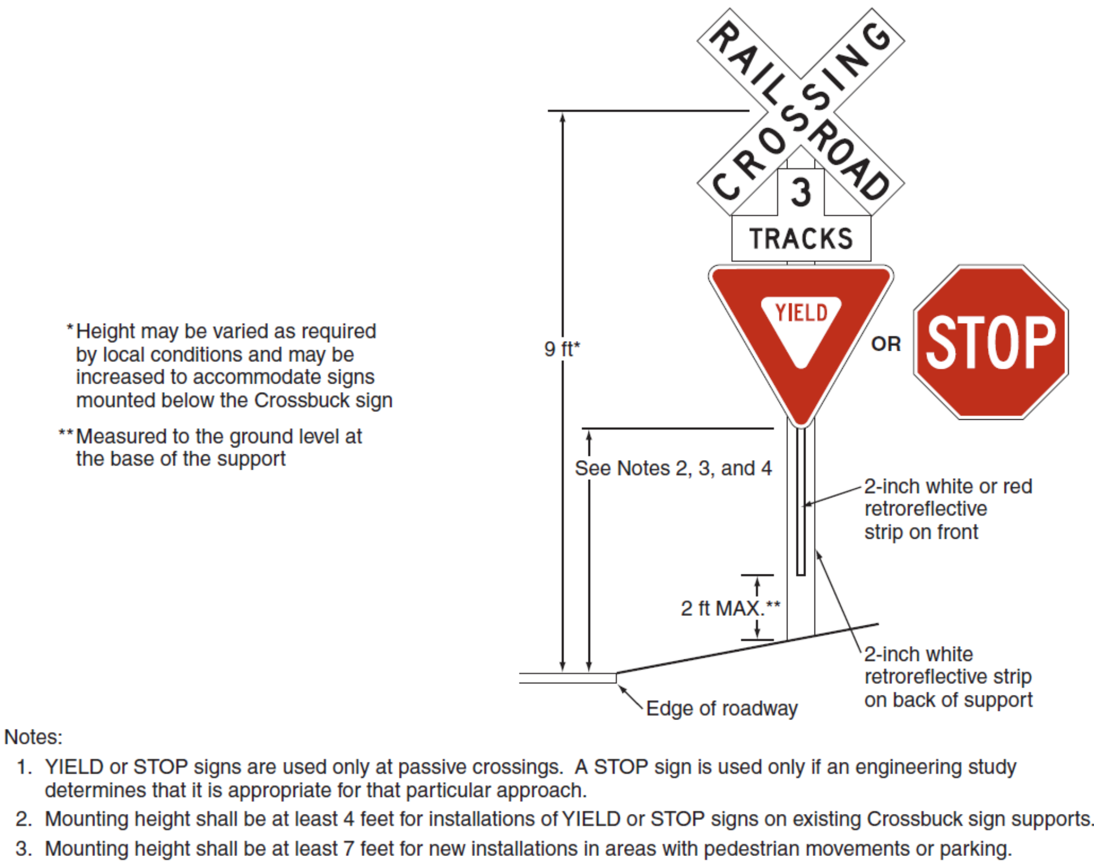

Figure 5. 2009 MUTCD Crossbuck Assembly with a YIELD or STOP Sign on the Crossbuck Sign Support

Methodology

Specifically, our study assesses the effectiveness of IdaShield signs using three measures:

1. Before-and-after analysis of historical crash data preceding and following the installation of the IdaShield marker.

2. Usability assessment survey measuring user understanding of the IdaShield and changes in user response due to the IdaShield.

3. Simulated driving test environment that exposed participants to various controlled circumstances related to highway, railroad crossings.

The crash data analysis portion of the report (Chapter 2) details the collection of highway-rail crossing crash and crossing data from the Federal Railroad Administration (FRA) and ITD. A regression equation (Safety Performance Function) with crash frequency as the dependent variable and crossing conditions as independent variables was derived and used in a before and After statistical analysis, which estimates the IdaShield's effect on highway-rail crossing crash frequency. Analyses on daytime and nighttime IdaShield effectiveness and statewide Idaho vehicle crash trends were also conducted.

The user acceptance survey portion of the report (Chapter 3) assessed the public perception of the IdaShield and other highway-rail crossing signs including the STOP, YIELD, and Crossbuck signs. Survey participants were recruited by phone interview. Surveys (784) were distributed by email and 265 surveys were completed. As part of this study, a web-based survey was conducted to assess highway users' understanding of and response to IdaShield signs at Idaho railroad crossings. Individuals were recruited to the survey via subsamples of landline and cellular telephone numbers. Of those who agreed to participate, 265 individuals completed the survey with an overall response rate of 37.5 percent. Comparative demographic analyses found that the survey respondents adequately represent the Idaho driving population. The results were analyzed for statistical significance with Statistical Analysis Software (SAS).

The driving simulation portion of the project (Chapter 4) recruited 20 participants to drive a simulated rural highway. Participants were divided into two groups to test both daytime and nighttime conditions. Rail crossings with various combinations of STOP, YIELD, and IdaShield signs were spaced intermittently along the highway section. A train was approaching the crossing in some of these scenarios. Vehicle trajectory data were collected from the simulator and statistically analyzed to reveal effects of the IdaShield. Each of these efforts is documented in its respective chapter, followed by overall conclusions and recommendations regarding the use of the IdaShield signs.

Chapter 2
Evaluation of IdaShield Safety Effectiveness Using Historical Crash Data

Introduction

This chapter details the Idaho highway-rail crossing crash data analysis used to evaluate the effectiveness of the IdaShield sign and includes discussion of:

- Key points from applicable previous literature.
- Steps taken to retrieve highway-rail crossing characteristics, traffic exposure, and crash data
- Procedures and results for Safety Performance Function (SPF) derivation, Empirical Bayes (EB) Method analysis, a comparison to statewide vehicle crashes, and analysis of IdaShield nighttime effectiveness.
- Discussion of results and conclusions.

Literature Review

A review of previous literature was conducted on the topics of Highway Safety Manual (HSM) "Before-and-after" Empirical Bayes (EB) method, statistical theory, Safety Performance Function (SPF) derivation, selection of the "best fit" SPF, and significant factors affecting crashes at highway-rail crossings.

There is no previous literature on SPF derivation for highway-rail crossings in particular. Therefore, sources were referenced on the topics of general SPF derivation and examinations of factors affecting vehicle-train crashes at highway-rail crossings.

Methodology

Our study followed the AASHTO and HSM recommendations, deploying the EB method, statistical theory, and SPF derivations. The SPF, used to calculate predicted crash frequency, is a regression equation with crash frequency as the dependent variable and crossing characteristics such as vehicle traffic volume, train traffic volume, and sign presence as independent or predictor variables.

Safety Performance Functions and HSM Empirical Bayes Method

The EB Method estimates treatment effectiveness by analyzing crash data "before-and-after" a large-scale treatment installation. The procedure begins by grouping data into "before-and-after" treatment implementation periods. The overall treatment effectiveness is calculated by dividing *observed* crash frequencies in the "after period" by *expected* crash frequencies (assuming no treatment) in the "after period." Expected crash frequency in the "after period" is calculated with a SPF, which can be derived from a dataset of similar crossings if there are no applicable standardized SPFs.

Crash Frequency vs. Crash Rate

HSM and previous studies recommend using crash frequency, rather than crash rate, as the performance measure for evaluating safety. Crash rate is crash frequency normalized by traffic exposure and can give a better representation of crash risk in some circumstances, such as when vehicle and train traffic vary greatly over time. However, increased exposure may not cause a linear, 1:1 increase in crashes. For example, if a treatment is implemented at a highway-rail crossing and there is a 2-fold increase in crashes with a 3-fold increase in exposure, a "before-and-after" crash rate comparison will show a decrease in crash rate and favorable treatment effect even though the number of crashes doubled. Crash rates conceal the true crash risk in these cases. Instead, the HSM suggests including exposure as independent variables in a SPF, which results in an exposure-crash frequency relationship representative of the sites being investigated.(6)

SPF Derivation

The distribution of highway-rail crossing crashes can be expected to follow that of a Poisson or Poisson-Gamma (negative binomial (NB)).(7) The two distributions are similar in that both model the results of a sequence of Bernoulli trials (observations are one of two outcomes: "success" or "failure"). For studies modeling vehicle crashes, a crash is considered a "success" and a failure to crash is considered a "failure". In a Poisson distribution, the variance of the dependent variable (crash frequency) is equal to the mean.(8) In a NB distribution, the variance is allowed to differ from the mean via the introduction of an error term ε.(7) The average of these error terms is the overdispersion parameter and used in the EB method to represent the variance of crash frequency in the dataset.(6) An overdispersion parameter of 1 indicates that the variance is equal to the mean and therefore follows a Poisson distribution. The model forms of the Poisson and NB distributions are shown below in Figure 6 and Figure 7, respectively.

$$\ln(\widehat{N}) = \hat{\beta}_0 + \sum_{i=1}^{p} \hat{\beta}_i x_i$$

Figure 6. Poisson Model Form Equation

$$\ln(\widehat{N}) = \hat{\beta}_0 + \sum_{i=1}^{p} \hat{\beta}_i x_i + \varepsilon$$

where:

$\widehat{N}$ = predicted crash frequency

$\hat{\beta}_0$ = intercept

$\hat{\beta}_i$ = coefficient for variable x_i

x_i = independent variable

p = number of independent variables

ε = error term

Figure 7. Negative Binomial Model Form Equation

Goodness-of-fit tests such as Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) have been used in previous literature to select the "best-fit" SPF from a number of alternatives. Smaller values of AIC and BIC indicate a better-fitting model.(7,9) AIC tends to assign better scores to models with more variables and is therefore more susceptible to Type I error or false positive (i.e. declaring a treatment improves safety when it actually does not).(10)

Various statistical software packages such as SPSS, SAS, NLOGIT, and R were used by previous studies to estimate SPF overdispersion parameters, variable coefficients, and correlations between variables.(7,9,11,12,13)

Transportation research uses a relatively relaxed statistical significance level. A significance level of 0.10 is considered adequate for road-road intersection SPF coefficients.(14) For this project, a significance level of 0.10 is adequate because a Type I error (incorrectly declaring IdaShield effectiveness) is more desirable than Type II error (incorrectly declaring the IdaShield is ineffective).

Factors Influencing Crashes at Highway-Rail Crossings

Previous research identified independent variables that may have a significant effect on crash frequency. These are:

- Average Annual Daily Traffic (AADT).
- Total Trains per Day (TTPD).
- Highway Separation (Road Separated by Median).
- Paved/Unpaved Highway.

- Maximum Train Speed.
- Number of Tracks.
- Number of Road Lanes.
- Vehicle Speed.
- Crossing Angle (Angle Separating Roadway and Railroad Tracks).
- Treatment Presence (Crossbuck, STOP sign, Flashing Lights, Gates).[12,15]

Previous studies also found higher crash rates at STOP sign treated crossings than crossings treated with flashing lights, gates, or Crossbuck signs. Proposed causes of STOP sign ineffectiveness are:

- Reduced stopping compliance at low volume train crossings.

- Underestimated train speed by drivers, causing drivers to attempt to clear the crossing from a complete stop when there is insufficient time to clear the crossing before the train arrives.[12.16]

Unexplained decreases in crash frequency over time have been discovered in previous research. These decreases may be caused by greater penalties for driving while intoxicated, increased public awareness of highway-rail crossing danger, and increased enforcement of traffic regulations at highway-rail crossings.[17]

Several main points were taken from the literature reviewed for the crash data analysis portion of the project:

- Collect data on sign presence, crossing characteristics, exposure, and crashes.

- Derive an SPF predicting crash frequency as a function of vehicle exposure, train exposure, crossing characteristics, and sign presence at passive highway-rail crossings in Idaho.

- Evaluate effectiveness of 1997 - 1998 IdaShield installation with SPF and HSM EB Method.

Data

The crossing and crash data used in this study were obtained from the FRA and ITD websites. The following sections explain specifics about data obtained from these sites.

FRA Data

The crossing and accident data from 1980 to 2011 used in this study were obtained from 3 database files on the FRA website: Idaho Highway-Rail Crossing Inventory, National Crossing History, and Idaho Highway-Rail Accidents. The Idaho Highway-Rail Crossing Inventory file contains the most recent crossing inventory data for all highway-rail crossings in Idaho. The National Crossing History file contains past crossing inventory data for all highway-rail crossings nationwide. The Idaho Highway-Rail Accidents file contains data on all Idaho highway-rail crossings crashes by year.[18]

ITD Data

ITD highway-rail crossing and crash data provided more details than the FRA data. Therefore, a list of IdaShield-controlled highway-rail crossings and AADT data for passive highway-rail crossings in Idaho were requested and obtained from ITD. For some of the originally requested crossings, AADT data was only available from ITD. The FRA AADT records were replaced with ITD records from ITD. ITD's list of IdaShield-controlled crossings was used to verify FRA records of IdaShield-controlled crossings.

In addition, yearly totals of Idaho vehicle crashes, road miles, and vehicle miles traveled (VMT) were requested and obtained for the years 1984 - 2011.

Data Alterations

The raw crash data were transformed into a more usable form. First, the crossing inventory entries were converted from a "start date – end date" format into yearly records. The following data were then removed:

- Crossings that at some point during the time period 1980 - 2011 were either:
  - Private.
  - Non at-grade.
  - Active-treatment.
- Crossings with less than 3 years of data.
- Closed or abandoned crossing entries.

A small portion of the FRA inventory data for highway-rail crossing was found to be inaccurate through spot checks on suspicious crossing entries. For example, some FRA highway-rail crossing records indicated IdaShield presence with no Crossbucks, which is suspicious because Crossbucks were installed with IdaShields in 1997 and 1998. Google Earth was used to verify the current state of the crossings and correct these inaccuracies. Previous studies by Raub utilizing FRA data questioned the quality of FRA accident data but found it to be more accurate than Fatality Analysis Reporting System (FARS) data.[11,15] See Appendix B for a list of all data alterations and corrections.

Final Dataset

The dataset used to derive SPFs consists of 34,477 crash frequency data points over 1,341 crossings from 1980 - 2011. There are 449 crashes in the dataset. A summary of the crossings by year and sign presence is presented in Appendix B.

Results

This section presents the results the SPF derivation, EB Method, comparison of highway-rail crossing and statewide crash trends, and nighttime IdaShield effectiveness analysis.

Safety Performance Function

The statistical software SPSS was utilized to derive an SPF for passive at-grade highway-rail crossings in Idaho. The SPF is in the NB model form with log-link function, chosen from the Generalized Linear Models options in SPSS.

The first step in the SPF derivation was creating a model with crash frequency as the dependent variable and the following independent variables.

- AADT (Average Annual Daily Traffic)
- TTPD (Total Trains Per Day)
- XBUCK (Crossbuck Presence Dummy Variable)
- STOPSIGN (STOP Sign Presence Dummy Variable)
- IDASHIELD (IdaShield Presence Dummy Variable)
- HWYPVED (Paved Highway Dummy Variable)
- MAXSPD (Maximum Train Speed)
- TRAFICLN (Number of Road Lanes)
- NUMTRKS (Number of Tracks)
- XANGLE (Crossing Angle)
- PCTTRCK (Percent Trucks)
- HWYCLASS (Roadway Functional Classification)

Correlations between all possible pairs of these variables were checked to identify possible multicollinearity. SPSS appropriately manages correlations involving binary variables. YIELD sign presence was not included in the model because there were only 11 crossings with YIELD signs in the dataset.

A manual backwards stepwise procedure was utilized to improve the model fit and remove statistically insignificant variables TRAFICLN, XANGLE, PCTTRCK, and HWYCLASS. XBUCK was redundant because Crossbucks are present at nearly all crossings in the dataset.

At this point, all possible 2-way interactions between remaining independent variables (excluding NUMTRCKS) were added into the model. NUMTRCKS interactions were not included because the variable differs in type from the other variables. Interaction variables were eliminated via a backwards stepwise procedure until the model with the best BIC score was achieved. The model iteration with the best AIC score was also identified but contained unexplainable interaction variables, which raised concerns of over-fitting the dataset. The variables in the model with best BIC were more justifiable.

Therefore, the model with lowest BIC was chosen as the final SPF. The variable coefficients, standard deviation, and significance levels of the best-fit SPF are shown below in Table 5. The model intercept and all independent variables are statistically significant at the study significance level of 0.05.

Table 5. SPF Parameter Coefficients, Parameter Significance, and Goodness-of-Fit Measures

Parameter	Coefficient	95% CI		P-value
		Lower	Upper	
(Intercept)	-6.503	-6.918	-6.088	<0.001
AADT	0.00007	0.00002	0.00012	0.003
TTPD	0.015	0.007	0.022	<0.001
MAXSPD	0.028	0.022	0.034	<0.001
STOPSIGN	0.629	0.259	1.000	<0.001
IDASHIELD	-0.658	-0.887	-0.430	<0.001
HWYPVED	1.312	0.962	1.662	<0.001
NUMTRKS	0.151	0.065	0.238	<0.001
STOPSIGN * HWYPVED	-0.699	-1.129	-0.269	0.001
Overdispersion Parameter	1.929	0.939	3.962	

The negative IDASHIELD coefficient suggests the 1997 - 1998 IdaShield installations reduced crashes at highway-rail crossings.

AADT and TTPD account for the vehicle and train exposure, respectively, and as expected have positive coefficients. MAXSPD has a positive coefficient as expected because faster moving trains allow vehicles less time to clear the crossing. Also expected, NUMTRKS has a positive coefficient because higher numbers of rail tracks increase crossing traverse time and allow for trains on different tracks to obscure view of one another.

STOPSIGN and HWYPVED need further analysis because of their significant interaction. Since both variables are binary, their effects can be investigated by comparing the four possible combinations of their conditions. Unpaved crossings without STOP signs have the lowest crash frequency, while paved crossings without STOP signs unexpectedly have the highest crash frequency. The correlation between paved crossings and higher crash frequency may be due to an association between paved roadways, higher speed limits, and dense, distracting urban environments.

Crash frequency at paved crossings with STOP signs is slightly lower than paved crossings with no STOP signs, showing that the effects of paved roads and STOP signs are not additive. STOP signs are correlated with higher crash frequency on unpaved crossings. These two results suggest that STOP signs are more effective in denser urban environments and may tend to be ignored at low-volume, rural crossings. The latter conclusion has been suggested in previous studies. Lastly, the overdispersion parameter estimate of 1.929 shows that the variance of crash frequencies is relatively high, which can be expected because crashes at highway-rail crossings are relatively rare. Since the overdispersion parameter is greater than 1, more weight will be assigned to the observed crash frequencies than predicted crash frequencies in the EB method.

The equation for the SPF is shown below in Figure 8.

$$\begin{aligned}
&\mathit{Predicted\ Crash\ Frequency}\\
&\quad = \exp[-6.50 + (0.00007 * AADT) + (0.015 * TTPD) + (0.028 * MAXSPD)\\
&\quad + (0.629 * STOPSIGN) - (0.658 * IDASHIELD) + (1.31 * HWYPVED)\\
&\quad + (0.151 * NUMTRKS) - (0.699 * STOPSIGN * HWYPVED)]
\end{aligned}$$

Figure 8. SPF Equation

Observed crash frequencies are compared with the SPF predicted crash frequencies in Figure 9 below.

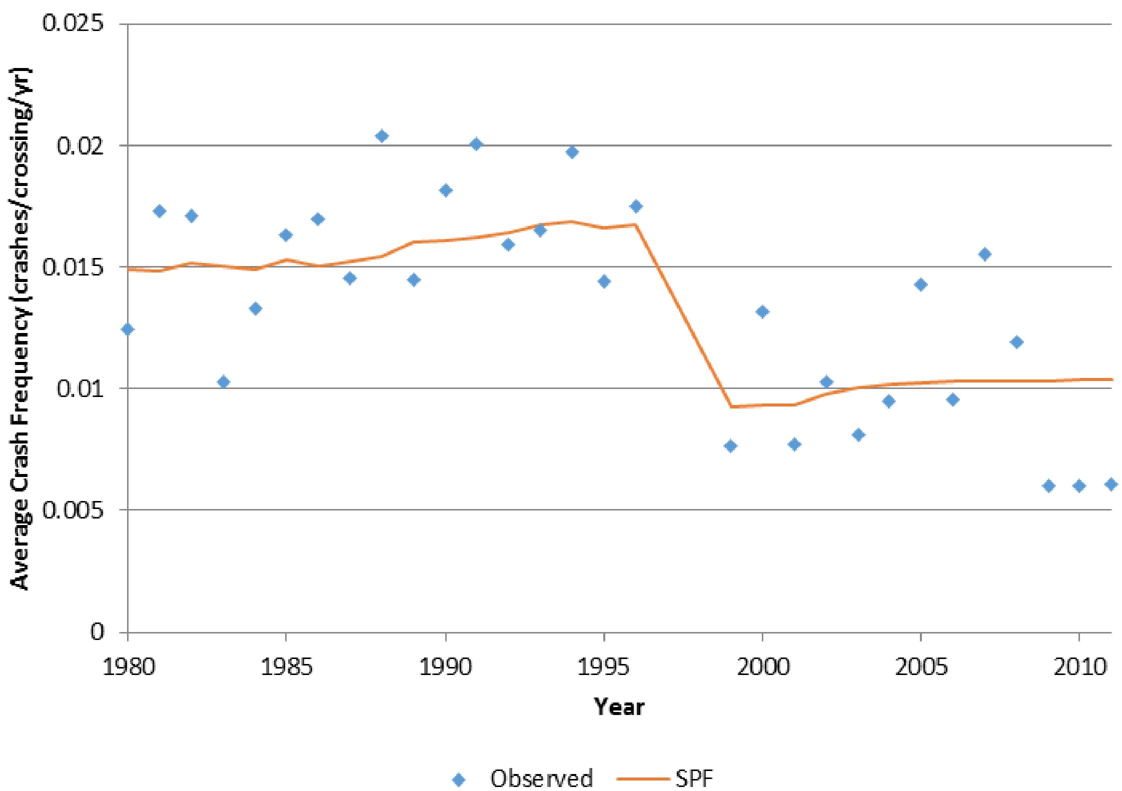

Figure 9. Observed and Predicted Crash Frequencies

The final SPF shows a steady climb in crash frequency before IdaShield installation (1980 - 1996), a significant drop in predicted crash frequency after the IdaShield installation period (1997 - 1998), and another steady climb in crash frequency after IdaShield installation (1999 - 2011). This follows the trend of observed crash frequency closely and is evidence of a good model fit.

Empirical Bayes Analyses

A HSM before-and-after Empirical Bayes method analysis was conducted on a smaller dataset of 734 crossings set aside from the dataset used to develop SPFs. The smaller dataset was used because the EB method requires complete records for all crossings and some crossing records in the SPF dataset did not span the full analysis period (1984 - 2011). The EB “before period” was defined as 1984 - 1996 and the “after period” was defined as 1999 - 2011. IdaShield installation years, 1997 and 1998, were left out of the analysis because the exact IdaShield installation dates for each crossing were not documented. It was ensured that IdaShields were absent from all crossings in the “before period” and IdaShields were present at all crossings in the “after period”.

The results of an EB Analysis are shown below in Table 6.

Table 6. Empirical Bayes Results

Overall Safety Effectiveness (percentage)	95% Confidence Interval		P-Value
	Lower	Upper	
38.6	25.0	52.2	<0.001

The EB analysis shows a 38.6 percent decrease in crash frequency following IdaShield installation. This result is statistically significant at the study significance level of 0.05. Based on this analysis it appears the 1997 - 1998 statewide IdaShield installations significantly reduced crash frequency at passive Idaho highway-rail crossings.

Comparison of Total Vehicle Crash and Highway-Rail Crossing Crash Trends

While the SPF accounts for most of the variation in crash frequency over time, there are sudden spikes (from 2005 - 2007) and drops (from 2009 - 2011) in highway-rail crossing crash frequency that necessitate further investigation (see Figure 9). Comparison with total vehicle crash trends in Idaho can reveal if these short-term variations in highway-rail crossing crashes are caused by factors other than the IdaShield, such as inherent randomness of highway-rail crossing crashes or statewide influences such as the economy or safety awareness programs.

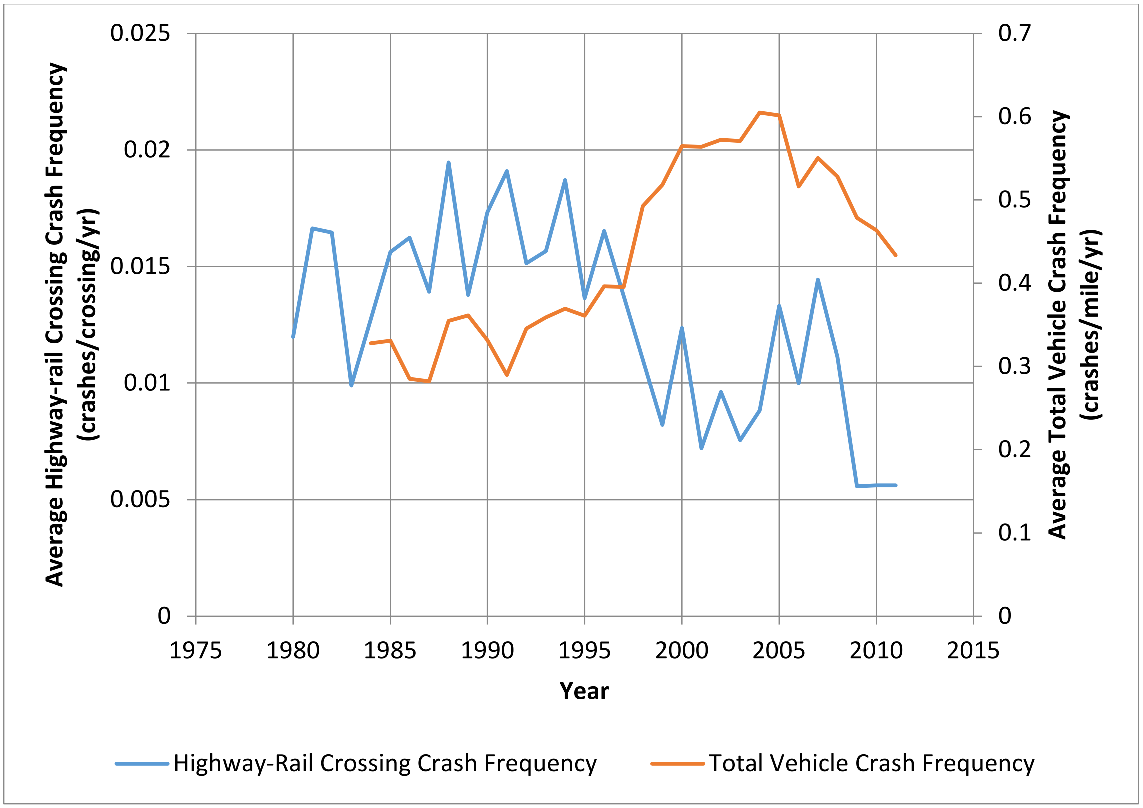

Figure 10. Comparison of Statewide Vehicle Crash Frequency and Highway Rail Crossing Crash Frequency

Figure 10 above shows the total vehicle crash frequency over time, which was calculated by dividing total Idaho vehicle crashes per year by total Idaho road miles per year. The total vehicle crash frequency increases slightly from 1984 - 1991, then steadily rises from 1991 - 2005 before rapidly decreasing from 2005 - 2011.

For the most part, these trends do not follow those of highway-rail crossings. While highway-rail crossing crash trends decreased from 1996 - 2001, total vehicle crashes increased. This suggests a factor specific to highway-rail crossings, such as the IdaShield, reduced crashes at highway-rail crossings.

However, a decreasing crash frequency from 2008 - 2011 was found for all vehicle crashes and for crashes at highway-rail crossings. A logical cause for this drop is a decrease in vehicle and train traffic following the 2008 recession. FRA and ITD exposure data did not show a decrease in vehicle or train traffic during this time, so the 2008 recession cannot confidently be stated a cause for the drop in crash frequency. Further investigation is required to determine the cause of the 2008 - 2011 decrease in crash frequency.

Nighttime Effectiveness of IdaShield

It is important to assess the nighttime effectiveness of the IdaShield because of its high reflectivity and angled sides, which would seem to make it more visible to drivers at night. SPF derivations were attempted using night crash frequency as the dependent variable; unfortunately there was not enough data to produce significant results. Instead, a one-sample t-test was conducted in SPSS on three variables. These are:

- Percent change in average day crash frequency from “Before to After” IdaShield installation. (%ΔDayCrashFrequency)
- Percent change in average night crash frequency from “Before to After” IdaShield installation. (%ΔNightCrashFrequency)
- Difference between %ΔDayCrashFrequency and %ΔNightCrashFrequency. (%ΔDayminus%ΔNight)

These three variables were determined for each crossing in the EB dataset. The results are shown in Table 7 below.

Table 7. Test Between Changes in Day and Night Crash Frequency

Variables	Mean	95% CI		P-value
		Lower	Upper	
%ΔDayCrashFrequency	-39.5	-63.2	-15.8	0.001
%ΔNightCrashFrequency	-72.2	-102.4	-42.0	<0.001
%ΔDayminus%ΔNight	32.7	-5.3	70.7	0.083

The 2-tailed significance values for %ΔDayCrashFrequency and %ΔNightCrashFrequency show that both day and night crash frequency significantly decreased at the study significance level of 0.05. These results reflect the EB results showing that the IdaShield reduced overall crash frequency at highway-rail crossings. However, %ΔDayminus%ΔNight was not significantly different than zero despite the mean of %ΔNightCrashFrequency (-72.2) being almost double the mean of %ΔDayCrashFrequency (-39.5). The practical implication of this result is that the IdaShield is more effective at nighttime than during the daytime even though the available data do not offer enough power to detect a statistically significant difference.

Discussion/Conclusions

The purpose of this study was to evaluate the effectiveness of the IdaShield sign by analyzing historical crash data. After reviewing previous literature, Idaho crash and crossing inventory data were collected from FRA and ITD. A best-fit SPF was derived using SPSS. Using the best-fit SPF, a “before-and-after” EB analysis was conducted. Average yearly highway-rail crossing crash frequencies were then compared to total Idaho vehicle crash frequencies to determine if the crash reductions seen in the highway-rail data could be attributed to external factors other than the IdaShield. Lastly, a t-test was conducted between day and night crash frequency "before-and-after" IdaShield installations to assess the IdaShield's nighttime effectiveness.

Results of the EB analysis show a highly statistically significant 39 percent decrease in crash frequency after IdaShield installation. The one-sample t-test showed significant decreases in both day and night crash frequency after IdaShield installation, but no statistically significant difference between day and night performance. The comparison of total Idaho vehicle crashes and Idaho highway-rail crossing crashes revealed increasing statewide vehicle crash frequency with decreasing highway-rail crossing crash frequency from 1996 - 2005. This contrasting trend suggests that factors specific to highway-rail crossings, such as the IdaShield, reduced highway-rail crossing crash frequencies. Collectively, these results show that the IdaShield installations in 1997 and 1998 significantly decreased crashes at highway-rail crossings.

The decrease in crash frequency associated with IdaShield installation may be partially caused by the higher reflectivity and visibility of new signs and posts that were installed along with IdaShields. New signs are generally more reflective and therefore more visible than older signs due to weathering, dirt buildup, and exposure to the elements over time. This would explain the gradual increase in highway-rail crossing crash frequency after IdaShield installation from 1999 - 2007 caused by gradual weathering of the signs. Also, the sudden installation of new signs may have captured the attention of regular crossing users, causing them to be more alert when approaching the crossings. This effect may have diminished over the years as users became accustomed to the IdaShield's presence, which would also explain the gradual rise in crash frequency from 1999 - 2007.

Chapter 3
IdaShield Web Survey

A web-based survey was conducted to assess highway users' understanding of and response to IdaShield signs at passive highway railroad crossings. Idaho drivers were randomly sampled across the entire state and asked to complete an online survey. They responded to questions accompanied by pictures asking them to identify the meaning of different sign and marking conditions commonly encountered when driving, including the IdaShield. In addition to the crash data, the user assessment survey provided an indirect measurement of the IdaShield's impact on safety by way of effects to driver survey responses.

Methodology

Overview

The Social Science Research Unit (SSRU) at the University of Idaho conducted the survey. The survey instrument was designed using preliminary data collected from questionnaires filled out by individuals who had completed the driving simulation (Measure 3, See Chapter 4). The final survey instrument (Full Tabular Results) is shown in Appendix C. The survey took, on average, 12 minutes to complete and was approved by the University of Idaho Institutional Review Board.

Individuals were recruited from the *2013 Idaho Transportation Department's Public Opinion Study* using a sample of 4,000 landline and 1,600 mobile telephone numbers with Idaho area codes.[19] A pre-notification email was sent to 784 eligible Idaho residents as an invitation to participate (Appendix D) with additional reminder emails (Appendices E, F, G).

Of those who agreed to participate over the phone, 265 completed the survey and 29 completed a portion of the survey. The final response rate of those who were eligible and provided contact information was 37.5 percent

Comparative analyses found that survey respondents adequately represent the Idaho driving population (see Appendix C). Statistically significant differences in responses to account for respondent age and education level were tested for using Fisher's Exact Tests; however, these results generally did not yield biases within the respondent sample to affect results (see Appendix C).

Results

The results of survey questions on signage comprehension, daytime and nighttime effects, and IdaShield effects are summarized in this section.

Signage Comprehension

Respondents were asked to determine the meaning of each sign from a list of possible answers. Almost all respondents had a basic understanding of signage in Idaho. When asked to identify the meaning of "Merge", "Railroad Adjacent", "Railroad Crossing", and "Traffic Circle" signs, almost all respondents were able to identify each road sign correctly (99 percent, 90 percent, 100 percent, and 97 percent respectively).[20] Of the respondents 71 percent believed that a Crossbuck is most similar to a YIELD sign. Respondents showed general understanding of correct behavior when approaching highway-rail crossings. Complete signage comprehension results are included in Appendix C.

Comparisons of Signage Scenarios by Day and Night

Respondents were shown five railroad signage scenarios:

- Crossbuck - STOP Sign.
- Crossbuck - STOP Sign - IdaShield.
- Crossbuck - YIELD Sign.
- Crossbuck - YIELD Sign - IdaShield.
- Crossbuck - IdaShield.

For each signage scenario, respondents were asked "If You Approached an Intersection Such as the Following What Action Should You Take?" Respondents were able to choose one of the following options:

- Look for Trains and Use Caution.
- Slow Down.
- Speed Up.
- Continue with the Same Speed.
- Stop.
- I Do Not Know.

The responses were randomized to avoid response order bias.

Each scenario included a follow-up question as such: "If You Approached This Point and Simultaneously Notice a Train is Approaching, What Would You Do?" Respondents were able to choose one of the following:

- Continue With the Same Speed.
- Slow Down.
- Stop.
- Speed Up.
- I Do Not Know

Respondents were randomly assigned to view the scenarios as daytime or as nighttime to test for any differences in response. The resulting distributions of the daytime and nighttime responses are extremely similar, with no statistically significant differences revealed for how respondents understand the signage.

IdaShield Effects

IdaShield and no-IdaShield conditions were compared across various sign and time of day and light conditions. In scenarios that tested drivers' responses to YIELD signage in day and night scenarios, the majority of all respondents (88.8 - 93.3 percent) "Look for Trains and Use Caution" when no train is coming (see Figure 11). When combined with an IdaShield sign, the YIELD signage during the day elicited a slightly higher percentage of respondents indicating they would "Slow Down" instead of "Look for Trains and Use Caution".

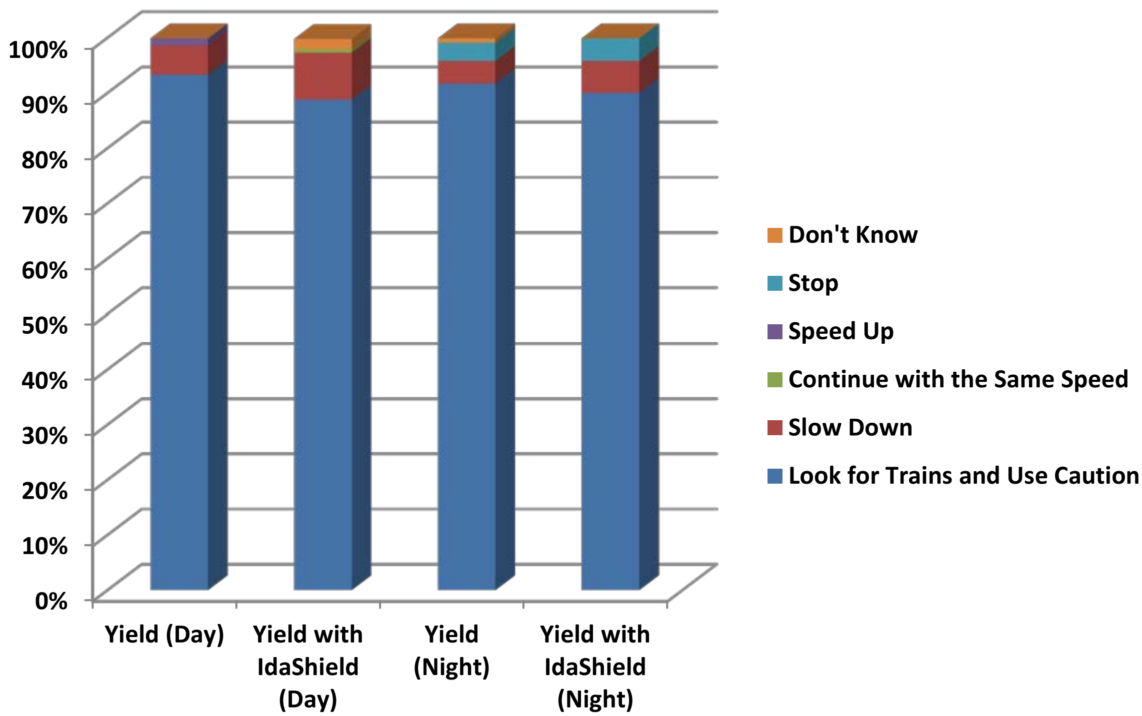

Figure 11. YIELD with IdaShield and No IdaShield by Day and Night No Train Approaching

When presented with a scenario of a train approaching at the intersection, responses of the effects of YIELD signage, at day and night were similar (see Figure 12). The majority of respondents (92.5 - 98.3 percent) "STOP with a train coming". The effect of the YIELD signage at night, both with and without the IdaShield, was slightly greater during the day.

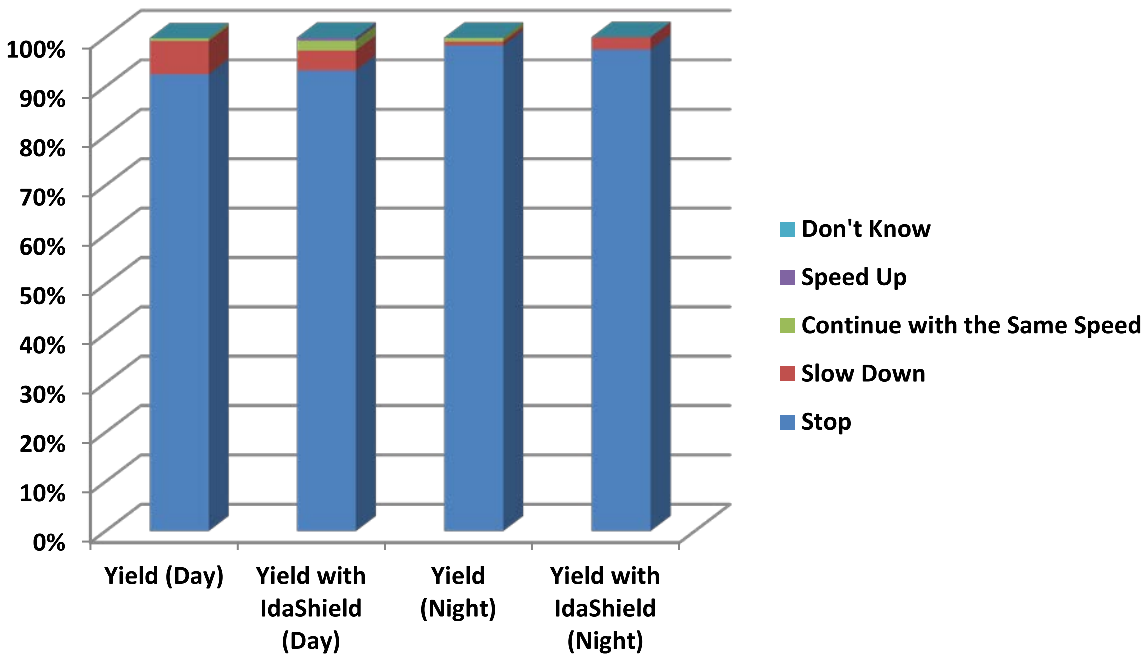

Figure 12. YIELD Scenarios by Day and Night Train Approaching

In scenarios that tested drivers' responses to STOP signage in day and night scenarios, similarly high overall percentages of respondents (90.1 - 96.0 percent) indicated caution about railroad crossings and that they would stop (see Figure 13) with no train approaching. Most of the remaining respondents who did not indicate they would stop in the STOP signage scenarios did indicate they would look for trains and use caution.

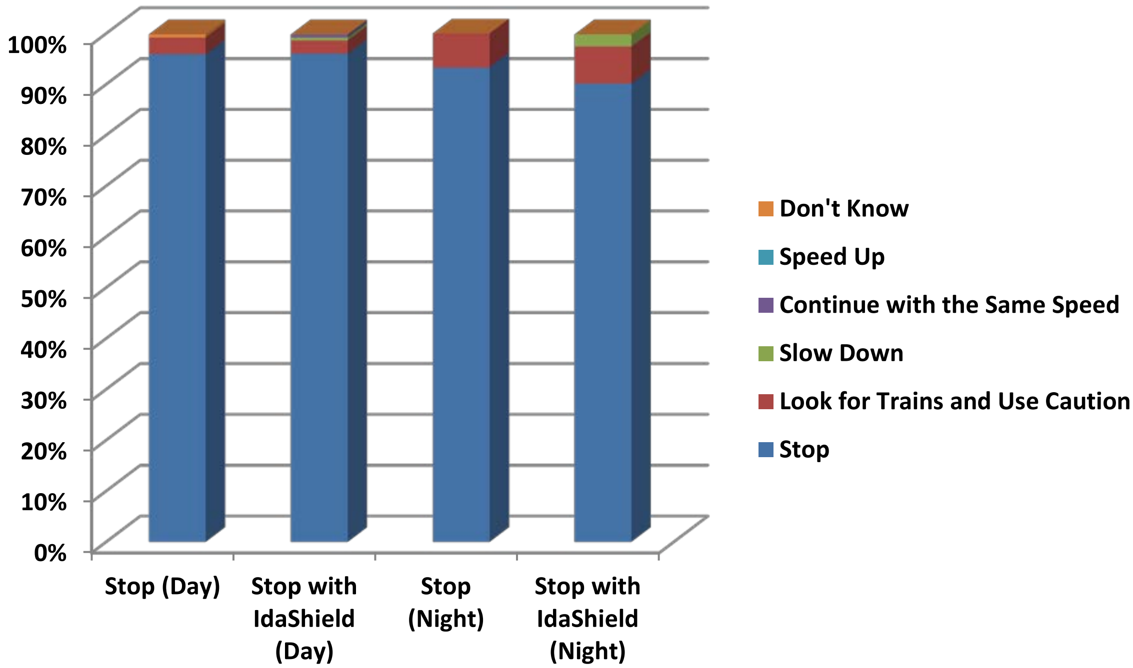

Figure 13. STOP Scenarios by Day and Night No Train Approaching

When presented with a scenario of a train approaching at the intersection, responses of the effects of STOP signage, at day and night (see Figure 14). The greatest majority of respondents (96.0 - 100.0 percent) “STOP” with a train coming. The effect of the STOP signage combined with the IdaShield did not appear to have differential effects except that in the daytime scenario a few more individuals indicated they would only “slow down” or “did not know” how to respond.

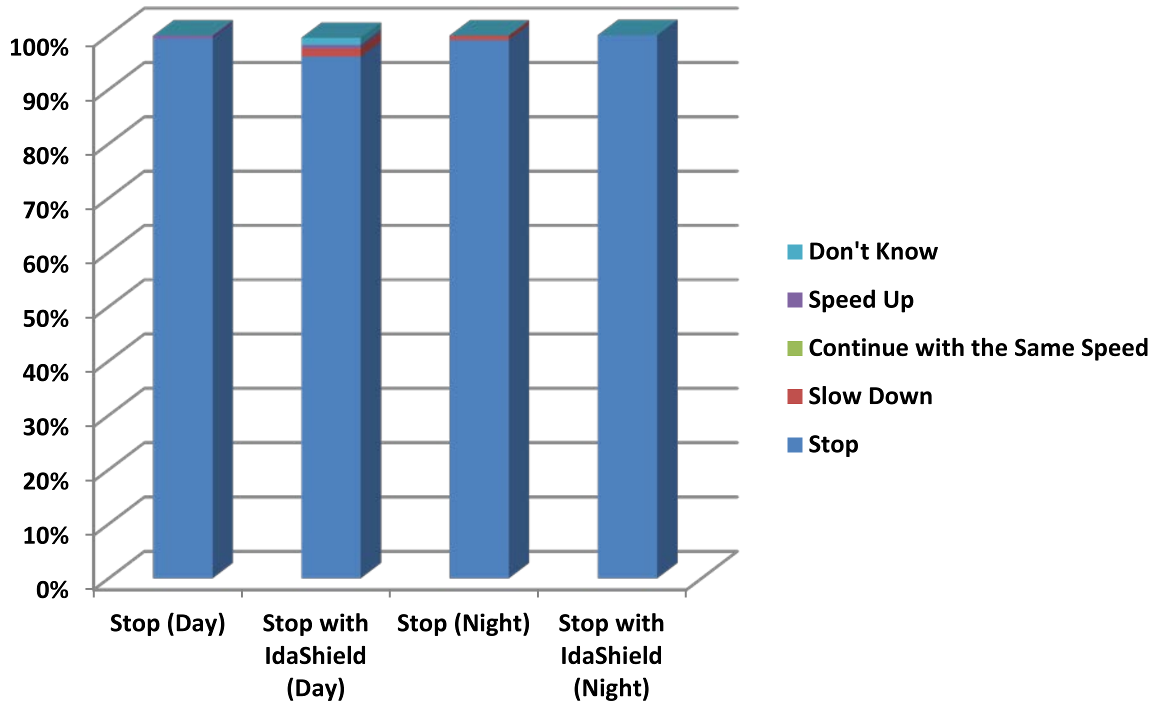

Figure 14. Stop Scenarios by Day and Night Train Approaching

Mixed results of the combined signage scenarios indicate that some drivers may interpret the presence of an IdaShield more as a YIELD than a STOP.

When unaccompanied by other signage, the IdaShield had a positive effect on drivers' caution at railroad crossings. The majority of respondents in both day (90.7 percent) and night (94.1 percent) scenarios indicated they would stop for the scenario of only having an IdaShield sign (see Figure 15). Most of the remaining respondents also indicated they would slow down within the daytime and nighttime scenarios.

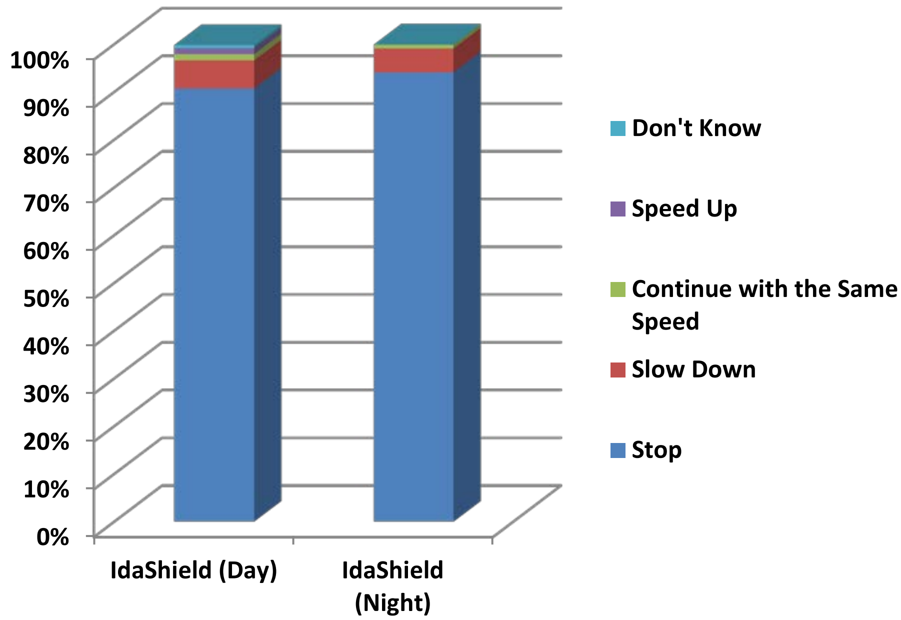

Figure 15. IdaShield Alone by Day and Night No Train Approaching

The IdaShield had no significant effects on a respondent's comprehension of railroad intersections. See Appendix C for full description of survey questions and responses.

IdaShield Effect on Visibility and Safety

At the end of testing differences with the IdaShield, respondents were asked whether they felt that the sign increased the visibility and safety of each railroad crossing. Nearly two-thirds of respondents felt the IdaShield "increased" visibility of the railroad crossing (63 percent). In contrast, 23 percent of respondents felt the IdaShield signs did not increase the visibility of the crossings. An additional 14 percent of respondents indicated "I am not sure" whether the IdaShield signs increased visibility of the crossings (see Figure 16).

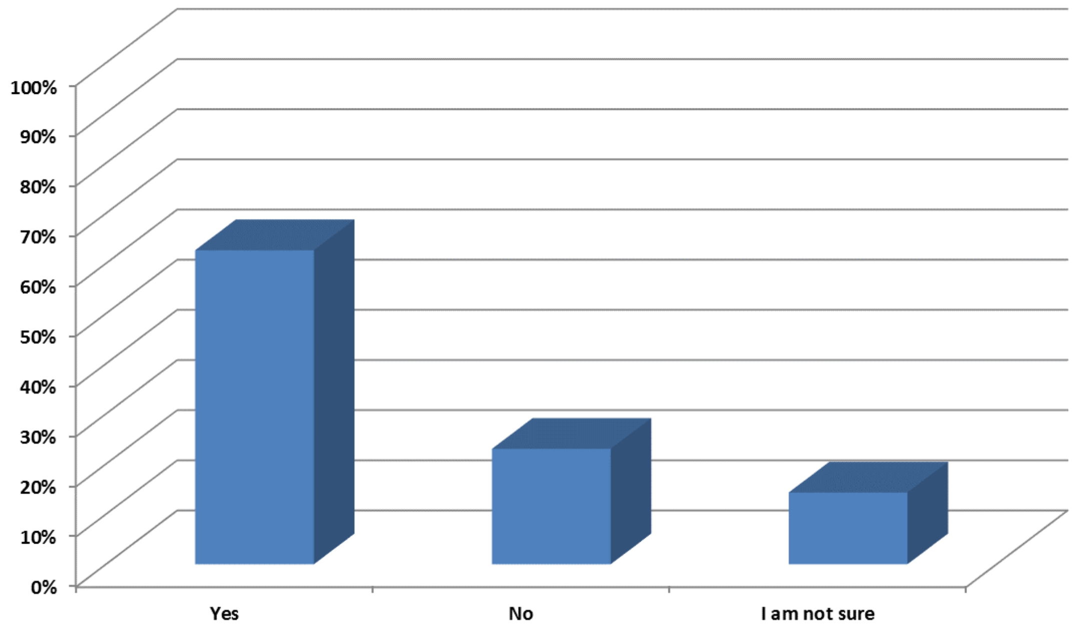

Figure 16. IdaShield and Visibility

In a similar pattern, half of respondents (50 percent) felt that the IdaShield increased safety of railway crossings. The other portion of respondents was divided with 22 percent indicating “No” the IdaShield did not increase safety at railway crossings. An additional 24 percent of respondents indicated “I am not sure” whether the sign increased safety at the crossings (see Figure 17).

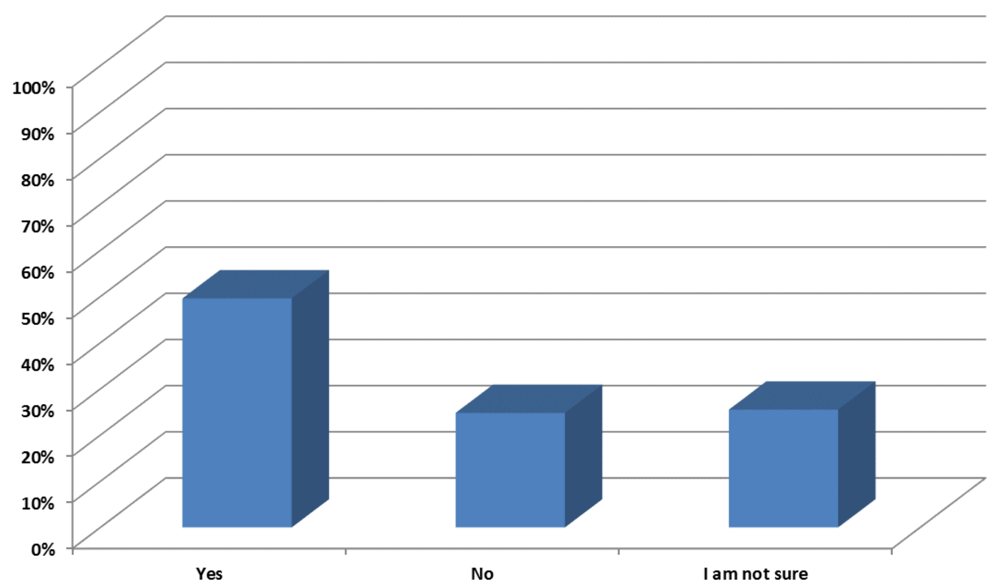

Figure 17. IdaShield and Safety

Summary of Results

This study provides data that measured Idaho residents' understanding and comprehension of signage and railroad crossings in the state of Idaho. A summary of several key findings includes:

- A majority of Idaho drivers responding to the survey generally have a correct understanding of road signage in Idaho.
- When unaccompanied by other signage, the IdaShield sign elicits responses similar to a YIELD sign.
- The presence of the IdaShield did not generate any statistically significant differences in driver actions in daytime or nighttime railroad crossing scenarios.
- Most residents (63 percent) feel that the IdaShield increases the visibility of highway-rail crossing intersections.
- While a majority of residents indicated the IdaShield sign increases safety at railway crossings, a higher percentage of respondents also indicated they were less sure compared to how the sign increased visibility at the intersections.

Chapter 4
Driving Simulation: Effects and Perception of the IdaShield

This chapter presents the results of a driving simulation experiment designed to evaluate the effects of the IdaShield on driver behavior at passive rural railroad crossings under tightly controlled conditions. Driver simulation was also used to assess the impact of the IdaShield. Of the participants, 20 drove their simulated vehicle along stretches of rural highway containing railroad crossings under both daytime or nighttime conditions. Crossings were passively marked with different combinations of signs, including conditions both with and without IdaShield signs. The presence or absence of an approaching train was also varied. The simulator recorded vehicular control (e.g., position, acceleration, and speed) and eye movement patterns. Detailed insights into driver responses resulted from this data, allowing more effective evaluation of the quality of driver compliance to highway railroad crossing traffic control devices. The following sections describe the driver simulation methodology and analysis of the results. Technical details of the experimental methodology can be found in Appendix A. The actual field of view in the simulator included displays to each side which tripled the horizontal extent of the field of view in Figure 18.

Overview of Simulation Method

Each driver was presented with 10 simulations of 4 - 5 mile stretches of rural highway using the University of Idaho's National Advanced Driving Simulator (NADS) Minisim. At about 3 - 4 miles, each simulated stretch of roadway contained a railroad crossing marked with passive signs only. The 10 railroad crossings differed in 2 ways:

a. The status of a train approaching the crossing from the left (present or absent).
b. The configuration of signs marking the crossing.

We examined 5 sign configurations, which can be seen in Figure 19 to Figure 23, respectively:

1. The railroad crossing Crossbuck paired with a standard YIELD sign (CB-YIELD).
2. The Crossbuck paired with a standard STOP sign (CB-STOP).
3. The Crossbuck paired with an IdaShield (CB-Ida).
4. The Crossbuck with both a YIELD sign and IdaShield (CB-YIELD-Ida).
5. The Crossbuck with both a STOP sign and IdaShield (CB-STOP-Ida).

Figure 18. Overhead View of the NADS Minism

Above figure shows the Chevy S-10 Cab, Main Forward Displays, and Right Side Mirror Display is Visible.
Note: The instrument cluster, left side mirror, and center rearview mirror are not visible in this view.

Figure 19. Scenario 1 - Crossbuck with YIELD Sign

Figure 20. Scenario 2 - Crossbuck with STOP Sign (CB-STOP)

Figure 21. Scenario 3 - Crossbuck with IdaShield (CB-Ida)

Figure 22. Scenario 4 - Crossbuck with YIELD Sign-IdaShield (CB-YIELD-Ida)

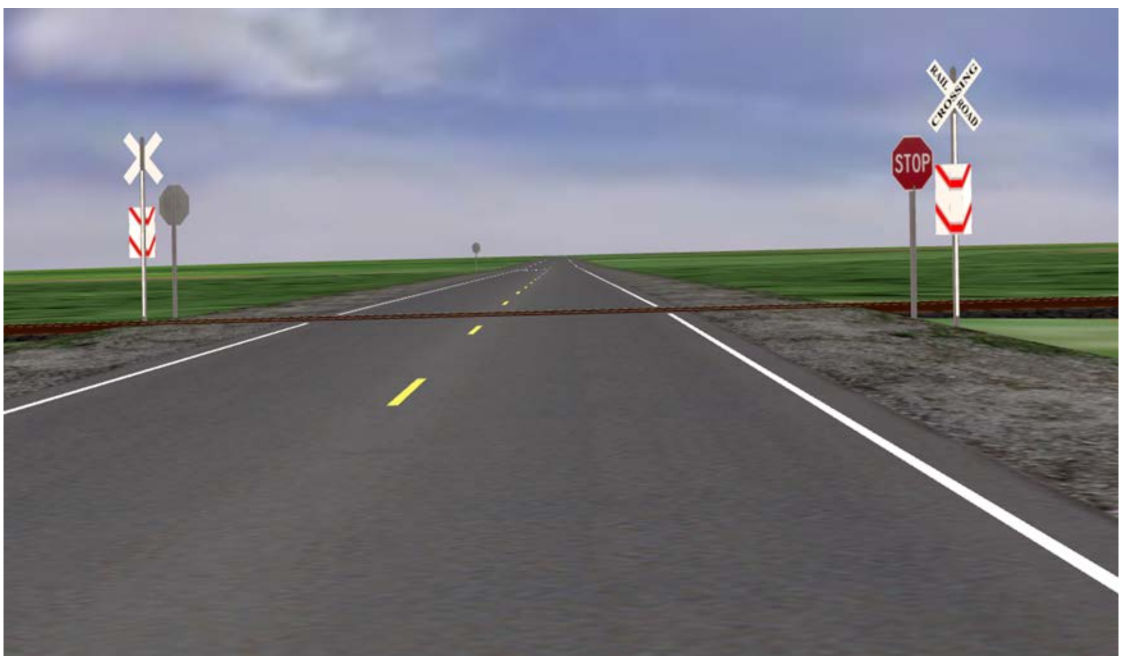

Figure 23. Scenario 5 - Crossbuck with STOP Sign - IdaShield (CB-STOP-Ida)

Drivers encountered each of the five sign configurations twice, once with a train approaching from the left and once with no train present. The trajectory of the train was specifically designed to allow drivers the choice of whether to "speed up" and "cross ahead of the train", or "slow down and stop to wait for the train".

Traffic, terrain layout and highway geometry were otherwise identical for all 10 highway-rail crossings (see Figure 19 to Figure 23). Details of the configuration of these stimuli are provided in Appendix H.

Drivers were divided into two groups for testing the sign configurations under both day and nighttime conditions. Daytime drivers viewed a simulation with lighting simulating midday sunshine. Nighttime drivers experienced a simulation of a moonless dark night where only objects illuminated by vehicle headlights are clearly visible. Importantly, for nighttime drivers the headlight of the train approaching from the left illuminated the angled left third of the IdaShield, while the Crossbuck, STOP and YIELD signs, which are oriented parallel to the train headlight's direction, were illuminated by the driver's headlights only.

This experiment used a mixed factorial design, with sign configuration and train status manipulated within-subjects (each subject experienced each of the 10 unique combinations of these variables), and time of day manipulated between groups of participants (half of the participants experienced only daytime conditions and the other half only nighttime conditions).

We examined two classes of measures: vehicular control, and eye movements. Our vehicular control measures included the driver's control inputs to the steering wheel, brake and accelerator pedals as well as the simulated speed and position of the vehicle on the roadway. In particular, we expected that enhanced warning and safety at a railroad crossing would reduce the frequency of crossing in front of an approaching train, and for the final 500 feet before the crossing, reduce speed and increase transit time.

Gaze dwell time in different areas of interest (AOIs) within the simulation displays served as our primary measure of eye movements. As we drive, our eyes continually scan the environment, fixating on objects of interest (e.g., the roadway ahead, signs, the train when present, the instrument cluster, etc.), often for only a fraction of a second, before quickly jumping to another object. Because these jumps - known as saccadic eye movements - occur very quickly (20 - 100 ms) and visual input during the jumps is suppressed, we typically have no awareness of the blurred image occurring during the saccade. We are aware only of the period when our eyes are relatively stationary, fixating or tracking an object in the environment. The locations of fixations occurring between saccadic eye movements are strongly linked to the location of our visual attentional focus (which acts as a target for eye movements). Gaze dwell time is the total duration of all eye fixations within an AOI defining a particular object or region of space, and therefore reflects the duration of visual attention to that object or region.

Figure 24 and Table 8 illustrate and list the 16 objects and regions used to define AOIs for this study. To determine whether a participant's gaze fell within any of the AOIs we first analyzed the raw time-series of X-Y eye coordinates using the default algorithm implemented by Applied Science Laboratory's (ASL) EYENAL eye data analysis application, which determines the beginning and end of fixations based on statistical functions of eye stability. The time-coded fixation locations, scene planes, and durations output by EYENAL were then linked with the virtual model defining the simulation environment and the time-coded vehicle telemetry data using a program written in-house in the Python programming language. This program determined where in the 3D scene the participant's gaze was fixating at any given moment returned the total gaze dwell time in each of the 16 AOIs. Due to the 1^{o} spatial resolution of the eye tracking system, identification of fixations on the driver's lane railroad sign cluster was only possible within a distance of 200 feet. Beyond this distance, only very large AOIs such as the sky, ground, and roadway are resolvable. Our analysis thus focused only on gaze dwell time during transit of the last 200 feet before each crossing.

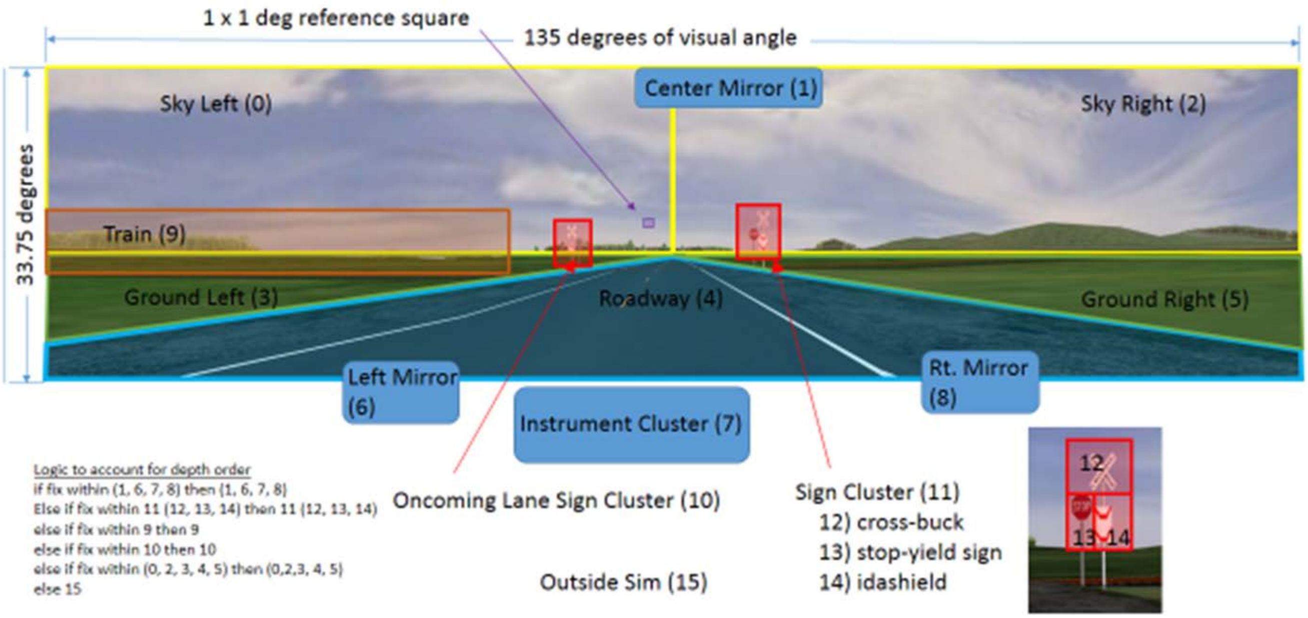

Figure 24. Definition of the 16 Areas of Interest (AOIs) for Calculating

Table 8. Sixteen Areas of Interest (AOIs) Defined as Categories for Gaze Dwell Time

Categories	
0. Sky Left of Center	**8. Right Side Mirror**
1. Center Rearview Mirror	**9. Train (If Present)**
2. Sky Right of Center	**10. Oncoming Lane Railroad Sign Cluster**
3. Ground Left of Center	**11. Driver's Lane Railroad Sign Cluster**
4. Roadway	**12. Crossbuck Within Sign Cluster**
5. Ground Right of Center	**13. STOP or YIELD Within Sign Cluster**
6. Left Side Mirror	**14. IdaShield Within Sign Cluster**
7. Instrument Cluster	**15. Outside the Simulator**

Questions

We designed our study to address the following questions:

1. ***Does the IdaShield have a measurable effect on human behavior (vehicular control, eye movements)?***
   If the answer is "NO", then our remaining questions, which all assume some measurable effect on human behavior, are moot, and we can only conclude that any behavioral effects of the IdaShield are too subtle to be measured in our driving simulation. Certainly, such a result would not support arguments that the IdaShield significantly enhances safety at passive rural railroad crossings.

2. ***Does the IdaShield enhance safety? If so, under what specific conditions? During the day? At night? By what mechanism? Increased warning? Increased visibility of signs? Of trains?***
   The IdaShield may indeed meet its design goal of providing additional warning to drivers that changes their behavior in a manner enhancing safety at passive rural railroad crossings. Behaviors that would most directly reflect enhanced warning and safety include:

   a. Reduction in the frequency of crossing in front of an approaching train.
   b. Reduction in speed while traversing the final 500 feet before the crossing.
   c. Increased transit time for the final 500 feet of roadway before the crossing.

   Addressing which specific condition(s) is(are) affected by the IdaShield and what mechanism(s) underlie these effects leads us to a number of sub-questions.

   2.1. ***Does the IdaShield enhance safety under all conditions?***
   It is possible that the IdaShield aids in increasing driver attention to the cluster of railroad signs under all conditions (day or night) by providing a general warning effect. If so, we expect the presence of an IdaShield to reduce speed and increase transit times. Because eye movements reflect the direction of attention, we also expect the IdaShield will increase the amount of time that drivers look at the railroad crossing sign cluster. Finally, we expect the presence of an IdaShield will decrease the frequency of crossing in front of an approaching train both day and night.

   2.2. ***Does adding the IdaShield to crossings with a stop sign enhance safety, but only at nighttime by increasing attention to the railroad crossing sign cluster?***
   Unlike the railroad crossing Crossbuck or a YIELD sign, which provide only a cautionary warning, STOP signs have a clear and unambiguous interpretation: the driver must "STOP." We expect that the unambiguous stop command communicated by a STOP sign will supersede all warning effects of the Crossbuck or IdaShield, as long as the STOP sign is clearly seen. Behavior at crossings with a STOP sign would thus be unaffected by the presence or absence of the IdaShield during the day. However, at night the additional reflectivity of the IdaShield, particularly when illuminated by a train headlight, might enhance safety by guiding drivers'

attention to the railroad crossing sign cluster, thereby increasing the visibility of the STOP sign. To answer this question, we will compare vehicular control for the CB-STOP and CB-STOP-Ida configurations at nighttime in the presence or absence of a train. Further, if the IdaShield increases attention to the railroad sign cluster at night we expect to observe longer gaze dwell times on the STOP sign, IdaShield location, and Crossbuck when the IdaShield was present at night, particularly when illuminated by an approaching train.

2.3. ***Does adding the IdaShield to crossings with a yield sign enhance safety, but only at nighttime when a train is present?***
Unlike a STOP sign, the response to a YIELD sign depends upon on the presence and visibility of an oncoming train. We therefore expected that the presence of a YIELD sign will cause drivers to search for an oncoming train, then stop or proceed, depending upon whether a train is detected. During the daytime, when the train is plainly visible, we did not expect the IdaShield to significantly affect this search or to enhance safety. However, safety could be enhanced at nighttime when the headlight of the train illuminates the IdaShield, drawing attention to it, and perhaps alerting drivers to the oncoming train. To answer this question, we compared vehicular control for the CB-YIELD to CB-YIELD-Ida sign configurations at night in the presence vs. absence of the train. If the IdaShield provides additional warning by reflecting the train headlight, we would also expect it may produce longer gaze dwell times on the YIELD sign or IdaShield at night.

2.4. ***Does the IdaShield provide warning similar to a STOP Sign or Yield Sign?***
Our last two questions address how drivers interpret the IdaShield when it is presented with only a Crossbuck (no STOP or YIELD sign). Do they respond to it like a YIELD sign or a STOP sign? These questions were addressed by comparing driver responses to the CB-Ida, CB-STOP, and CB-YIELD conditions during the daytime when the train is present or absent.

Next, we review how the vehicular control and eye movement data from the simulation experiment address these questions.

Results

The data provide a clear answer to Question 1: the IdaShield measurably affected both vehicular control and eye movements in our simulation, albeit in a complex manner. Below we summarize these effects for each of our measures.

The IdaShield Affects the Frequency of Crossing Ahead of an Approaching Train

The most direct indicator of safety enhancement is the frequency with which participants created a dangerous situation by crossing ahead of the oncoming train. Table 9 lists the number of participants who crossed ahead of an approaching train for the five different sign conditions presented under both daytime and nighttime conditions. Note that for each combination of sign configuration and time of day, we obtained one observation per participant tested, resulting in a maximum frequency of 10 for each variable combination. Time of day was the primary factor affecting whether participants crossed ahead of the train. Overall, they were more than 7 times more likely to cross ahead of the train at nighttime than during the daytime. Sign configuration may also have had a small effect: approximately twice as many participants crossed ahead of the train when a YIELD sign accompanied the Crossbuck as compared to a STOP sign or an IdaShield. Taking the frequency numbers at face value (which we do with caution given the small sample size), it appears that the STOP sign is best at dissuading drivers from crossing in front of an approaching train, followed closely by the IdaShield, and then the YIELD sign, with the pattern more evident at nighttime than during the daytime.

Table 9. Number of Participants Out of Maximum of 10 for Each Time of Day Who Crossed Ahead of the Train by Sign Configuration and Time of Day

Sign Configuration	Time of Day		Totals
	Day	Night	
Crossbuck + STOP	0	3	3
Crossbuck + STOP + IdaShield	0	4	4
Crossbuck + IdaShield	1	4	5
Crossbuck + YIELD	1	7	8
Crossbuck + YIELD + IdaShield	1	4	5
Totals	3	22	25

A number of inferences can be drawn from the crossing frequencies listed in Table 10. First, our simulation provided dynamics between the train and the driver's vehicle suitable for presenting drivers with a choice between safely stopping and waiting for the train to pass or continuing on at highway speed to cross ahead of the train. During daytime simulations when the train was easily visible, drivers were 94 percent more likely to choose to "stop and wait for the train to pass;" they clearly perceived crossing ahead of the train as risky. Second, since it seems implausible that our sample of nighttime drivers had 7 times the risk tolerance as our sample of daytime drivers, we also infer that the vast increase in crossing ahead of the train at nighttime is likely due to decreased visibility of the train, the railroad crossing signs, or both. Given this conclusion, it appears that the IdaShield may provide a specific rather than general safety enhancement: it reduces the number of dangerous crossings ahead of trains, but only for crossings that do not include a STOP sign during nighttime conditions.

The IdaShield Affects Transit Time Over the Last 500 Feet Preceding the Railroad Crossing

To examine how the IdaShield affected vehicle speeds and transit times, we compared pairs of conditions which differed only by the presence or absence of an IdaShield. Hence, this analysis ignored the CB - Ida scenarios (1 and 6 for train present or absent, respectively) and focused only on scenarios 0, 2, 3, 4, 5, 7, 8, and 9 (see Table 9). These 8 scenarios were organized as a mixed factorial research design with time of day (day or night), train status (present or absent), sign type (STOP or YIELD), and

IdaShield status (present or absent) as 4 fully-crossed independent factors each with 2 levels. To evaluate the independent and synergistic effects of these 4 factors, 2 x 2 x 2 x 2 mixed factor analyses of variance (ANOVAs) were conducted on measures of speed and transit time for traversing the final 500 feet before the crossing. Table 10 summarizes the statistically reliable results revealed by the ANOVAs. For mean speed there were significant main effects of sign type (S) and train status (T), and a significant interaction between sign type and train status (S x T). For transit times, we found significant main effects of sign type (S), train (T), a significant 2-way interaction between sign type and IdaShield status (S x I) and a significant 3-way interaction between sign type, train, and IdaShield status (S x T x I). No other main effects or interactions were significant for either measure (p > 0.05).

Table 10. Significant Effects on Mean Speed and Transit Time Identified by ANOVA

Mean Speed: Significant Effects and Interactions									
Source	df	MS	F	p	η_G^2	N	SE	95% CI	Power
Sign Type: S	*1*	*10,517.91*	*32.61*	*<0.0001*	*0.18*	*80*	*2.15*	*4.22*	*1.00*
Error (S)	*18*	*322.51*							
Train Status: T	*1*	*22,790.59*	*36.01*	*<0.0001*	*0.32*	*80*	*3.02*	*5.91*	*1.00*
Error(T)	*18*	*632.88*							
S x T	*1*	*1,718.32*	*10.85*	*0.004*	*0.04*	*40*	*2.13*	*4.18*	*1.00*
Error (S x T)	*18*	*158.38*							
Transit Times: Significant Effects and Interactions									
Source	df	MS	F	p	η_G^2	N	SE	95% CI	Power
Sign Type: S	*1*	*2,138.80*	*40.01*	*<0.0001*	*0.14*	*80*	*0.88*	*1.71*	*1.00*
Error (S)	*18*	*53.46*							
Train Status: T	*1*	*12,267.53*	*61.51*	*<0.0001*	*0.48*	*80*	*1.69*	*3.32*	*1.00*
Error (T)	*18*	*199.45*							
S x IdaShield Status (I)	*1*	*252.31*	*10.50*	*0.005*	*0.02*	*40*	*0.83*	*1.63*	*1.00*
Error (S x I)	*18*	*24.03*							
S x T x I	*1*	*386.96*	*11.22*	*0.004*	*0.03*	*20*	*1.41*	*2.76*	*0.92*
Error (S x T x IS)	*18*	*34.50*							

Note: All other main effects and interactions were not significant (N.S., p > 0.05)

Four aspects of the results are directly relevant to determining whether the IdaShield affects behavior and enhances safety.

- First and second, overall IdaShield status had no significant main effects on mean speeds or transit times (31.62 mph and 19.20 seconds for IdaShield absent vs. 32.67 mph and 19.80 seconds for IdaShield present), which suggests the IdaShield does not provide a general safety enhancement.

However, two significant interactions on transit times indicate that the IdaShield reliably affected vehicular control for some of our conditions.

- First, a significant 2-way interaction between sign type and IdaShield status (S x I) shows that the IdaShield slowed transit times when paired with a YIELD sign, but not when paired with a STOP sign.

- Further, a significant 3-way interaction of sign type, train status, and IdaShield status (S x T x I) shows the increased transit times occurred only when the IdaShield was paired with a YIELD sign and a train was approaching (see Figure25).

We confirmed these effects post-hoc using paired sample t-tests, which found that when a train is present:

- Adding the IdaShield to a Crossbuck and YIELD sign (comparison indicated by the red arrow in Figure 25) reliably increased transit times by roughly 35 percent (20.95 s to 28.28 s).

- Adding the IdaShield to a Crossbuck and STOP sign (comparison indicated by the orange arrow in Figure 25) reliably decreased transit times by roughly 13 percent (33.82 s to 29.90 s).

Taken together with the lack of significant main effects of IdaShield status, these interactions suggest that the while the IdaShield does not provide a general safety enhancement it does indeed affect behavior in some specific contexts when a train is present: increasing transit times when paired with a YIELD sign and decreasing transit times when paired with a STOP sign.

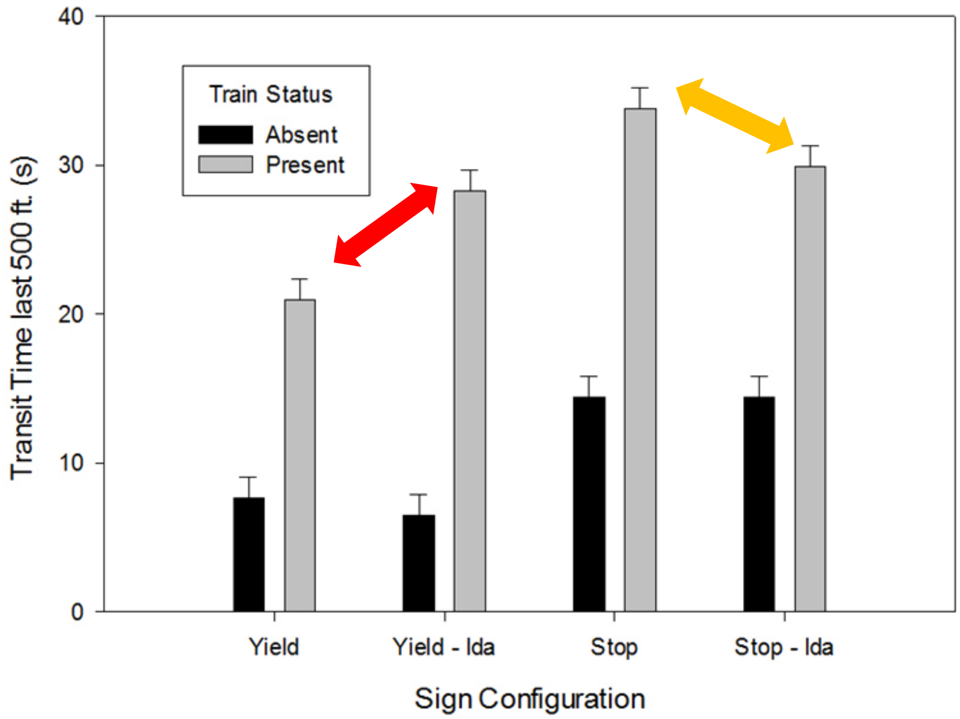

Figure 25. Transit Times Over the Last 500 Feet Before a Railroad Crossing in Seconds as a Function of Sign Configuration and Train Status

Note: Error bars represent 1 se. IdaShield Significantly increases transit times when paired with a YIELD sign and train present. See text for details.

Finally, the main effects of sign type (S) show that participants drove at lower mean speeds and took more time to transit the last 500 ft. before a railroad crossing when a STOP sign was present compared to a YIELD sign (24.04 vs. 40.26 mph and 23.14 vs. 15.83 seconds , respectively). The main effect of train status shows that participants drove at lower mean speeds and took more time to transit when a train was approaching (20.12 vs. 44.08 mph and 28.24 vs. 10.73 seconds, respectively). These effects, while not surprising, are important, for they confirm that our drivers were recognizing the different signs as well as the train and reacting appropriately.

The IdaShield Does Not Affect Gaze Dwell Times Over the Last 200 Feet Preceding the Railroad Crossing

To determine how the IdaShield affects attentional allocation, we computed gaze dwell times for each AOI identified in Figure 24 as the sum of all durations for eye fixations falling within it. For AOIs overlapping in depth, priority was given to the AOI nearest to the participant's eye-point or virtual eye-point (AOIs were not considered transparent). The definitions of the sign AOI are defined in Table 11. The "Sign Cluster" (AOI 12) contained 3 sub-AOIs: Crossbuck (AOI 13), STOP/YIELD sign (AOI 14), and IdaShield (AOI 15). Fixations falling within the 3 sub-AOIs 13 - 15 were also considered to be within their hierarchical parent, the "Sign Cluster." The total dwell time across all participants for each of the 16 AOIs is listed in Table 11. Notably, participants looked at the roadway 55.03 percent of the time. Also of note, participants only very rarely looked at the "Sign Cluster" (0.35 percent) or its sub-AOIs.

Table 11. Gaze Dwell Time and Percentages (Across All Participants) for Each Area of Interest (AOI) Defined in Figure 24

AOI	Gaze Dwell Time(s)	Percent of Total*
1. Sky Left	18.62	0.62
2. Center Mirror	127.31	4.22
3. Sky Right	30.22	1.00
4. Ground Left	125.79	4.17
5. Roadway	1,661.64	55.03
6. Left Mirror	4.42	0.15
7. Ground Right	269.07	8.91
8. Instruments	275.03	9.11
9. Right Mirror	3.60	0.12
10. Train	162.28	5.37
11. Oncoming Signs	2.03	0.07
12. Sign Cluster	10.54	0.35
13. Crossbuck	2.57	0.09
14. STOP/YIELD	1.12	0.04
15. IdaShield	0.35	0.01
16. Outside Simulator	325.14	10.77

*Due to rounding error these numbers do not sum to 100 percent.

We analyzed gaze dwell time for each AOI independently using 2 x 2 x 2 x 2 mixed ANOVAs with time of day (day, night) treated as a between-subjects factor, and train status (absent, present), sign type (YIELD, STOP), and IdaShield status (absent, present) treated as repeated measures (within-subjects) factors.

For 9 of the 16 AOIs: sky left, sky right, ground left, ground right, oncoming sign cluster, sign cluster, Crossbuck, STOP/YIELD and IdaShield - we found no significant effects or interactions with any of the 4 variables ($p > 0.05$). Many of these AOIs had very few fixations, which likely undermined the reliability of the data.

For the remaining 7 AOIs - center mirror, roadway, left mirror, Instruments, right mirror, train, and outside the simulator - train status and sign type were the only variables that had reliable effects, and these effects mirrored the main effects of train status and sign type on transit time: longer times for STOP signs or when a train was present. Essentially, longer transit times afforded longer gaze dwell times in these AOIs. Importantly for all 16 AOIs, IdaShield status had no effect or interactions ($p > 0.05$), the IdaShield did not reliably influence gaze dwell times.

Overall Conclusion: The IdaShield affects Human Behavior and Enhances Safety, But Not Equally For All Conditions

The data analyses presented above clearly indicate that in our driving simulation the IdaShield slowed transit times, but only when it was paired with a YIELD sign and a train was approaching. Interestingly, this slowing occurred both day and night - suggesting that slowing was not entirely due to enhanced warning from reflections of the train headlight from the angled portions of the IdaShield. However, the most tangible safety benefit of the slowed transit times induced by the IdaShield when paired with a YIELD sign was to reduce the frequency of crossing in front of an approaching train at night. It is possible that at night slower transit times allowed drivers more time to perceive the approaching train and decide to stop for it. During the day, when the train was clearly visible the additional transit time most likely was not needed to perceive the approaching train.

The results of the simulation experiment thus provide clear "YES" answers the first two Questions we posed above. The IdaShield had a measurable effect on human vehicular control behavior - though not eye movements - and reliably enhanced safety by slowing transit times and reducing the frequency of crossing in front of an approaching train at night.

Importantly, the safety enhancement provided by the IdaShield is specific to its pairing with a YIELD sign. There appears to be no safety benefit to adding the IdaShield to crossings containing a STOP sign, most likely because the STOP sign is a regulatory sign that supersedes the IdaShield. The gaze dwell analyses also provided no evidence that the IdaShield affected driver attention to the cluster of railroad signs. Based on this evidence our answer to Question 2.1 is that the IdaShield does not provide any sort of general safety enhancement by increasing driver attention to the railroad crossing sign cluster.

The following section addresses the specific conditions under which the IdaShield affects behavior and the most likely mechanism of safety enhancement in more detail.

Additional Evidence for When and How the IdaShield Enhances Safety

Questions 2.2 - 2.4 addressed when and how the IdaShield enhances safety. Here we present additional data analyses designed to address each question specifically.

Question 2.2 concerned whether the reflectivity of the IdaShield enhanced safety at night by drawing attention to - and enhancing the visibility of - the sign cluster due to its additional reflectivity, particularly when illuminated by an approaching train. Because the response to a STOP sign is unambiguous (you stop), this question is most directly answered by examining only nighttime drivers approaching crossings that contain STOP signs. If the IdaShield draws additional attention to the sign cluster at night, we should find fewer dangerous crossings, lower mean speeds, longer transit times, and longer fixation dwell on the on the STOP sign, IdaShield location, and Crossbuck, particularly when an approaching train headlight illuminates the IdaShield.

As shown in Table 9, 3 out of 10 of our nighttime drivers crossed ahead of an oncoming train at crossings with a STOP sign but no IdaShield (CB-STOP) while 4 out of 10 of our nighttime drivers crossed ahead of an oncoming train at crossing with a STOP sign and IdaShield. The addition of an IdaShield did not appear to enhance the visibility of the railroad crossing sign cluster or draw attention to it.

The effect of the IdaShield on mean speeds and transit times for night trials in which the sign configuration contained a STOP sign was tested with two, two-factor (2 x 2) ANOVAs using IdaShield status (present or absent) and train status (present or absent) as the two factors. The significant results from these analyses are listed in Table 12. We found significant main effects of train status on both measures, with lower mean speeds and longer transit times occurring when the train was present (9.69 mph, 36.71s) compared to when the train was absent (28.15 mph, 16.99s). Further, train status and IdaShield status had a significant interactive effect on transit times.

The pattern of means shown in Figure 26 shows that adding the IdaShield to a STOP sign significantly reduced transit times at night when a train was approaching. Though the magnitude of this effect is small (~3 mph), this result contradicts our prediction that the IdaShield might slow drivers and cause longer transit times when a train is present at nighttime. However, this small effect is likely a corollary of the higher proportion of drivers crossing ahead of the train at night when the crossing signs contained both a STOP sign and IdaShield (4/10) as opposed to just a STOP sign (3/10).

Table 12. Significant Effects on Transit Time and Mean Speed Identified by ANOVAs

Mean Speed: Significant Effects and Interactions									
Source	**df**	**MS**	**F**	***p***	η_G^2	**N**	**SE**	**95% CI**	**Power**
Train: T	1	3,408.92	7.99	0.020	0.38	20	5.33	10.45	0.96
Error (T)	9	426.72							
Effects on Transit Time									
Source	df	MS	F	*p*	η_G^2	N	SE	95% CI	Power
Train: T	1	3,389.37	173.56	<0.0001	1.88	20	1.22	2.40	1.00
Error (T)	9	22.41							
Train x IdaShield Status (T x I)	1	51.21	7.97	0.020	0.025	10	0.93	1.81	0.76
Error (T x I)	9	6.42							

Note: Analysis included data for scenarios containing a STOP sign at night only. All other main effects and interactions were not significant (N.S., p > 0.05).

These results, taken together with the lack of effect of the IdaShield on gaze dwell time presented earlier do not support the conclusion that the IdaShield increases attention to the railroad sign cluster generally, or at night specifically.

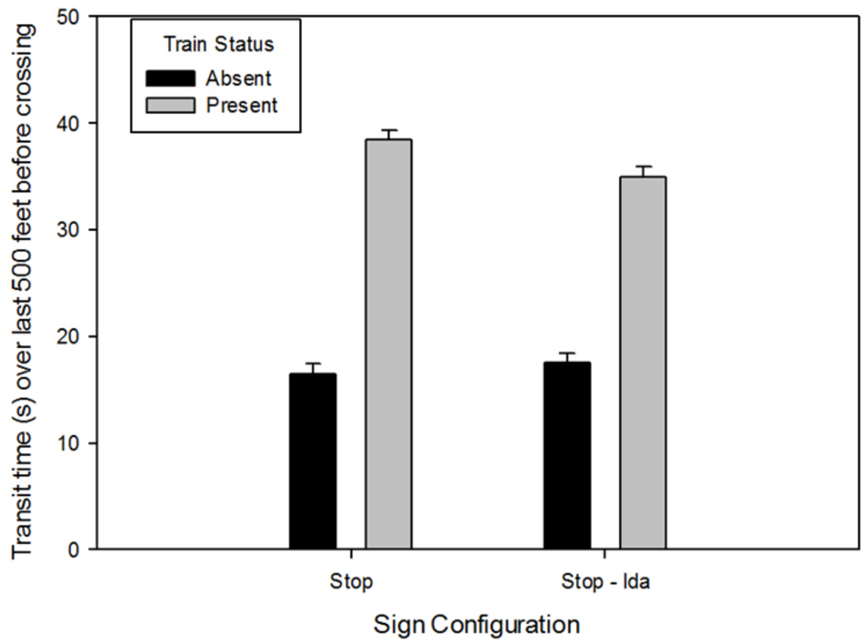

Figure 26. Transit Time Over the Last 500 Feet Before a Railroad Crossing in Seconds as a Function of Sign Configuration (STOP, STOP + IdaShield) and Train Status (Present/Absent)

Note: Time of day for all trials was night. Error bars represent 1 se. IdaShield significantly decreases transit times when paired with a STOP sign and train present. See text for details.

Question 2.3 concerned whether the reflectivity of the IdaShield enhanced safety at night by drawing attention to - and enhancing the visibility of - an approaching train. Because the response to a YIELD sign depends upon whether a train is perceived as approaching, this question is most directly answered by examining only nighttime drivers approaching crossings that contain YIELD signs. If the IdaShield enhances visibility of a train approaching at night, we should find fewer dangerous crossings, lower mean speeds, longer transit times, and longer fixation dwell on the on the train and railroad sign cluster when an approaching train headlight illuminates the IdaShield.

According to the frequency of dangerous crossings data presented in Table 9, 7 out of 10 nighttime drivers crossed ahead of the train when the crossing sign cluster contained only a Crossbuck and YIELD sign. This number was reduced to 4 out of 10 when an IdaShield was included with the Crossbuck and YIELD. No difference in the frequency of crossing ahead on the train was observed during daytime conditions. These crossing data suggest the IdaShield's greatest safety enhancement is to reduce the number of dangerous crossings ahead of approaching trains at night.

However, other evidence suggests that pairing an IdaShield with a YIELD sign affects the responses to an oncoming train of both daytime and nighttime drivers equally. We examined the effects of IdaShield status (present/absent) and time of day (day, night) train by conducting two 2 x 2 mixed ANOVAs on mean speed and transit time for only trials in which a train was approaching a crossing containing a YIELD sign. The analyses revealed a significant effect of IdaShield status on transit time, F (1, 18) = 6.87, MSE = 78.00, $p = 0.017$, $\eta^2_G = 0.073$, se = 2.12, 95% CI = 4.15, power = 0.74. Transit times reliably increased from 20.95s to 28.28s when an IdaShield was included in the crossing sign cluster containing a YIELD sign. There were no other significant effects or interactions ($p > 0.05$). Interestingly, there was no interaction of IdaShield status and time of day, the IdaShield increased transit times by roughly 7s regardless of time of day. These simulation results show that the IdaShield slows transit time when paired with a YIELD sign, day or night, and reduces the frequency of dangerous crossings ahead of the train at night. A likely mechanism for this pattern of results is that a YIELD sign paired with an IdaShield provides greater warning urgency than a YIELD sign alone, slowing drivers generally and affording more of a chance for nighttime drivers to detect the train.

Question 2.4 addresses how drivers interpret the IdaShield when it is presented with only a Crossbuck (no STOP or YIELD sign): do drivers perceive warning from the IdaShield as more similar to a YIELD sign or a STOP sign? These questions can be answered by comparing driver responses to the CB-Ida, CB-STOP, and CB-YIELD conditions when the train is present or absent.

We will first consider the crossing frequencies presented in Table 9. Taken at face value these data suggest that when a train is present, time of day influences participants' interpretation of the IdaShield: responses to it are more similar to YIELD sign responses during the day, but at night more similar to STOP sign responses.

Mean speed and transit time measures allow us to characterize the interactions of sign type and time of day with train status in more detail. We submitted these measures to separate 3 x 2 x 2 mixed ANOVAs with sign type (YIELD, STOP, or IdaShield) and train status (present absent) as within-subjects factors and time of day (day, night) as a between-subjects factor. Both analyses revealed significant main effects of sign type and train status, as well as a significant 2-way interaction between these variables (see Table 13**).** Interestingly, there was no significant main effect of time of day, or significant interactions of time of day with other variables ($p > 0.05$), despite the effect of time of day on the frequency of hazardous crossing ahead of the train.

The interactions of sign type and train status for both measures are shown in Figure 27. The inverse relationship between these measures is evident in the graphs. Notably, when a train is absent, speeds and transit times for the IdaShield are similar to those for YIELD signs and significantly different from those for STOP signs. However, when the train is present, mean speeds and transit times for the IdaShield fall in-between those for YIELD and STOP signs.

Table 13. Significant Effects on Mean Speeds and Transit Times Identified by ANOVAs

Mean Speed: Significant effects and Interactions									
Source	**df**	**MS**	**F**	***P***	η_G^2	**N**	**SE**	**95% CI**	**Power**
Sign Type: S	2	3,936.79	25.96	<0.0001	0.19	40	2.02	3.95	1.00
Error (S)	36	151.64							
Train: T	1	20,470.60	39.78	<0.0001	0.38	60	3.14	6.15	1.00
Error (T)	18	151.64							
ST x T	2	429.28	3.57	0.038	0.03	20	2.54	4.97	0.38
Error (S x T)	36	120.17							
Transit Time: Significant Effects and Interactions									
Source	**df**	**MS**	**F**	***P***	□G□	**N**	**SE**	**95% CI**	**Power**
Sign Type: S	2	1,053.48	22.27	<0.0001	0.19	40	1.13	2.20	1.00
Error (S)	36	47.30							
Train: T	1	9,286.05	57.23	<0.0001	0.50	60	1.76	3.46	1.00
Error (T)	18	162.26							
ST x T	2	137.38	3.91	0.029	0.03	20	1.37	2.69	0.42
Error (S x T)	36	120.17							

Note: All other main effects and interactions were not significant (N.S., p > 0.05).

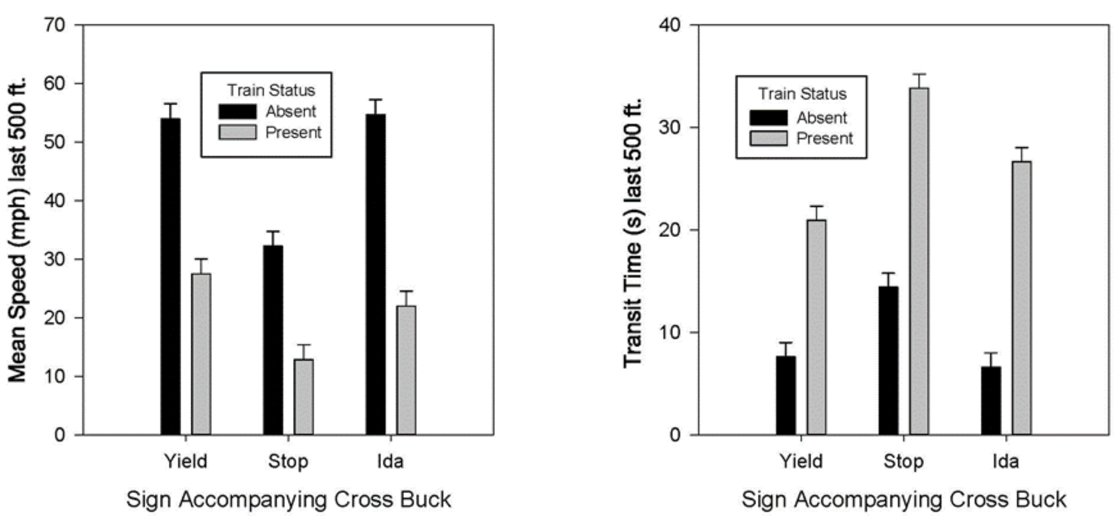

Figure 27. Mean Speeds (Left Panel) and Transit Times (Right Panel) Over the Last 500 Feet Before a Railroad Crossing as a Function of Sign Type (YIELD, STOP, IdaShield, and Train Status (Present/Absent)

Note: Error bars represent 1 se. When train is absent IdaShield is similar to YIELD sign. When train is present, IdaShield falls between STOP and YIELD signs. See text for details.

In sum, when a train is present, the IdaShield reliably lowers mean speed, increases transit time and decreases the frequency of drivers crossing ahead of the train as compared to a YIELD sign (see Figure 26 and Table 12). When the train is absent, however, the IdaShield affects behavior almost identically to a YIELD sign and differently than a STOP sign. These unexpectedly complex results suggest that Question 2.4 was overly simplistic: the IdaShield mimics neither a YIELD sign nor a STOP sign. In the presence of an oncoming train, the IdaShield provides greater warning than a YIELD sign, slowing drivers and increasing transit times both day and night. Moreover, at night, the IdaShield decreases the frequency of crossing ahead of the train. Earlier we argued that crossing ahead of the train at night was likely due to decreased visibility of the train, the railroad crossing signs, or both. The data taken as a whole therefore suggest that at night, the IdaShield serves to increase the visibility of an oncoming train, the railroad crossing signs, or both.

Summary Conclusions

- IdaShield does reliably affect driver behavior, but not in a simple and straightforward manner. Evidence from eye movements and vehicular control is inconsistent with the IdaShield having a general safety enhancement effect. Rather the effect of the IdaShield depends on the time of day and presence or absence of a train.
- There was no evidence that the IdaShield affects the pattern of eye movements directly.
- There was no evidence for additional fixations on the railroad sign cluster when IdaShield is included. In fact, few participants fixed their gaze on the sign cluster under any conditions.
- Pairing the IdaShield with a STOP sign did not enhance safety at night by drawing attention to STOP sign.
- Pairing the IdaShield with a YIELD sign enhances safety at night as compared to a YIELD sign with no IdaShield.
- Driver interpretation of IdaShield depends on whether a train is present. When no train is present, drivers respond to the IdaShield like it represents a YIELD sign. When a train is present, either daytime or nighttime, drivers show greater decreases in speed and increases in transit time for the IdaShield as compared to a YIELD sign, as well as less tendency to cross ahead of the train.

Chapter 5
Conclusions and Recommendations

Statewide, crashes were significantly decreased by 38.6 percent after the IdaShield installation and these effects were largely attributed to the IdaShield. However this decrease could not be fully attributed to the IdaShield design because the possible benefits of increased retroreflectivity (from the new IdaShield, Crossbucks, and posts) could not be separated from the effect of the IdaShield design. User assessment confirmed that drivers understand the IdaShield and feel it enhances intersection safety. Finally, driver simulation testing revealed that the IdaShield does not enhance STOP sign compliance, but it does enhance YIELD sign compliance. In addition, driver response to the IdaShield depends on whether a train is present. When no train is present, drivers respond to the IdaShield like it represents a YIELD sign. When a train is present, either day or night, drivers show greater decreases in speed and increases in transit time for the IdaShield as compared to only a YIELD sign, as well as less tendency to cross ahead of the train.

The findings from our research show that the IdaShield does positively impact safety. Average crash frequency significantly reduced after IdaShield installation. Users understood the IdaShield's purpose and most felt it improved the visibility of crossing markings. In addition, the driver simulation test indicated some positive changes in driver behavior at crossings when IdaShields are present. The crash data analysis provided the strongest evidence of the IdaShield's effect, while the user survey and driver simulation data provided more detailed understanding of this evidence by pointing to IdaShield benefits for YIELD sign traffic control.

Based on our findings, we recommend the following:

- Because the IdaShield produces positive overall outcomes on driver safety and does not have any apparent negative effects, the signage should continue to be required at crossings controlled through a YIELD sign to increase visibility and safety at passive at-grade railway crossings in Idaho.

- When combined with a STOP sign, the safety effect of IdaShield does not seem to be significant. As a result, we recommend that IdaShield signs not be required at passive at-grade railway crossings when a STOP sign is present. Guidelines to use IdaShield at crossings controlled by a stop sign should be adjusted to reflect this recommendation.

- It is recommended that ITD work with the national committees to amend the national standard for signage at public passive Railroad/Highway Grade Crossings in the MUTCD and to include the IdaShield Crossbuck as an approved object marker.

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Appendix A
IdaShield Background

Figure 28. Ohio Buckeye Crossbuck

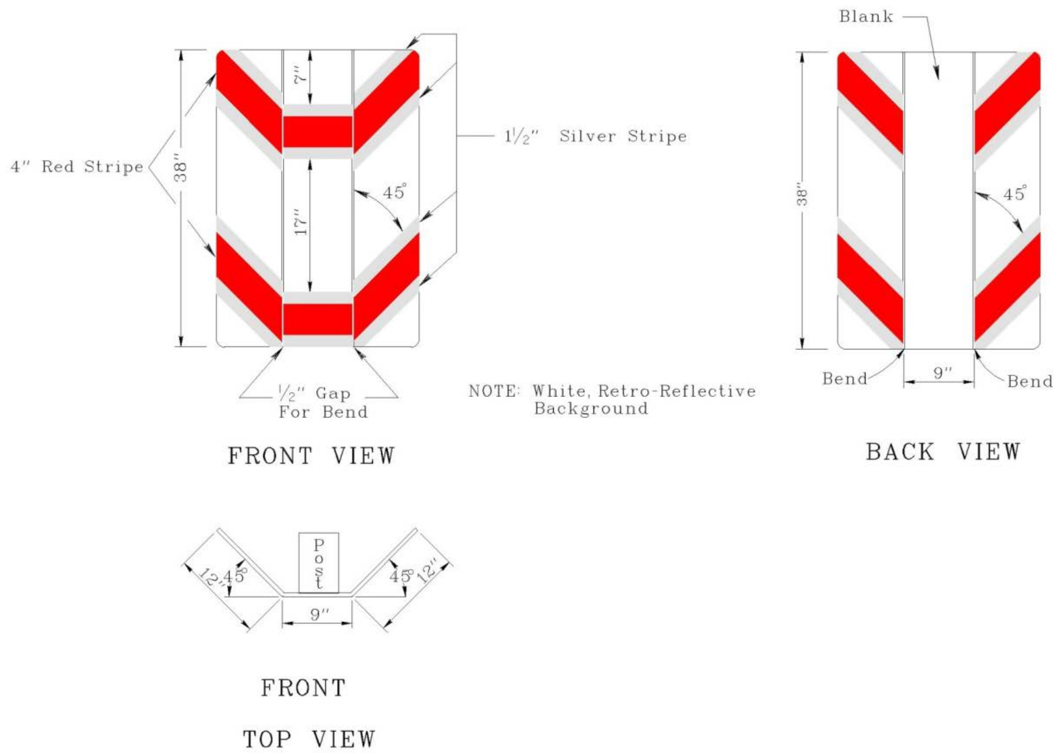


Figure 29. IdaShield Design Drawing

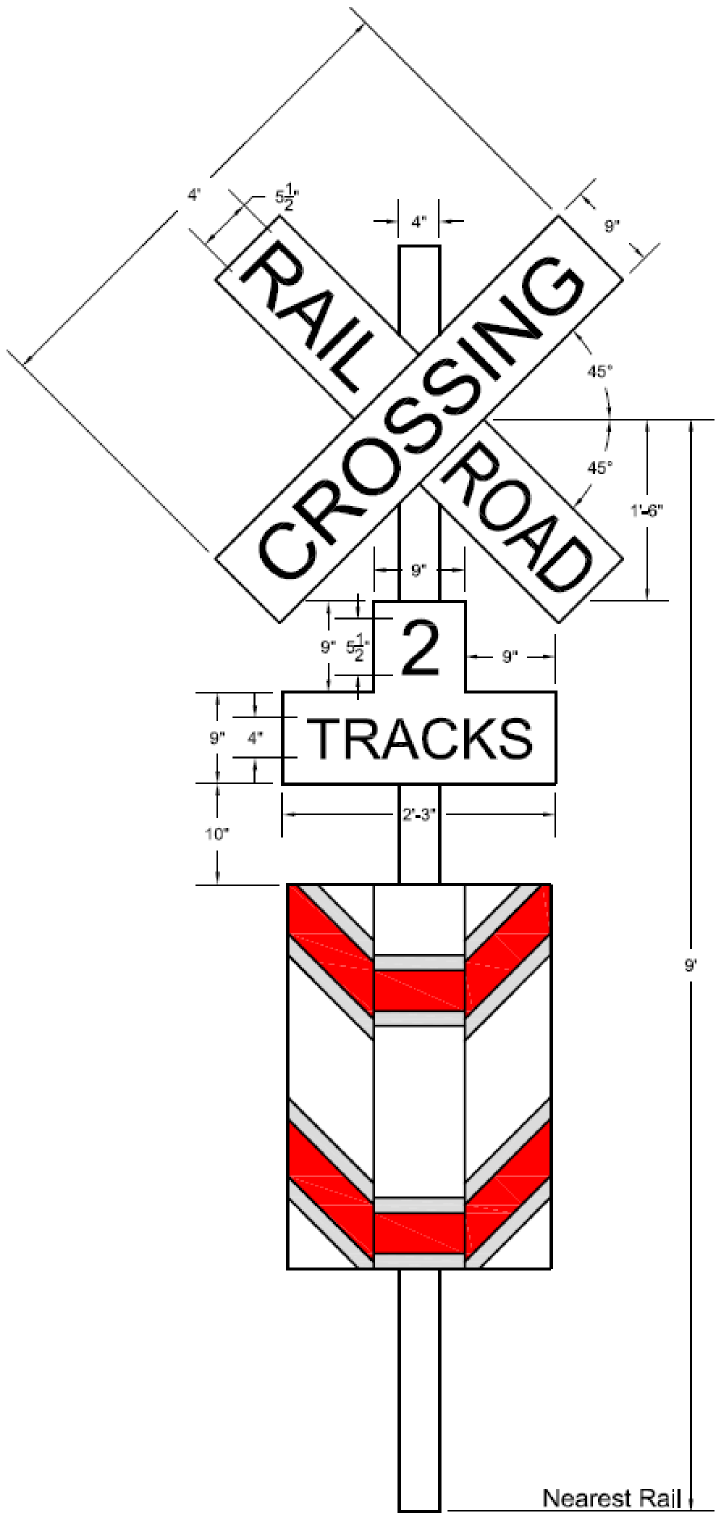


Figure 30. Crossbuck with IdaShield Design Drawing

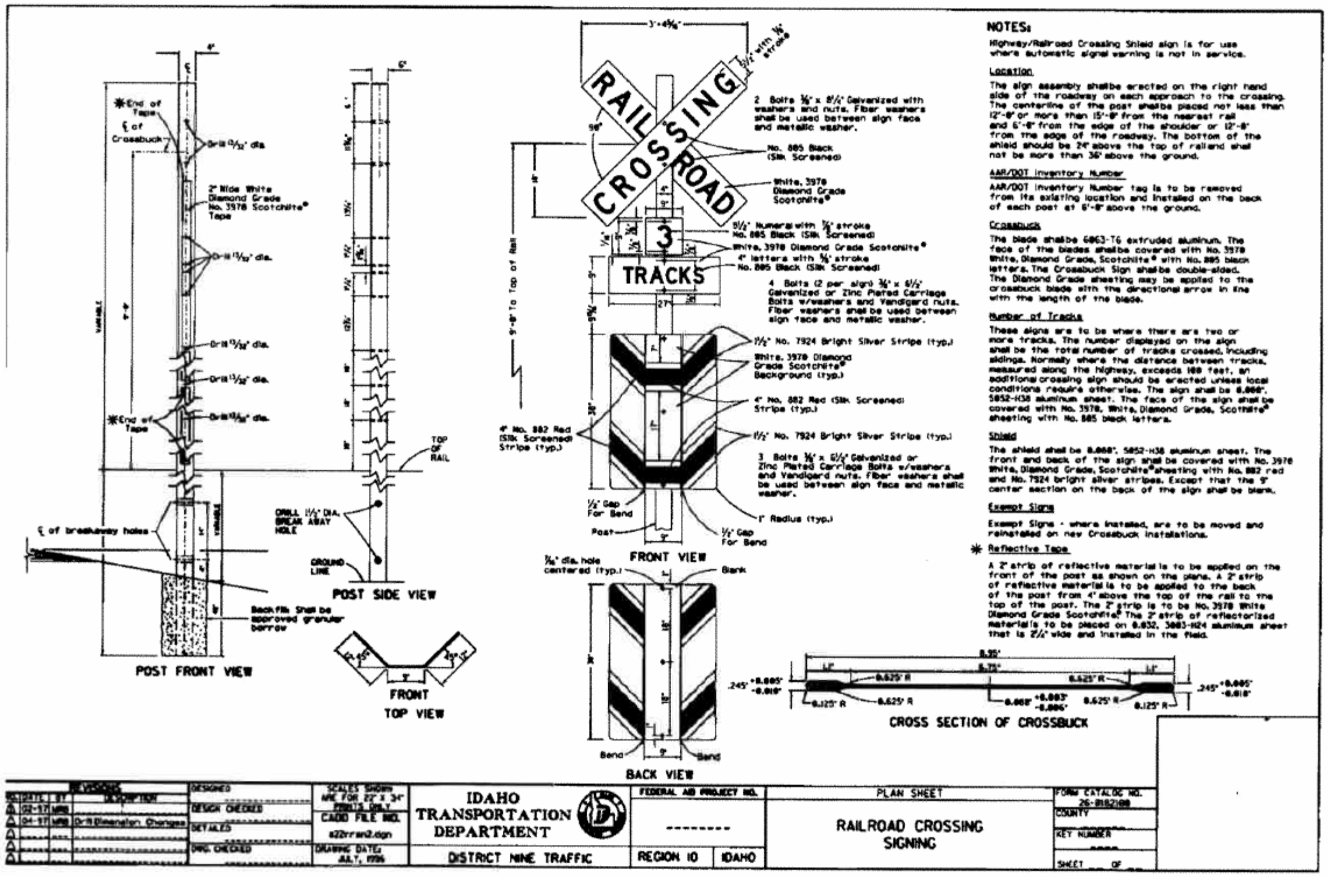


Figure 31. IdaShield Design Schematic

Appendix B
Crash Data Analysis

Data Alterations

The following changes were made to the FRA crossing inventory dataset:

- Increased DTPD (Day Trains per Day) to 0.5 for crossings with less than 1 movement per day.
- Increased NTPD (Night Trains per Day) to 0.5 for crossings with less than 1 movement per day.
- Combined reflective and non-reflective Crossbuck fields into a single XBUCK dummy variable.
- Combined standard and non-standard STOP sign fields into a single STOPSIGN dummy variable.
- Added the values of MAINTRK and OTHRTRK to create NUMTRKS variable.
- Changed data to reflect assumption that all crossings with IdaShield installed later than 1999 (as indicated by FRA records) were installed in 1999.
- Changed data to reflect assumption that all IdaShield-treatment crossings without Crossbuck treatment (as indicated by FRA records) have both Crossbucks and IdaShields.

Table 14. SPF Independent Variable Correlation Matrix

		AADT	TTPD	MAXSPD	STOPSIGN	IDASHIELD	HWYPVED	NUMTRKS
AADT	**Pearson Correlation**	1.000	-0.075**	-0.170**	-0.056**	0.037**	0.236**	0.035**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.000
TTPD	**Pearson Correlation**	-0.075**	1.000	0.708**	0.263**	0.064**	-0.165**	0.150**
	Sig. (2-tailed)	0.000		0.000	0.000	0.000	0.000	0.000
MAXSPD	**Pearson Correlation**	-0.170**	0.708**	1.000	0.415**	0.109**	-0.219**	-0.007
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.211
STOPSIGN	**Pearson Correlation**	-0.056**	0.263**	0.415**	1.000	0.243**	0.031**	-0.065**
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000
IDASHIELD	**Pearson Correlation**	0.037**	0.064**	0.109**	0.243**	1.000	0.061**	-0.016**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000		0.000	0.004
HWYPVED	**Pearson Correlation**	0.236**	-0.165**	-0.219**	0.031**	0.061**	1.000	0.058**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000		0.000
NUMTRKS	**Pearson Correlation**	0.035**	0.150**	-0.007	-0.065**	-0.016**	0.058**	1.000
	Sig. (2-tailed)	0.000	0.000	0.211	0.000	0.004	0.000	

Table 15. SPF Dataset Summary

Year	Crossbucks	STOP Signs	IdaShields	Total Crossings
1980	1,246	309	0	1,252
1981	1,256	313	0	1,262
1982	1,270	315	0	1,276
1983	1,307	322	0	1,313
1984	1,329	331	0	1,334
1985	1,276	330	0	1,281
1986	1,227	327	0	1,232
1987	1,217	332	0	1,222
1988	1,178	329	0	1,182
1989	1,157	406	0	1,161
1990	1,152	402	0	1,155
1991	1,202	431	0	1,205
1992	1,186	431	0	1,189
1993	1,147	455	0	1,149
1994	1,122	446	0	1,123
1995	1,099	489	1	1,100
1996	1,088	525	1	1,089
1997	1,003	488	2	1,003
1998	979	481	15	979
1999	975	495	837	975
2000	971	499	837	971
2001	971	499	837	971
2002	936	494	833	936
2003	927	496	833	927
2004	907	496	829	907
2005	901	496	825	901
2006	901	492	825	901
2007	900	489	824	900
2008	900	489	824	900
2009	898	489	822	898
2010	892	489	816	892
2011	891	503	816	891

Appendix C
User Acceptance Survey

Full Tabular Results

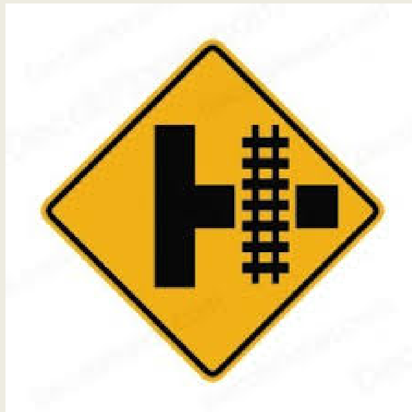
Table 16. Responses to Highway User Survey Question 1

Question 1. Please identify this road sign by selecting an option below.

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
No Entrance	1	0.3	0.3%	0.0% - 1.0%
Merging Traffic	289	99.0	0.6%	97.8% - 100.0%
YIELD	2	0.7	0.5%	0.0% - 1.6%
Three-Way Intersection	0	0.0	0.0%	0.0% - 0.0%
Total	292	100.0		

Table 17. Responses to Highway User Survey Question 2

Question 2. Please identify this road sign by selecting an option below.



	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Railroad Crossing	26	8.9	1.6	5.9% - 12.1%
Three-Way Intersection	1	0.3	0.3	0.0% - 1.0%
Merging Traffic	1	0.3	0.3	0.0% - 1.0%
Side Road with Railroad Crossing	265	90.4	1.7	87.0% - 93.8%
Total	293	100.0		

Table 18. Responses to Highway User Survey Question 3

Question 3. Please identify this road sign by selecting an option below.

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Railroad Crossing	291	99.7	0.3	98.9% - 100.0%
STOP	1	0.3	0.3	0.0% - 1.0%
Intersection Ahead	0	0.0	0.0	0.0% - 0.0%
YIELD	0	0.0	0.0	0.0% - 0.0%
Total	292	100.0		

Table 19. Responses to Highway User Survey Question 4

Question 4. Please identity this road sign by selecting an option below.

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Three Way Intersection	9	3.0%	1.0%	1.0% - 5.0%
No Entrance	0	0.0%	0.0%	0.0% - 0.0%
Merging Traffic	1	0.3%	0.3%	0.0% - 1.0%
Traffic Circle Ahead	281	96.7%	1.05%	94.4% - 98.6%
Total	291	100.0%		

Table 20. Responses to Highway User Survey Question 5

Question 5. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	13	8.5%	2.2%	4.0% - 13.0%
Continue with the Same Speed	1	0.8%	0.6%	0.0% - 1.9%
Look for Trains & Use Caution	135	88.8%	2.5%	83.7% - 93.88%
STOP	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	3	1.9%	1.1%	0.0% - 4.2%
Total	152	100.0%		

Table 21. Responses to Highway User Survey Question 6

Question 6. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	3	2.0%	1.4%	0.0% – 4.2%
Slow Down	6	4.0%	1.6%	0.8% - 7.1%
STOP	140	93.3%	2.0%	89.2% - 97.3%
Speed Up	1	0.7%	0.6%	0.0% - 1.9%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	150	100.0%		

Table 22. Responses to Highway User Survey Question 7

Question 7. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	0	0.0%	0.0%	0.0% - 0.0%
Continue With the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	5	3.3%	1.4%	0.4% - 6.3%
STOP	142	95.9%	1.6%	92.7% - 99.1%
I Do Not Know	1	0.8%	0.6%	0.0% - 2.0%
Total	148	100.0%		

Table 23. Responses to Highway User Survey Question 8

Question 8. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	0	0.0%	0.0%	0.0% - 0.0%
STOP	145	99.3%	0.6%	97.9% - 100%
Speed Up	1	0.7%	0.6%	0.0% - 2.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	146	100.0%		

Table 24. Responses to Highway User Survey Question 9

Question 9. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	2	1.3%	0.9%	0.0% – 3.1%
Slow Down	8	5.3%	1.8%	1.6% - 8.9%
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	140	93.4%	2.0%	89.2% - 97.3%
STOP	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	150	100.0%		

Table 25. Responses to Highway User Survey Question 10

Question 10. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	1	0.8%	0.6%	0.0% - 2.0%
Slow Down	10	6.7%	2.0%	2.6% - 10.8%
STOP	137	92.5%	2.1%	88.2% - 96.8%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	148	100.0%		

Table 26. Responses to Highway User Survey Question 11

Question 11. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	1	0.6%	0.6%	0.0% - 31.9%
Continue with the Same Speed	1	0.6%	0.6%	0.0% - 1.9%
Look for Trains & Use Caution	4	2.6%	1.3%	0.5% - 5.2%
STOP	145	96.2%	1.5%	92.8% - 99.1%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	151	100.0%		

Table 27. Responses to Highway User Survey Question 12

Question 12. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	3	1.6%	1.1%	0.0% - 4.2%
STOP	145	96.5%	1.5%	92.8% - 99.1%
Speed Up	1	0.6%	0.6%	0.0% - 1.9%
I Do Not Know	2	1.3%	0.9%	0.0% - 3.1%
Total	151	100.0%		

Table 28. Responses to Highway User Survey Question 13

Question 13. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	4	2.6%	1.3%	0.0% - 5.2%
Continue with the Same Speed	4	2.6%	1.3%	0.0% - 5.2%
Look for Trains & Use Caution	140	92.9%	2.1%	88.5% - 96.9%
STOP	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	3	1.9%	1.1%	0.0% - 4.2%
Total	151	100.0%		

Table 29. Responses to Highway User Survey Question 14

Question 14. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	2	1.3%	0.9%	0.0% - 3.1%
Slow Down	9	5.9%	1.9%	2.1% - 9.7%
STOP	138	90.9%	2.3%	86.1% - 95.4%
Speed Up	2	1.3%	0.9%	0.0% - 3.1%
I Do Not Know	1	0.6%	0.6%	0.0% - 1.9%
Total	152	100.0%		

Table 30. Responses to Highway User Survey Question 15

Question 15. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	7	5.8%	2.1%	1.5% - 10.0%
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	108	90.1%	2.7%	84.5% - 95.4%
STOP	5	4.1%	1.8%	0.5% - 7.7%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	120	100.0%		

Table 31. Responses to Highway User Survey Question 16

Question 16. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	3	2.5%	1.4%	0.0% - 5.4%
STOP	116	97.5%	1.4%	94.6% - 100.0%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	120	100.0%		

Table 32. Responses to Highway User Survey Question 17

Question 17. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	0	0.0%	0.0%	0.0% - 0.0%
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	8	6.7%	2.3%	2.1% - 11.3%
STOP	110	93.3%	2.3%	88.6% - 97.8%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	118	100.0%		

Table 33. Responses to Highway User Survey Question 18

Question 18. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	1	0.8%	0.8%	0.0% - 2.5%
STOP	117	99.2%	0.8%	97.4% - 100%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	118	100.0%		

Table 34. Responses to Highway User Survey Question 19

Question 19. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	5	4.1%	1.8%	0.5% - 7.7%
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	111	91.8%	2.5%	86.7% - 96.7%
STOP	4	3.3%	1.6%	0.0% - 6.5%
I Do Not Know	1	0.8%	0.8%	0.0% - 2.4%
Total	121	100.0%		

Table 35. Responses to Highway User Survey Question 20

Question 20. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	1	0.8%	0.8%	0.0% - 2.5%
Slow Down	1	0.8%	0.8%	0.0% - 2.5%
STOP	117	98.4%	1.1%	95.9% - 100%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	119	100.0%		

Table 36. Responses to Highway User Survey Question 21

Question 21. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	3	2.4%	1.4%	0.0% - 5.2%
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Look for Trains & Use Caution	9	7.3%	2.3%	2.6% - 12.0%
STOP	110	90.3%	2.7%	84.8% - 95.5%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	122	100.0%		

Table 37. Responses to Highway User Survey Question 22

Question 22. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	0	0.0%	0.0%	0.0% - 0.0%
STOP	122	100.0%	0.0%	100%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	122	100.0%		

Table 38. Responses to Highway User Survey Question 23

Question 23. If you approached an intersection such as the following, what action should you take?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
Slow Down	6	5.0%	1.9%	1.0% - 8.9%
Continue with the Same Speed	1	0.8%	0.8%	0.0% - 2.4%
Look for Trains & Use Caution	107	90.9%	2.8%	83.5% - 94.8%
STOP	4	3.3%	1.6%	0.0% - 6.5%
I Do Not Know	2	1.6%	1.1%	0.0& - 3.9%
Total	120	100.0%		

Table 39. Responses to Highway User Survey Question 24

Question 24. If you approach this point and simultaneously notice a train is approaching, what would you do?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue with the Same Speed	1	0.8%	0.8%	0.0% -2.5%
Slow Down	6	5.0%	2.0%	1.1% - 9.0%
STOP	112	94.2%	2.2%	89.8% - 98.4%
Speed Up	0	0.0%	0.0%	0.0% - 0.0%
I Do Not Know	0	0.0%	0.0%	0.0% - 0.0%
Total	120	100.0%		

Table 40. Responses to Highway User Survey Question 25

Question 25.In terms of driver adherence, the crossbuck sign is similar to a _____________ at some road Intersections.

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
STOP Sign	33	12.7%	2.0%	8.6% - 16.8%
YIELD SIgn	185	71.6%	2.8%	65.8% - 76.9%
One Way Sign	3	1.1%	0.6%	0.0% - 2.4%
Do Not Enter Sign	38	14.6%	2.2%	10.3% - 19.0%
Total		100.0%		

Table 41. Responses to Highway User Survey Question 26

Question 26. If you are approaching a railroad crossing that is not controlled by any signals, gates, or flashing lights, you should….

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Continue Driving Normally, as Trains Rarely Pass Through that Crossing	10	3.7%	1.1%	1.4% - 6.0%
Be Extra Cautious & Slow Down, as Trains May Approach at Anytime	256	96.0%	1.2%	93.4% - 98.2%
Speed Up & Cross the Tracks as Soon as Possible, as Trains May Approach at Anytime	1	0.3%	0.3%	0.0% - 1.1%
Avoid Driving Through Such Crossings	0	0.0%	0.0%	0.0% - 0.0%
Total	267	100.0%		

Table 42. Responses to Highway User Survey Question 27

Question 27. When you see the following highway markers it means:

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
You are Driving on a Road that Runs Parallel to a Railroad	2	0.7%	0.5%	0.0% - 1.7%
YIELD	0	0.0%	0.0%	0.0% - 0.0%
You are Approaching an Inactive Railroad Crossing, Therefore Keep Driving Without Hesitation	2	0.7%	0.5%	0.0% - 1.7%
You are Approaching a railroad crossing, Use caution	213	79.9%	2.4%	74.9% - 84.6%
No Entrance	0	0.0%	0.0%	0.0% - 0.0%
You are Approaching a Railroad Crossing which is Not Controlled By Any Signals, Flashing Lights, Or Gates	47	17.6%	2.3%	13.0% - 22.2%
I Am Not Sure	3	1.1%	0.6%	0.0% - 2.3%
Total	267	100.0%		

Table 43. Responses to Highway User Survey Question 28

Question 28. All drivers should be aware that the following vehicles must stop at a railroad crossing before proceeding:				
	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
School Buses, Passenger Buses, & Trucks Carrying Hazardous Materials	265	99.7%	0.3%	98.8% - 100%
Motorcycles, Mopeds, & Bicycles	0	0.0%	0.0%	0.0% - 0.0%
Ambulances & Fire Engines	0	0.0%	0.0%	0.0% - 0.0%
None of the Above	1	0.3%	0.3%	0.0% - 1.1%
Total	266	100.0%		

Table 44. Responses to Highway User Survey Question 29

Question 29. Please take a moment to view this railroad crossing:

Which sign did you notice first?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Yield Sign	185	70.1%	2.8%	64.5% - 75.6%
Crossbuck	79	29.9%	2.8%	24.3% - 35.4%
Total	264	100.0%		

Table 45. Responses to Highway User Survey Question 30

Question 30. Please take a moment to view this second railroad crossing:

Which sign did you notice first?

	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
YIELD Sign	165	62.2%	2.9%	65.3% - 68.1%
Crossbuck	100	37.7%	2.9%	31.8% - 43.6%
Total	265	100.0%		

Table 46. Responses to Highway User Survey Question 31

Question 31. How many years of driving experience do you have?				
	Frequency	**Percentage**	**Standard Error**	**95% Confidence Limits for Percent**
Between 0 - 5 yrs	5	1.9%	0.8%	0.2% - 3.6%
Between 5 and 10 yrs	8	3.0%	1.1%	1.0% - 5.1%
Between 10 and 20 yrs	28	10.6%	1.9%	6.9% - 14.4%
Between 20 and 30 yrs	42	16.0%	2.3%	11.5% - 20.4%
Between 30 and 40 yrs	63	24.0%	2.6%	18.8% - 29.1%
More than 40 yrs	117	44.5%	3.1%	38.4% - 50.5%
Total	263	100.0%		

Table 47. Responses to Highway User Survey Question 32

Question 32. What type of vehicle do you drive most often?				
	Frequency	**Percentage**	**Standard Error**	**95% Confidence Limits for Percent**
Car	133	50.1%	3.0%	44.1% - 56.2%
Van	15	5.6%	1.4%	2.8% - 8.4%
Sport Utility Vehicle (SUV)	67	25.2%	2.6%	20.0% - 30.7%
Truck	48	18.1%	2.3%	13.4% - 22.7%
Motorcycle	2	0.7%	0.5%	0.0% - 1.8%
Total	265	100.0%		

Table 48. Responses to Highway User Survey Question 33

Question 33. Are the majority of your driving miles on…				
	Frequency	**Percentage**	**Standard Error**	**95% Confidence Limits for Percent**
City Streets	117	44.3%	3.0%	38.2% - 50.3%
Rural Roads	51	19.3%	2.4%	14.5% - 24.8%
Highways	93	35.2%	2.9%	29.4% - 41.0%
Other	3	1.1%	0.6%	0.0% - 2.4%
Total	264	100.0%		

Table 49. Responses to Highway User Survey Question 34

Question 34. What is the highest level of education that you have received?				
	Frequency	**Percentage**	**Standard Error**	**95% Confidence Limits for Percent**
Some High School, No Diploma	5	1.9%	0.9%	0.2% - 3.6%
High School Graduate or GED	22	8.4%	1.7%	5.0% - 11.8%
Some College or Vocational Degree	79	30.3%	2.8%	24.7% - 35.9%
Associate's Degree	31	11.9%	2.0%	7.9% - 15.8%
Bachelor's Degree	82	31.4%	2.9%	25.7% - 37.1%
Graduate or Professional Degree	42	16.1%	2.3%	11.6% - 20.6%
Total	261	100.0%		

Table 50. Responses to Highway User Survey Question 35

Question 35. What is your gender?				
	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Female	141	53.8%	3.0%	47.7% -59.8%
Male	121	16.1%	3.0%	40.1% - 52.2%
Total	262	100.0%		

Table 51. Responses to Highway User Survey Question 36

Question 36. Approximately how many miles do you drive each week?				
	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
Between 0 and 25	22	8.4%	1.7%	5.0% - 11.8%
Between 25 and 50	49	18.7%	2.4%	13.9% - 23.5%
Between 50 and 75	26	9.9%	1.9%	6.3% - 13.6%
Between 75 and 100	53	20.2%	2.5%	15.3% - 25.1%
Between 100 and 150	24	9.2%	1.8%	5.6% - 12.7%
Between 150 and 200	40	15.3%	2.2%	10.9% - 19.7%
More than 200	48	18.3%	2.4%	13.6% - 23.0%
Total	262	100.0%		

Table 52. Responses to Highway User Survey Question 37 - 1

Question 37. In what year were you born?				
	Frequency	Percentage	Standard Error	95% Confidence Limits for Percent
18 – 19	2	0.7%	0.5%	0.0% - 1.8%
20 – 24	10	3.8%	1.2%	1.5% - 6.2%
25 – 34	25	9.6%	1.8%	6.0% - 13.3%
35 – 44	38	14.7%	2.2%	10.3% - 19.0%
45 – 54	46	17.9%	2.3%	13.1% - 22.5%
55 – 59	34	13.2%	2.1%	9.0% - 17.3%
60 - 64	31	12.0%	2.0%	8.0% - 16.0%
65 – 74	65	25.3%	2.7%	19.8% - 30.5%
75 - 84	7	2.7%	1.0%	0.7% - 4.7%
85 or Older	0	0.0%	0.0%	0.0% - 0.0%
Total	258	100.0%		

Table 53. Responses to Highway User Survey Question 37 - 2

Question 37. In what year were you born?				
	Frequency	**Percentage**	**Standard Error**	**95% Confidence Limits for Percent**
18 – 34	37	14.3%	2.1%	10.0% - 18.6%
35 – 44	38	14.7%	2.2%	10.3% - 19.0%
45 – 54	46	17.9%	2.3%	13.1% - 22.5%
55 – 64	65	25.2%	2.7%	19.8% - 30.5%
65 – 74	65	25.2%	2.7%	19.8% - 30.5%
75 or Older	7	2.7%	1.0%	0.7% - 4.7%
Total	258	100.0%		

Table 54. Responses to Highway User Survey Question 38

County	Frequency	Percentage	Standard Error (percentage)	95% Confidence Limits		County	Frequency	Percentage	Standard Error (percentage)	95% Confidence Limits
Ada	75	29.1	2.8	23.5 - 34.6		**Gem**	2	0.8	0.5	0.0 - 1.2
Adams	0	0.0	0.0	0.0 - 0.0		**Gooding**	0	0.0	0.0	0.0 - 0.0
Bannock	12	4.7	1.3	2.1 - 7.2		**Idaho**	0	0.8	0.5	0.0 - 1.9
Bear Lake	2	0.4	0.4	0.0 - 1.2		**Jefferson**	3	1.2	0.7	0.0 - 2.5
Benewah	2	0.8	0.5	0.0 - 1.9		**Jerome**	6	2.3	0.9	0.5 - 4.2
Bingham	14	0.8	0.5	0.0 - 1.9		**Kootenai**	18	7.0	1.6	3.8 - 10.1
Blaine	3	5.4	1.4	2.6 - 8.2		**Latah**	13	5.0	1.4	2.4 - 7.7
Boise	7	1.2	0.7	0.0 - 2.5		**Lemhi**	0	0.0	0.0	0.0 0.0
Bonner	20	2.7	1.0	0.7 - 4.7		**Lewis**	1	0.4	0.4	0.0 1.2
Bonneville	2	7.8	1.7	4.5 - 11.0		**Lincoln**	0	0.0	0.0	0.0 0.0
Boundary	1	0.8	0.5	0.0 - 1.9		**Madison**	4	1.6	0.8	0.0 - 3.1
Butte	20	0.4	0.4	0.0 - 1.2		**Minidoka**	3	1.2	0.7	0.0 - 2.5
Camas	0	0.0	0.0	0.0 - 0.0		**Nez Perce**	9	3.5	1.1	1.2 - 5.7
Canyon	2	7.8	1.7	4.5 - 11.0		**Oneida**	0	0.0	0.0	0.0 - 0.0
Caribou	1	0.8	0.5	0.0 - 1.9		**Owyhee**	1	0.4	0.4	0.0 - 1.2
Cassia	2	0.4	0.4	0.0 - 1.2		**Payette**	1	0.4	0.4	0.0 - 1.2
Clark	0	0.0	0.0	0.0 - 0.0		**Power**	1	0.4	0.4	0.0 - 1.2
Clearwater	2	0.8	0.5	0.0 - 1.9		**Shoshone**	3	1.2	0.7	0.0 - 2.5
Custer	3	0.8	0.5	0.0 - 1.9		**Teton**	1	0.4	0.4	0.0 - 1.2
Elmore	1	1.2	0.7	0.0 - 2.5		**Twin Falls**	10	3.9	1.2	1.5 - 6.2
Franklin	1	0.4	0.4	0.0 - 1.2		**Valley**	5	1.9	0.9	0.2 - 3.6
Fremont	1	0.4	0.4	0.0 - 1.2		**Washington**	5	1.9	0.9%	0.2 - 3.6

Comparison to Census Data

In order to determine sample representativeness, we compared the age, education, and county distributions of adults (over 18) from the respondents in the web survey to the percent of adults over age 18 in the State of Idaho as estimated in the 2007 - 2011 American Community Survey (ACS) by the U.S. Census Bureau.[(21)] As shown in Table 55, when the Census figures are compared to the 95 percent confidence intervals of the sample estimates, the youngest residents are underrepresented, middle aged respondents are appropriately represent, and the older age groups are overrepresented.

Table 55. Comparison of Sample Estimates to ACS Age Estimates for Idaho Residents

Age Category	Census (percentage)	Total Sample (percentage)	95% Confidence Limits
18 – 19 Years Old	4.1	0.7	0.0% - 1.9%
20 – 24 Years Old	9.7	3.8	1.5% - 6.2%
25 – 34 Years Old	18.3	9.6	6.0% - 13.3%
35 – 44 Years Old	17.1	14.7	10.3% - 19.1%
45 – 54 Years Old	18.4	17.8	13.1% - 22.5%
55 – 59 Years Old	8.4	13.1	9.0% - 17.3%
60 – 64 Years Old	7.1	12.0	8.0% - 16.0%
65 – 74 Years Old	9.4	25.1	19.8% - 30.5%
75 – 84 Years Old	5.3	2.7	0.7% - 4.7%
Over 85 Years Old	2.1	0.0	0.0% - 0.0%

When the Census figures are compared to the 95 percent confidence intervals of the sample estimates, the residents with lower levels of education are underrepresented and the residents with higher levels of education are overrepresented (see Table 56).

Table 56. Comparison of Sample Estimates to ACS Education Estimates for Idaho Residents

Education Category	Census (percentage)	Total Sample (percentage)	95% Confidence Limits
Less Than 12th Grade	11.6	1.9	0.2% - 3.6%
High School Graduate	28.4	8.4	5.0% - 11.8%
Some College	26.9	30.3	24.7% - 35.9%
Associates	8.6	11.9	7.9% - 15.8%
Bachelors	16.9	31.4	25.7% - 35.9%
Graduate	7.6	16.1	11.6% - 20.6%

When the Census figures are compared to the 95 percent confidence intervals of the sample estimates, generally each county is accurately represented in the study sample.

Table 57. Comparison of Sample Estimates to ACS Population County Estimates for Idaho Residents

County	Census (percentage)	Sample (percentage)	95% Confidence Limits		County	Census (percentage)	Sample (percentage)	95% Confidence Limits
Ada	25.0	29.1	23.5% - 34.6%		Gem	1.1	0.4	0.0% - 1.2%
Adams	0.3	0.0	0.0% - 0.0%		Gooding	1.0	0.0	0.0% - 0.0%
Bannock	5.3	4.7	2.1% - 7.2%		Idaho	1.0	0.8	0.0% - 1.9%
Bear Lake	0.4	0.4	0.0% - 1.2%		Jefferson	1.6	1.2	0.0% - 2.5%
Benewah	0.6	0.8	0.0% - 1.9%		Jerome	1.4	2.3	0.5% - 4.2%
Bingham	2.9	0.8	0.0% - 1.9%		Kootenai	8.9	7.0	3.8% - 10.1%
Blaine	1.4	5.4	2.6% - 8.2%		Latah	2.4	5.0	2.4% - 7.7%
Boise	0.5	1.2	0.0% - 2.5%		Lemhi	0.5	0.0	0.0%- 0.0%
Bonner	2.6	2.7	0.7% - 4.7%		Lewis	0.2	0.4	0.0% - 1.2%
Bonneville	6.6	7.8	4.5% - 11.0%		Lincoln	0.3	0.0	0.0% - 0.0%
Boundary	0.7	0.8	0.0% - 1.9%		Madison	2.4	1.6	0.0% - 3.1%
Butte	0.2	0.4	0.0% - 1.2%		Minidoka	1.3	1.2	0.0% - 2.5%
Camas	0.1	0.0	0.0% - 0.0%		Nez Perce	2.5	3.5	1.2% - 5.7%
Canyon	12.0	7.8	4.5% - 11.0%		Oneida	0.3	0.0	0.0% - 0.0%
Caribou	0.4	0.8	0.0% - 1.9%		Owyhee	0.7	0.4	0.0% - 1.2%
Cassia	1.5	0.4	0.0% - 1.2%		Payette	1.5	0.4	0.0% - 1.2%
Clark	0.1	0.0	0.0% - 0.0%		Power	0.5	0.4	0.0% - 1.2%
Clearwater	0.6	0.8	0.0% - 1.9%		Shoshone	0.8	1.2	0.0% - 2.5%
Custer	0.3	0.8	0.0% - 1.9%		Teton	0.6	0.4	0.0% - 1.2%
Elmore	1.7	1.2	0.0% - 2.5%		Twin Falls	4.9	3.9	1.5% - 6.2%
Franklin	0.8	0.4	0.0% - 1.2%		Valley	0.6	1.9	0.2% - 3.6%
Fremont	0.8	0.4	0.0% - 1.2%		Washington	0.7	1.9	0.2% - 3.6%

Although older and more educated individuals are over represented in this sample, the results of this survey are generally homogenous (in most cases over 8 percent and in a few cases over 90 percent).

Addressing Response Bias

To ensure bias is not present in any of these cases we ran cross tabulations to check for differences in response between those who were under represented, adequately represented, or over represented. Cross tabulations were conducted using Fisher's Exact Test. When comparing age, 3 questions contained statistically significant differences (see Tables 58 - 60). When comparing education, 4 questions contained statistically significant differences (see Table 58 - 59, 61 - 62).

Respondents were shown several Idaho road signs and asked to identify the meaning. When shown a Traffic Circle respondents could choose 1 of 4 possible meanings: "Three-Way Intersection", "No Entrance", "Merging Traffic", and "Traffic Circle Ahead". A statistically significant relationship was found between age and Traffic Circle sign comprehension (chi-square p-value = 0.0421). Older drivers are slightly less likely to identify a Traffic Circle sign to mean "Three-Way Intersection." Although younger drivers are more likely to identify it this way, the large majority of all types of respondents identify the sign to mean "Traffic Circle Ahead." This relationship, though significant, does not greatly affect the survey outcome.

Table 58. Age and Education by Traffic Circle Sign

Question. "Please identify this road sign by selecting an option below?", crossed by "What year were you born?" and "What is the highest level of education that you have received?"

	3-Way Intersection (percentage)	No Entrance (percentage)	Merging Traffic (percentage)	Traffic Circle Ahead (percentage)
Age				
Under 35 Years Old	5.4	0.0	0.0	94.6
Between 35 & 54 Years Old	4.4	0.0	0.0	95.7
Over 54 Years Old	0.0	0.0	1.0	99.0
Education				
High School Diploma or Less	8.5	0.0	0.0	91.5
Some College or Associate's Degree	3.7	0.0	0.0	96.3
Bachelor's Degree or More	0.0	0.0	1.8	99.2

A significant relationship was also found between respondent education level and Traffic Circle comprehension (chi-square p-value = 0.0042). Drivers with lower levels of education are slightly more likely to identify a “Traffic Circle” sign to mean “Three-Way Intersection.” The large majority (over 90 percent) of all types of respondents identify the sign to mean “Traffic Circle Ahead.” This relationship, though significant, does not greatly affect the results of the survey.

Respondents were also shown several railroad signage scenarios (in daytime or nighttime) and were asked “If You Approached an Intersection Such as the Following What Action Should You Take?” Respondents were able to choose one of the following options:

- Look for Trains and Use Caution
- Slow Down
- Speed Up
- Continue with the Same Speed
- Stop
- I Don’t Know

When shown a scenario with daytime scenario with a Crossbuck and YIELD sign, younger residents are more likely to respond to a by selecting “Slow Down.” Although younger drivers are more likely to respond this way, the majority of all types of respondents would respond by “Look for Trains and Use Caution.” This relationship, though significant (chi-square p-value = 0.0224), does not change the overall results for this scenario.

Table 59. Age and Education by Crossbuck + YIELD + Daytime, No Train Approaching

Questions. “If you approached an intersection such as the following, what action would you take?” by “What year were you born?” and “What level of education do you have?”

	Speed Up (percentage)	Look for Trains & Use Caution (percentage)	Slow Down (percentage)	STOP (percentage)	Continue with the Same Speed (percentage)
Age					
Under 35 Years Old	3.1	81.3	15.6	0.0	0.0
Between 35 & 54 Years Old	1.6	96.8	1.6	0.0	0.0
Over 54 Years Old	0.0	96.4	3.6	0.0	0.0
Education					
High School Diploma or Less	9.1	90.9	0.0	0.0	0.0
Some College or Associate's Degree	0.0	96.4	3.6	0.0	0.0
Bachelor's Degree or More	0.0	91.7	8.3	0.0	0.0

In the same daytime scenario with a Crossbuck and YIELD sign, drivers with lower levels of education are slightly more likely (chi-square p-value = 0.038) than other drivers to “Speed Up.” While younger drivers are more likely to select "Speed Up" the majority (about 90 percent) selected "Look for Trains and Use Caution." The relationship between age and response to this scenario does not greatly change the results of the survey.

Drivers were also shown an intersection with a YIELD and Crossbuck without an IdaShield, then with an IdaShield. Each respondent was asked which sign they noticed first. Younger drivers are less likely to report noticing the Crossbuck first in the scenario where the IdaShield was not present. While there is a significant relationship between age and response, the majority respondents of younger drivers reported noticing the YIELD sign first.

Table 60. Age by IdaShield - Not Present

Questions. "In the scenario below, which sign did you notice first?" by "What year were you born?"

	YIELD Sign (percentage)	Crossbuck (percentage)
Under 35 Years Old	83.3	16.7
Between 35 and 54 Years Old	73.0	27.0
Over 54 Years Old	60.4	39.6
Fisher's Exact Test p = 0.0108		

Also, drivers with lower levels of education were more likely to report noticing the Crossbuck first in the scenario where the IdaShield was present. Although there is a statistically significant relationship between education level and response, it is not great enough to significantly influence survey results.

Table 61. Education by IdaShield - Present

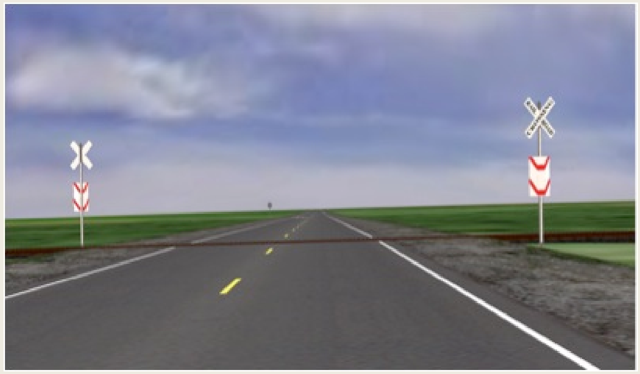
Questions. “In the scenario below, which sign did you notice first?” by “What is the highest level of education that you have received?”

	YIELD Sign (percentage)	Crossbuck (percentage)
High School Diploma or Less	43.80	56.30
Some College or Associate's Degree	68.20	31.80
Bachelor's Degree or More	61.80	38.20
Fisher’s Exact Test p = 0.0434		

When respondents were shown a highway-rail crossing daytime scenario of a Crossbuck with an IdaShield drivers with lower levels of education were slightly less likely to respond with “STOP”. While a significant relationship exists between age and response to this scenario, it does not greatly change the results of the survey considering the majority of younger drivers selected “STOP”.

Table 62. Education by Crossbuck-IdaShield-Daytime, No Train Approaching

Questions. "If you approached an intersection such as the following, what action would you take?' by "What is the highest level of education that you have received?"



	Continue With the Same Speed (percentage)	Slow Down (percentage)	STOP (percentage)	Look for Trains and Use Caution (percentage)	Speed Up (percentage)	I Don't Know (percentage)
High School Diploma or Less	4.6	4.6	86.4	4.6	0.0	0.0
Some College or Associate's Degree	0.0	0.0	100.0	0.0	0.0	0.0
Bachelor's Degree or More	0.0	0.0	95.9	4.1	0.0	0.0
Fisher's Exact Test p = 0.0208						

Appendix D
First Email Invitation

September 9th, 2013

The University of Idaho's Social Science Research Unit would like to thank you for agreeing to participate in a survey that we are conducting with the Idaho Transportation Department. We need Idaho residents like you to provide insight and experience on how to best manage Idaho's highways.

Your response to this survey is very important and will help in shaping future maintenance and management decisions. As a part of this survey we are also asking you about how you might respond to different highway management changes.

This is a short survey and should take no more than twelve minutes to complete. Please click on the link below to go to the survey website. Your Login ID and password should already be entered when you arrive at the site.

Your participation in this survey is voluntary and all of your responses will be kept confidential. The unique URL you have received will help us in removing you from the list once you have completed the survey. No personally identifiable information will be associated with your responses in any reports of this data. Should you have any further questions or comments please feel free to contact me at mareyna@uidaho.edu or 877-542-3019.

We appreciate your time and consideration in completing the survey. It is only through the help of Idaho residents like you that we can provide information to help guide the policies and practices of public organizations like the Idaho Transportation Department.

Many thanks,

Monica Reyna
Research Associate
Social Science Research Unit
Agricultural Economics and Rural Sociology
College of Agriculture and Life Sciences
University of Idaho
P.O. Box 444290
Moscow ID 83844-4290
208-885-5595
http://web.cals.uidaho.edu/ssru/

Appendix E
First Email Reminder

September 12th, 2013

Last week the University of Idaho's Social Science Research Unit sent you an email with a link to a survey we are conducting with the Idaho Transportation Department about highways in Idaho. We have not yet received your completed survey. This is a short survey and should take about twelve minutes to complete.

Your response to this survey is very important and will help shape policies and practices that will impact all Idahoans.

Please click on the link below to go to the survey website. Your Login ID and password should already be entered when you arrive at the webpage.

If you are having trouble completing the survey or you have already completed the study please contact me at mareyna@uidaho.edu or call our office toll-free at 1-877-542-3019.

Getting direct feedback from Idaho residents is crucial in improving the quality of service offered by the Idaho Transportation Department. Thank you for your help by completing this survey.

Sincerely,

Monica Reyna
Research Associate
Social Science Research Unit
Agricultural Economics and Rural Sociology
College of Agriculture and Life Sciences
University of Idaho
P.O. Box 444290
Moscow ID 83844-4290
208-885-5595
http://web.cals.uidaho.edu/ssru/

Appendix F
Second Email Reminder

September 18, 2013

We understand how valuable your spare time is during this season of the year. We are hoping you are able to give 12 minutes of your time before the end of the week to help us collect important information for the Idaho Transportation Department by completing our short survey.

If you have already completed the survey, we really appreciate your participation. If you have not yet responded, we would like to urge you to complete the survey. We plan to end this study early next week so we wanted to email everyone who has not responded to make sure you had a chance to participate.

Please click on the link below to go to the survey website. Your Login ID and password should already be entered when you arrive at the webpage.

%URL%

It is very important to contact us as soon as possible if you are experiencing difficulties completing this survey. You may call our office toll-free at 1-877-542-3019, during office hours. After office hours you may contact me at mareyna@uidaho.edu.

Thank you in advance for completing this survey. Your responses are important! Idaho residents are the best source of information to help best manage Idaho's roadways.

Many thanks,

Monica Reyna
Research Associate
Social Science Research Unit
Agricultural Economics and Rural Sociology
College of Agriculture and Life Sciences
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P.O. Box 444290
Moscow ID 83844-4290
208-885-5595
http://web.cals.uidaho.edu/ssru/

Appendix G
Final Email Reminder

September 2013

A few weeks ago the University of Idaho's Social Science Research Unit called to recruit you for a web survey for the Idaho Transportation Department. We thank you for agreeing to participate in our study. The research we are conducting will directly affect how Idaho roads are managed.

We are contacting you once again as we have not received your completed survey. Full participation is needed in order to add value and meaning to the data we collect.

Some respondents experienced technical difficulties with the unique URLs and were unable to complete the study. To fix this issue, we have created a new survey web page and given you a new unique URL. Please use the link given below and disregard links you received in previous emails.

Your responses are invaluable and we urge you to complete the survey as soon as possible.

My sincere thanks for your time and consideration,

Monica Reyna
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Social Science Research Unit
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Appendix H
Driving Simulation: Details of Experimental Methodology

Introduction

This appendix provides details of the experimental methodology used for the driving simulation experiment presented in Chapter 3.

Experimental Design

The experiment presented each driver 10 simulations of 4 - 5 mile stretches of rural highway containing a railroad crossing marked with passive signs only. The 10 railroad crossings differed in 2 ways:

- The status of a train approaching the crossing from the left (present or absent).
- The configuration of signs marking the crossing.

We examined five sign configurations:

1. The railroad crossing Crossbuck paired with a standard YIELD sign (CB-YIELD).
2. The Crossbuck paired with a standard STOP sign (CB-STOP).
3. The Crossbuck paired with an IdaShield (CB-Ida).
4. The Crossbuck with both a YIELD sign and IdaShield (CB-YIELD-Ida).
5. The Crossbuck with both a STOP sign and IdaShield (CB-STOP-Ida).

Drivers thus encountered each of the five sign configurations twice, once with a train approaching and once with no train present. The terrain layout and highway geometry were otherwise identical for all 10 highway-rail crossings. Refer back to Figures 9 - 13. Details of the configuration of these stimuli are provided in the Stimuli section below.

Drivers were divided into two groups for testing the sign configurations under both day and night conditions. Daytime drivers viewed a simulation with lighting simulating midday sunshine. Nighttime drivers experienced a simulation of a moonless dark night where only objects illuminated by vehicle headlights are clearly visible. More details on the demographic characteristics of the drivers can be found in the Participants section below.

This experiment thus used a mixed factorial design, with the variables of sign configuration and train status manipulated within-subjects (repeated measures), and the variable of time of day manipulated between subjects.

We examined two classes of measures.

a. Vehicular Control.
b. Eye Gaze Position and Duration.

Vehicular control measures included the driver's control inputs to the steering wheel, brake and accelerator pedals as well as the simulated speed and position of the vehicle on the roadway. Gaze dwell time in different areas of interest (AOIs) within the simulation displays (e.g., the roadway ahead, signs, the train when present, the instrument cluster, etc.) served as our primary measure of eye movements, which were monitored using a head-mounted eye tracking system. Gaze dwell time is determined by summing the durations of all eye fixations within a particular area of interest defined in the environment.

Stimuli

The simulated rural stretches of two lane highway contained a mix of both straight and level roadways and roadways with horizontal curves and vertical terrain. The speed limit for all roadways was posted at 65 miles per hour, with speed limit signs at various locations along the highway. The simulation also included advisory signs for curves ahead. Traffic occasionally appeared in the oncoming lane, but at low density, with approximately one car passing by the driver every mile. To avoid traffic effects on participant behavior, there was no traffic simulated in the participant's lane.

We placed passive railroad crossings with one of the five different sign configurations along a straight and level stretch of highway approximately 3 miles from the beginning of each highway stretch. Each driver experienced each sign configuration twice, once with a train approaching from the left and once with no train present. Crossing the 5 signs with train present or absent created 10 unique trial scenarios, which we ordered using a partial Latin square. This ordering procedure ensured that each trial scenario:

a. Occurred equally often in each place of the order.

b. Preceded and followed every other scenario an equal number of times (see Table 63).

Any effects of sign configuration or train status were thus independent of scenario order effects.

Table 63. The 10 Unique Orders of Scenarios Assigned to Participants

Participant	Order of Presentation for Railroad Crossing Scenarios									
1, 11	0	1	9	2	8	3	7	4	6	5
2, 12	1	2	0	3	9	4	8	5	7	6
3, 13	2	3	1	4	0	5	9	6	8	7
4, 14	3	4	2	5	1	6	0	7	9	8
5, 15	4	5	3	6	2	7	1	8	0	9
6, 16	5	6	4	7	3	8	2	9	1	0
7, 17	6	7	5	8	4	9	3	0	2	1
8, 18	7	8	6	9	5	0	4	1	3	2
9, 19	8	9	7	0	6	1	5	2	4	3
10, 20	9	0	8	1	7	2	6	3	5	4

Key to Scenario Numbers

0. CB - STOP - Ida, Train Present
1. CB - Ida, Train Present
2. CB - YIELD - Ida, Train Present
3. CB - STOP, Train Present
4. CB - YIELD, Train Present
5. CB - STOP - Ida, Train Absent
6. CB - Ida, Train Absent
7. CB - YIELD - Ida, Train Absent
8. CB - STOP, Train Absent
9. CB - YIELD, Train Absent

For scenarios with a train present, a 460 ft long train consisting of a single locomotive pulling 6 freight cars (see Figure 23) was initialized out-of-sight behind a row of trees 1,300 ft to the left of the highway when the driver was 17 seconds away from the highway-rail crossing (based on the driver's current speed). For drivers traveling at a speed of 65 mph, the train became visible approximately 1,600 ft short of the railroad crossing. Three seconds after the train was created a train horn sounded through the interior speakers mounted in the simulator cab. These settings were chosen to allow the driver to determine whether to "speed up" to try cross the railroad before the train, or to "slow down" and "stop" for the train.

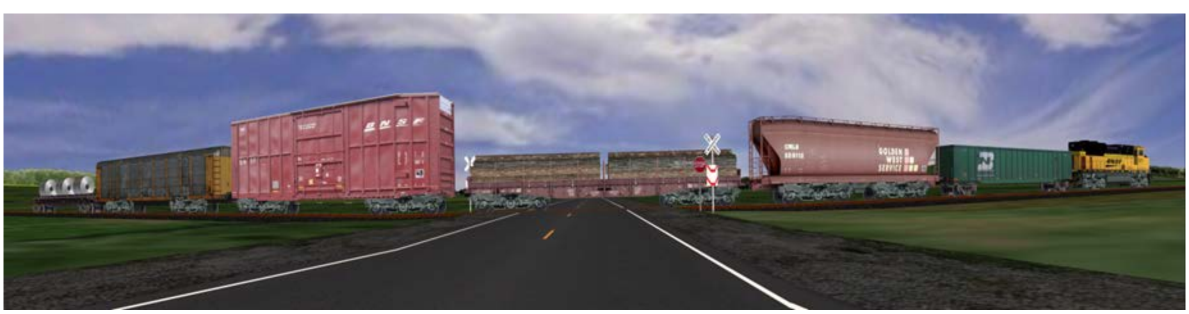

Figure 32. Image of Seven Unit Train as it Passes through Railroad Crossing in Daytime-CB-STOP-Ida Scenario

Note: The fish-eye lens effect visible in the figure is due to a flattening of the image projected onto the 3 screens of the driving simulator. Unlike the images in Figure 18, this image represents the entire 3-screen out-the-windshield field of view projected by the simulator, not just the center screen.

For drivers assigned to the nighttime condition, a headlight was visible on the train, and the left third of the IdaShield, angled back at 45^{o}, was illuminated. However, because the driving simulator models real-time lighting effects of the driver's vehicle headlights only, the train's headlight did not illuminate a cone of space in the environment. For nighttime train-present scenarios we simulated the train headlight's illumination of the IdaShield by substantially increasing the brightness of the angled left third of the IdaShield. The illumination of the IdaShield was therefore constant as the train passed through the railroad crossing. The Crossbuck, STOP and YIELD signs were not illuminated by the train headlight (though still illuminated by the driver's headlights) due to their roughly parallel orientation to the train headlight's direction. Although this lighting simulation did not ideally model the reflection of the IdaShield by the train's headlight, we believe the simulation provided imagery consistent with our field observations of how the IdaShield reflects light relative to the other signs present.

Participants

Of the participants with valid unrestricted driver's licenses, 23 were tested in this experiment. However, due to equipment failures with our eye tracking system that caused a partial loss of data, we excluded three participants from our data analysis. Of the 20 participants who provided full data sets, 7 were student volunteers from the University of Idaho; the remaining 13 participants were recruited from the general community using an online advertisement and paid $40 for their participation. Our participants consisted of 13 men and 7 women with a combined average age 23.5, and an average of 7.75 years of driving experience.

Materials & Apparatus

A seven video channel National Advanced Driving Simulator (NADS) MiniSim rendered the simulations and collected our behavioral data. Participants "drove" the simulations from an instrumented cab based on a 2001 Chevrolet S10 pick-up truck. The cab was located such that the driver's eyes were located at the projected eye-point of the simulated environment.

Three Canon REALiS SX800 projectors front-projected the main forward view of the environment onto three white screens arranged as three sides of an octagon (see Figure 32). The projected viewpoint of the simulation was located at the center of the octagon, 1.8 m from the center of each screen. These screens comprised a 135 x 33.75^{o} (horizontal x vertical) field of view with spatial resolution of 4200 x 1050 pixels (H x V) and a refresh rate of 60 Hz. In addition to the main view, two 0.203 m (8 in.) liquid crystal display (LCD) screens, each with a spatial resolution of 800 x 600 pixels (H x V), were mounted to the left and right side rearview mirror housings of the S10 cab (the right-side mirror is visible in Figure 8).

The center - windshield-mounted - rearview mirror of the cab reflected the view out the rear window of the cab, which was filled by imagery displayed on a 1.65 m (65 in.) plasma screen with 1280 x 720 pixel resolution and 60 Hz refresh rate located directly behind, and completely filling, the window opening. The seventh MiniSim video channel displayed the dashboard instrument cluster (tachometer, speedometer, engine temperature gauge, gear selection, fuel gauge) on a 0.254 m (10 in.) LCD with a spatial resolution of 1280 x 800. This display was mounted in place of the normal mechanical analog instrument cluster of the S10. All 7 displays were rendered by the NADS MiniSim software running under the Windows 7 operating system on a single graphics workstation containing a six-core Intel Core I7 processor running at 3.9 GHz, 32 GB of RAM, and two NVidia video display adapters. A GeForce GTX680 routed through a Matrox T2G-D3D-IF controlled the three main displays. This video adapter also rendered the dashboard and right side-mirror displays. A GeForce GTX660TI video adapter rendered the left side-mirror and center rearview mirror displays. A 5.1 channel audio system used the 4 speakers mounted in the cab doors and B pillars and a sub-woofer mounted behind the driver's seat to produce automobile and road sounds.

A US Digital USB4 Analog to Digital (DAC) interface with a rotary encoder connected the steering wheel, gear selector, turn signals, and brake and accelerator pedals to the MiniSim. The original S10 steering wheel provided 540 degrees of steering range and was self-centering. The original S10 brake and throttle controls provided touch displacement feedback similar to a normal automobile. A center console housed an automatic gear selector from a 2001 Honda Civic to provide participants with a standard interface for gear selection.

Real-time gaze position was monitored during this experiment with an Applied Science Laboratory (ASL) Model 5000 head-mounted eye-head tracking system. This device recorded eye and head position at 60 Hz. The Model 5000 measures gaze direction relative to the head by tracking movements of the pupil relative to the corneal reflection using an infrared video camera mounted on a headband. To determine the position and orientation of the head relative to the display screens the Model 5000 uses an Ascension Technology Flock of Birds magnetic motion tracker. The Model 5000 integrates the head and eye positions to calculate and record gaze position on the displays in real time. The eye-head tracking system was calibrated in accordance with ASL's 9 target point procedure (Figure 24). To insure the calibration was sufficient to record eye movements with round circles surrounding the calibration points are approximately 1^{o} in radius.

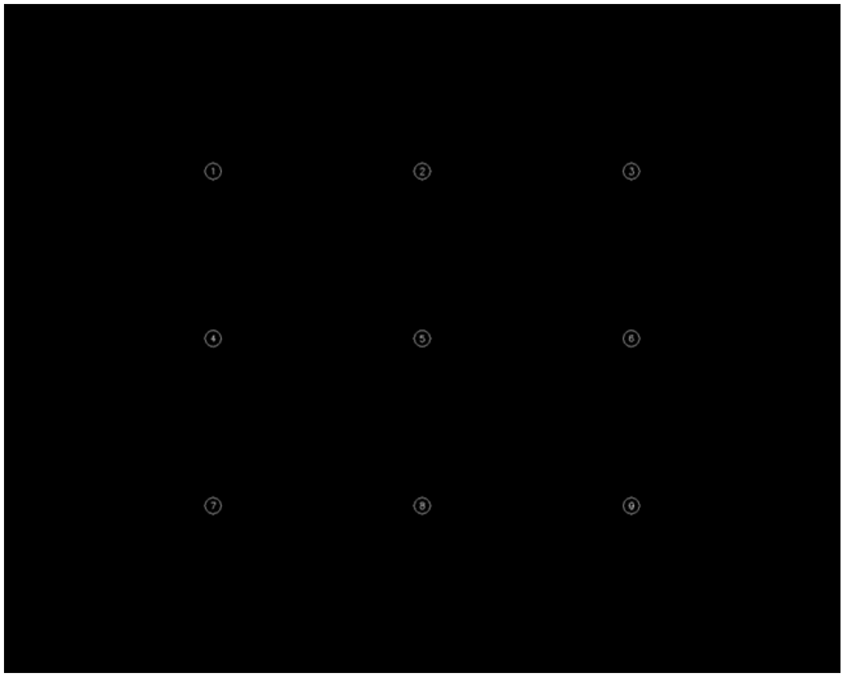

Figure 33. Calibration Screen with Nine Target Points Used to Calibrate the ASL Eye-Head Tracking System

Note: During calibration each of these points are displayed on the center of the panel of the main display 1 at a time and participants are asked to fixate on them. We checked proper calibration with the display showing all 9 points. Calibration was considered accurate if participants measured gaze direction fell within the 1^{o} radius circle for each point.

Calibration was repeated until the crosshair representing participant gaze location fell within a 1^{o} radius circle surrounding each and every point. Logging of eye position began when the driver reached one mile before the railroad crossing and continued until the driver crossed the tracks. All driver-vehicle performance and eye position data were recorded at 60 Hz.

Procedure

Participants were treated in accordance with a University-approved protocol governing the use of human subjects in research. Prior to participation, all participants received a general description of the study, including warnings of potential risks (primarily motion sickness), and asked to sign a consent form. Next, participants received the experimental instructions listed below:

This experiment examines driving behaviors on rural highways.

Your task will be to steer a simulated vehicle through a simulation of the Idaho countryside [at nighttime[1]]. Your goal is to keep your vehicle centered in your lane and moving at an appropriate speed, just as you would in everyday driving. Just like with any car, to turn right you move the top of the steering wheel to the right. To turn left you move the top of the steering wheel to the left. To accelerate you press the gas pedal. To slow down, you press the brake pedal. Turn signals operate just like in a real vehicle.

In this experiment you will go through 10 trials, each lasting approximately 5 - 6 minutes which will simulate a drive through rural Idaho.

There will be vehicles ahead and behind you as well as in the oncoming lane. You should pay careful attention to the other vehicles, road signs, speed limits, etc. and use normal driving etiquette, just as you would if you were driving on a real rural highway.

You will receive a short break every two trials. During these breaks we ask that you get out of the simulator, and walk around/stretch your legs for a few minutes.

To get use to the sensitivity of the simulator (steering, pedals) you will have a 5 minute test drive to familiarize yourself with the controls. To begin each trial you will need to depress the brake pedal to release the transmission lock and shift the gear shift into "D" or "drive."

Do you have any questions?

Now please explain to me, in your own words, what you will be doing in this study.

After the instructions, participants drove a five minute test drive on a two lane rural highway to familiarize themselves with the driving simulator, and the sensitivity of the controls. Once participants felt comfortable with the controls the test drive was terminated. The eye-head tracking system was then placed on the participants' head and conducted the nine-point calibration procedure specified by ASL. Following this calibration, experimental trials began. After each experimental trial the calibration of the eye-head tracker was checked and adjusted, if necessary[2]. To reduce fatigue, every two trials participants took a two-minute break to walk around with the eye-head tracking apparatus removed. Following the last trial, participants completed a post-simulation questionnaire and were informed of the nature and purpose of the study. The entire experimental session lasted 120 minutes.

[1] "At nighttime" was added for participants assigned to our nighttime group only.

[2] Typically, calibration drifted slowly over time and only minor adjustment was necessary between trials. No trials needed to be rerun due to poor calibration.