SAFETY EVALUATION OF IDASHIELD SIGNS AT PASSIVE RAILROAD CROSSINGS USING CRASH DATA ANALYSIS, USER ASSESSMENT SURVEYS, AND DRIVING SIMULATION

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AUTHORIZATION TO SUBMIT THESIS

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ABSTRACT

This study evaluates the safety performance of the IdaShield experimental warning sign via crash data analysis, user assessment surveys, and driving simulation. Highway-rail crossing inventory and crash data from the Idaho Transportation Department and Federal Railroad Administration were used to develop a Safety Performance Function (SPF) for passive highway-rail crossings. A Highway Safety Manual Before/After Empirical Bayes analysis was performed using the SPF and revealed a significant decrease in crash frequency after the 1997 – 1998 IdaShield installations. This is the first study to develop a highway-rail crossing SPF and also use the SPF in the HSM Empirical Bayes method to evaluate the effectiveness of a sign treatment. A statistical comparison between nighttime and daytime crash frequency reduction due to IdaShield installations showed that the IdaShield performs notably better at nighttime relative to daytime. User assessment surveys and driving simulation revealed that drivers assign a “yield” meaning to the IdaShield.

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DEDICATION

Dedicated to Dr. Michael Dixon, who unexpectedly passed away just before completion of this thesis. His guidance was invaluable toward my professional development and the successful completion of this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

CHAPTER 1

This report details the historical crash data analysis used to evaluate the effectiveness of the IdaShield warning sign. This is one part of a three-part University of Idaho study assessing the IdaShield. The other two parts are a user assessment survey and driving simulation study that are referenced to complement the crash data analysis conclusions. The following information is included in this report:

- IdaShield purpose and background.
- Review of previous literature on the Highway Safety Manual (HSM) Before/After Empirical Bayes (EB) method, Safety Performance Function (SPF) development, and factors influencing highway-rail crossing crash frequency.
- Steps taken to construct Idaho highway-rail crossing inventory and crash datasets.
- Procedures and results for Safety Performance Function (SPF) development, Empirical Bayes (EB) method analysis, a comparison of statewide vehicle crash and highway-rail crossing crash trends, and an analysis of IdaShield nighttime effectiveness.
- Results of the user assessment survey and driving simulation studies.
- Discussion of results and conclusions.

IdaShield Background

The IdaShield is a highly reflective red and white warning sign used at passive at-grade highway-rail crossings in Idaho. These signs were installed statewide in 1997 and 1998 to reduce crashes at highway-rail crossings. The left and right edges of the IdaShield sign bend backwards at a 45 degree angle to reflect train headlights onto the roadway and make the sign more visible at angled approaches. The IdaShield was inspired by and is similar to the Ohio Buckeye Shield, which was used at Ohio highway-rail crossings.

IdaShields were initially installed by Idaho Operation Lifesaver (IOL) at 25 passive public highway-rail grade crossings in Idaho. After an encouraging 1994/1995 study on these crossings (summarized in Table 1), the IdaShield Experimental Project was requested by the Idaho Transportation Department (ITD) and approved by the Federal Highway Administration (FHWA) in October 1996. IdaShield Assemblies, consisting of a diamond grade reflective Crossbuck and IdaShield mounted on the same post with a diamond grade reflective strip, were installed at all passive public highway-rail grade crossings in Idaho between May 1997 and August 1998.

Previous IdaShield Studies

Three studies, conducted in 1994/1995, 1999/2000, and 2008, investigated IdaShield performance by observing driver stopping compliance and head movements at crossings with a) both IdaShields and STOP signs and b) STOP signs only. The results of these studies are shown in Table 1.

Table 1: Driver Stopping Compliance and Head Movement Results

Treatment Presence	Driver Stopping Compliance			Drivers Looking for Trains		
	1994/1995	1999/2000	2008	1994/1995	1999/2000	2008
IdaShields and STOP signs	74%	60%	83%	89%	87%	91%
STOP signs	52%	52%	52%	65%	64%	64%

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

IOL also conducted a public opinion poll in 2000 that asked Eastern and Western Idaho State Fair attendees to rate the usefulness of six highway-rail crossing signs. The results are shown in Table 2.

Table 2: Public Opinion Poll Responses

Sign	Usefulness
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. The IdaShield was pictured in the survey without its usual Crossbuck companion, which may have left participants confused about its meaning.

A crash data analysis included in a previous IdaShield Project report showed a 50 percent decrease in total reported collisions and 70 percent decrease in nighttime reported collisions after IdaShields were installed [1].

Unfortunately, the stopping compliance and head movement measures are indirect and subjective; data were collected by volunteers who observed driver behavior at highway-rail crossings. Statistical analyses of the driver behavior, survey, and crash data were not performed. This report contains a more thorough and objective statistical analysis of highway-rail crossing crashes. The results and conclusions are complemented by findings from an IdaShield user assessment survey and IdaShield driving simulation study.

CHAPTER 2

A review of previous literature was conducted on the extent of previous research on highway-rail crossing sign treatment evaluation, Highway Safety Manual (HSM) Before/After Empirical Bayes (EB) method, statistical theory, Safety Performance Function (SPF) development, selection of the "best fit" SPF, and significant factors affecting crashes at highway-rail crossings.

Extent of Previous Research

There is very little previous literature on SPF development for highway-rail crossings in particular. Millegan et al. developed negative binomial (NB) models to predict highway-rail crossing crashes and evaluate STOP sign effectiveness [2]. However, this model was not used in the HSM EB method, a warning device evaluation method originally explored by Hauer and Persaud in 1987 [3]. Therefore, the majority of references discuss the topics of general SPF development and factors affecting vehicle-train crashes at highway-rail crossings.

Safety Performance Functions and HSM Empirical Bayes Method

The HSM defines safety effectiveness evaluation methods for previously implemented treatments using observed crash data and statistical analysis. Safety effectiveness cannot be accurately evaluated using solely observed crash data because it is not certain whether short-term averages in crash frequency are representative of the long-term average or true crash risk. Failure to recognize this can result in a study with regression-to-the-mean (RTM) bias. The HSM EB method reduces the potential for RTM bias by averaging observed crash frequency and predicted crash frequency (calculated with a SPF). A SPF 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. Each SPF has an overdispersion parameter that represents the crash frequency variation unaccounted for by the SPF; larger overdispersion parameter values indicate a weaker SPF and weaken the influence of the SPF in the EB 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 the SPF.

Crash Frequency vs. Crash Rate

The HSM and previous studies recommend using crash frequency, rather than crash rate, as a safety performance measure. 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/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 [4].

SPF Development

The distribution of highway-rail crossing crashes can be expected to follow that of a Poisson or Poisson-Gamma (negative binomial (NB)) [5]. The two distributions are similar in that both model the results of a sequence of Bernoulli trials (observations with only 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 [6]. In a NB distribution, the variance is allowed to differ from the mean via the introduction of an error term [5]. The average of these error terms is the overdispersion parameter and is used in the EB method to represent the variance of crash frequency in the dataset [4]. 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 Equation 1,

Equation 1: Poisson and Negative Binomial Model Form Equation [7]

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

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

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 [5], [7]. Models within 2 AIC or BIC of each other are considered to have nearly indistinguishable goodness-of-fit; models with difference greater than 10 show strong evidence of one model over the other. AIC tends to error on the side of over-fitting the dataset, while BIC is more susceptible to under-fitting [8], [9]. This study monitors both AIC and BIC during model development to eliminate poor-fitting model alternatives.

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 [5], [7], [10]–[12].

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) [11], [13].

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 [14].

Conclusions

Several main points were taken from previous literature:

- Collect data on sign presence, crossing characteristics, exposure, and crashes.
- Since there are no standardized SPFs for highway-rail crossings, develop an SPF predicting crash frequency at passive highway-rail crossings.
- Evaluate effectiveness of 1997 – 1998 IdaShield installation with the SPF and HSM EB Method.

CHAPTER 3

The crossing and crash data used in this study were obtained from the Federal Railroad Administration (FRA) and the Idaho Transportation Department (ITD).

FRA Data

The crossing and accident data from 1980 to 2011 used in this study were obtained from three 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 [15].

ITD Data

ITD highway-rail crossing and crash data were considered to be more accurate than 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. AADT data were only available for a portion of the originally requested crossings. The FRA AADT records were replaced with ITD records.

Also requested was a list of current IdaShield-controlled crossings, which was used to verify FRA records of IdaShield-controlled crossings.

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

Data Transformations

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.
    - In use for less than 3 years.
- Closed or abandoned crossing entries.

This ensured that all crossings in the datasets were public, passive, at-grade, and in-use.

The crash history records were pared down to include only vehicle-train crashes in which vehicles failed to yield, stopped on the tracks, or stopped and then proceeded before striking/being struck by the train.

A small portion of the FRA inventory data for highway-rail crossings 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 Crossbuck, which is suspicious because Crossbucks were installed with all 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 using FRA data questioned the quality of FRA accident data but found it to be more accurate than Fatality Analysis Reporting System (FARS) data [11], [16].

Final Datasets

There are three datasets used in the crash data analysis portion of this project.

The dataset used to develop SPFs consists of 32,594 yearly crossing records over 1,403 crossings from 1980 to 2011. There are 447 crashes in the dataset.

The dataset used for the EB method and nighttime IdaShield effectiveness analysis consists of 23,342 yearly crossing records over 734 crossings from 1984 to 2011. There are 353 crashes in the dataset. This dataset is a pared down form of the SPF dataset that includes only IdaShield-controlled crossings with complete records from 1984 to 2011.

The dataset used for the comparison of statewide vehicle and highway-rail crossing crash trends includes yearly average crash frequencies of vehicles statewide and at highway-rail crossings from 1984 to 2011.

CHAPTER 4

This chapter presents the results the SPF development, EB method, comparison of highway-rail crossing and statewide crash trends, and nighttime IdaShield effectiveness analysis.

Safety Performance Function

This section details the SPF development procedure and results. The statistical software SPSS was utilized to fit an SPF for passive at-grade highway-rail crossings in Idaho. The SPF is in negative binomial (NB) model form.

Development

It was assumed that the dataset would be best fit by a NB model. However, the 95% confidence bounds of the overdispersion parameters in the initial NB regressions ranged from approximately 0.8 to 4.0. This range includes 1, implying that the data may be better fit by a Poisson model. The NB regressions were rerun with the overdispersion parameter fixed at 1, converting the NB to a Poisson. The Poisson parameter estimates and goodness-of-fit measures were very similar to those of the NB model. Since there was very little difference between the two models and previous literature favors NB models, the final SPFs are developed using NB models with log link functions, chosen from the Generalized Linear Models regression options in SPSS.

The first step in SPF development 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.

Descriptive statistics for the remaining independent variables are shown in Table 3.

Table 3: SPF Variable Descriptive Statistics

Variable	Mean	Minimum	Maximum	Type
AADT	514	10	31000	Continuous
TTPD	6.88	1	155	Continuous
MAXSPD	31.0	5	79	Continuous
STOPSIGN	0.419	0	1	Binary
IDASHIELD	0.329	0	1	Binary
HWYPVED	0.576	0	1	Binary
NUMTRCKS	1.41	1	15	Integer

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.

Final SPF Examination and Justification

The model coefficients, standard deviation, and significance levels of the final SPF are shown in Table 4. The model intercept and all independent variables are statistically significant at the study significance level of 0.05.

Table 4: Final SPF Variable Coefficients and Deviations

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. Table 5 shows the appropriate SPF coefficient for each condition.

Table 5: SPF Coefficients for each STOPSIGN/HWYPVED Combination

Condition	SPF Coefficient
No STOP sign, unpaved	0.000
No STOP sign, paved	1.312
STOP sign, unpaved	0.629
STOP sign, paved	1.242

Based on the coefficients in Table 5, 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 [16].

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 [4].

The equation for the final SPF is shown below in Equation 2.

Equation 2: SPF Equation

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

Observed crash frequencies are compared with the SPF predicted crash frequencies in Figure 1.

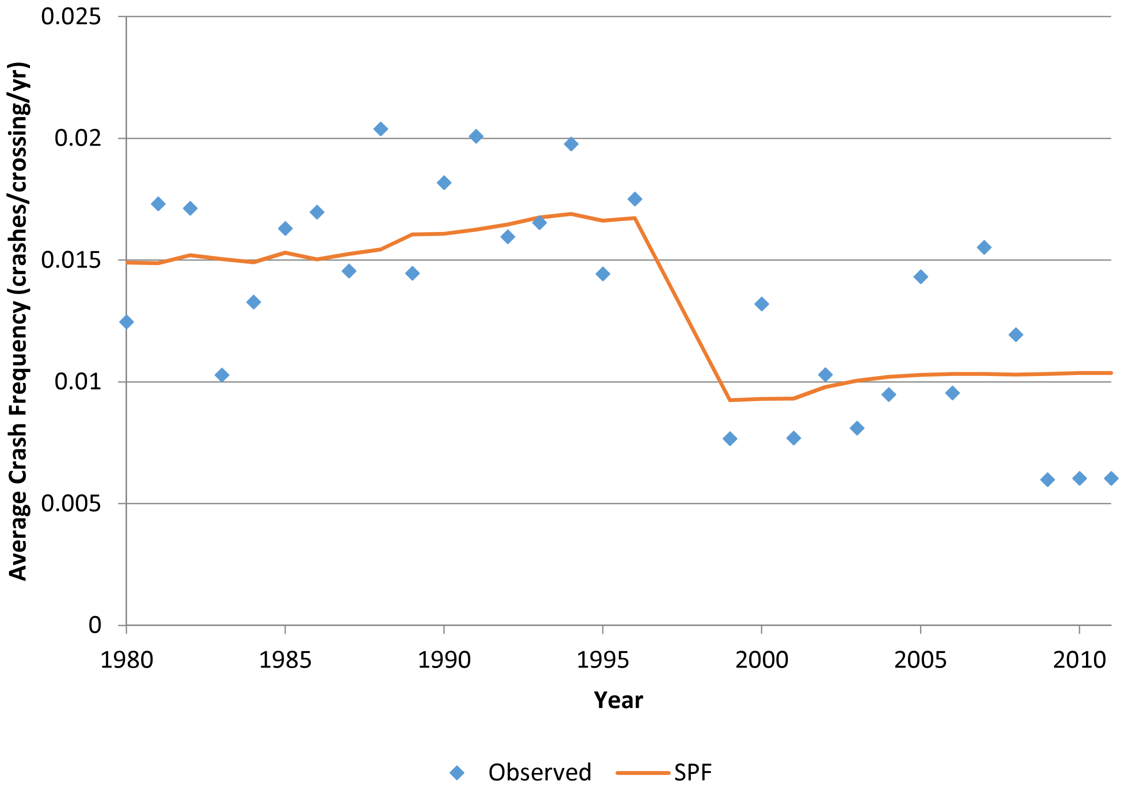

Figure 1: Comparison of Observed and SPF (Predicted) Crash Frequencies

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.

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 (2005 – 2007) and drops (2009 – 2011) in highway-rail crossing crash frequency that will necessitate further investigation (see Figure 2). 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.

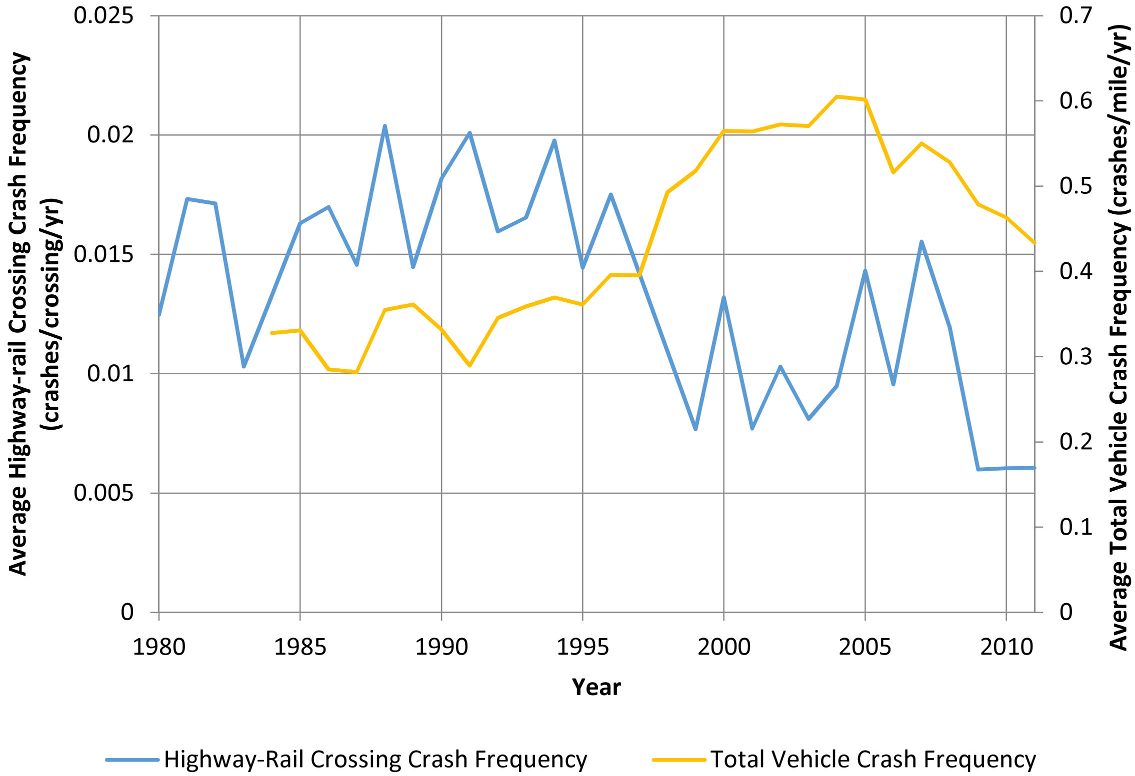

Figure 2: Statewide Vehicle Crash Frequency and Highway-Rail Crossing Crash Frequency

Figure 2 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 crash frequency 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. Though further investigation is required to determine the cause of the 2008 – 2011 decrease in crash frequency, there is no evidence from this analysis that questions the legitimacy of the final SPF.

HSM Before/After Empirical Bayes Method

A HSM Before/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 the EB method using the final SPF are shown 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.

Nighttime Effectiveness of IdaShield

It is important to assess the nighttime effectiveness of the IdaShield because its high reflectivity and angled sides 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, one-sample Wilcoxon signed rank tests were conducted in SPSS on each of three variables. These variables 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 calculated for each crossing in the EB dataset. The results of the tests are shown in Table 7. The 95% confidence intervals were estimated by conducting one-sample t-tests.

Table 7: Wilcoxon Signed Rank Test Results

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.

CHAPTER 5

This section contains a discussion of the crash data analysis results detailed in this report, as well as discussions of the user assessment survey and driving simulation portions of the IdaShield project conducted at the University of Idaho.

Crash Data Analysis

Results of the EB analysis show a highly statistically significant 39 percent decrease in crash frequency after IdaShield installation. The IdaShield performs notably better at nighttime relative to the daytime even though the analysis dataset did not offer enough power to detect a statistically significant difference. 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 frequency. Collectively, these results show that the IdaShield installations in 1997 and 1998 significantly decreased crash frequency 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 Crossbucks and posts that were installed with the 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. Large crash reductions due to sign replacement and modest crash reductions due to reflectivity upgrades have been observed in previous studies [17], [18]. These factors 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.

User Assessment Survey

The IdaShield user assessment survey was conducted via email and phone conversations. Survey respondents were asked questions about sign comprehension and actions they would take when approaching a crossing equipped with one of five tested sign combinations (Crossbuck+STOP, Crossbuck+YIELD, Crossbuck+STOP+IdaShield, Crossbuck+YIELD+IdaShield, and Crossbuck+IdaShield). The survey did not yield many significant differences in responses; however respondents seemed to assign a "yield" meaning to the IdaShield. 63 percent of respondents felt the IdaShield improved visibility of highway-rail crossings. 50 percent of drivers thought the IdaShield improved safety at highway-rail crossings [19].

Driving Simulation

The IdaShield driving simulation study recruited participants to drive a rural two-lane highway loop interspersed with passive highway-rail crossings in a driving simulator. Vehicle trajectory and eye movement data were collected. Participants' eye fixations did not vary significantly over the five tested sign combinations (Crossbuck+STOP, Crossbuck+YIELD, Crossbuck+STOP+IdaShield, Crossbuck+YIELD+IdaShield, and Crossbuck+IdaShield). However, the vehicle trajectory results showed that participants reacted to the Crossbuck+IdaShield and Crossbuck+YIELD combinations in similar manners. This reflects the user assessment survey findings. In addition, installing IdaShields at Crossbuck+YIELD controlled crossings significantly improved safety at night. Installing IdaShields at a Crossbuck+STOP controlled crossing did not significantly impact safety. The study did not test for the effects of sign reflectivity and brightness on driver behavior [19].

CHAPTER 6

This study evaluates the safety effectiveness of the IdaShield sign using crash data analysis, user assessment surveys, and driving simulation. After reviewing previous literature, Idaho crash and crossing inventory data were collected from the FRA and ITD. A SPF representing passive Idaho highway-rail crossings was developed using SPSS. Using the final SPF, a Before/After Empirical Bayes method analysis was conducted to quantify IdaShield safety performance. A Wilcoxon signed rank test was conducted between day and night crash frequency before and after IdaShield installation to assess the IdaShield's nighttime effectiveness. Lastly, results from the user assessment survey and driving simulation portions of the IdaShield project were referenced to complement these crash data analysis results.

The conclusions from these research efforts are:

- The 1997 – 1998 IdaShield installations improved safety under both nighttime and daytime conditions at Idaho highway-rail crossings.
- In practice, IdaShield nighttime performance is better than daytime performance even though statistical tests did not detect a significant difference.
- Drivers tend to assign a "yield" meaning to the IdaShield. Therefore the IdaShield may significantly increase yield compliance when paired with a YIELD sign.
- The large reduction in highway-rail crossing crash frequency after the 1997 – 1998 IdaShield installations may partially be due to the high retro-reflectivity of the new IdaShields, Crossbucks, and posts.

This study is of significance to future researchers because it is the first study to develop a highway-rail crossing SPF and also use the SPF in the HSM Empirical Bayes method to evaluate the effectiveness of a sign treatment. The passive highway-rail crossing inventory and crash databases constructed for this study may be useful to future researchers and engineers for highway-rail crossing studies or Idaho transportation projects.

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