U.S. Department of Transportation

Federal Highway Administration

Delta Region Transportation Development Program:

Rural Safety Innovation Program Evaluation

Final Report

February 2014

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-SA-14-029		

4. Title and Subtitle	5. Report Date
Delta Region Transportation Development Program: Rural Safety Innovation Program Evaluation	February 2014
	8. Performing Organization Report No.
7. Author(s) D. J. Torbic, K. M. Bauer, and J. M. Hutton	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Battelle and MRIGlobal 505 King Avenue, Columbus, Ohio 43201 425 Volker Boulevard, Kansas City, MO 64110	11. Contract or Grant No. DTFH61-08-D-00032
12. Sponsoring Agency Name and Address Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590	13. Type of Report and Period Covered Final Report September 2009-April 2014
	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contracting Officer Technical Manager: Roya Amjadi

16. Abstract

The objective of this research project was to evaluate the effectiveness of the highway safety improvement projects implemented under the Rural Safety Innovation Program – Delta Region Transportation Development Program (RSIP-DRTDP) toward reducing fatalities and injuries on rural roads. Many of the safety improvement projects implemented as part of the RSIP-DRTDP were able to achieve the overall goal of USDOT’s Rural Safety Initiative to improve safety on rural highways by decreasing loss of lives and injuries. In Mississippi, the installation of centerline rumble strips on rural two-lane roads where shoulder rumble strips were already present resulted in a decrease in target crashes. In Louisiana, improved signing and pavement markings at rural stop-controlled intersections effectively reduced total and fatal and all injury (FI) intersection and intersection-related crashes. In Arkansas, the safety evaluation of cable median barrier installed on rural interstates was able to demonstrate the beneficial effects on all crash types and severities, and in particular, fatal and serious (FS) injury crashes. For the remaining RSIP projects evaluated, the safety effects of the treatment combinations could not be reliably quantified at this time due to insufficient data. Finally, the lessons learned in developing a sign inventory system and installing dynamic message signs and closed-circuit video, respectively, will benefit other agencies interested in similar programs. The knowledge gained from the evaluation of the RSIP-DRTDP projects can benefit other highway agencies when making funding decisions concerning future safety improvement projects and programs.

17. Key Words	18. Distribution Statement
Highway safety Countermeasure evaluation Rural Safety Innovation Program	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	69	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Metric Conversion Chart

SI* (MODERN METRIC) 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	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yard	0.836	square meters	m^2	m^2	square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	square kilometers	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.314	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.307	cubic yards	yd^3
	NOTE: volumes greater than 1000 L shall be shown in m^3								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.202	pounds	lb
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")	Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)					**TEMPERATURE (exact degrees)**		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°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	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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List of Acronyms

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
AHTD	Arkansas State Highway and Transportation Department
CCTV	Closed Circuit Television Camera
CMF	Crash Modification Factor
DMS	Dynamic Message Sign
DRTDP	Delta Region Transportation Development Program
EB	Empirical Bayes
FHWA	Federal Highway Administration
FI	Fatal and All Injury Crashes
FS	Fatal and Serious Injury Crashes
GEE	General Estimating Equation
GLM	Generalized Linear Model
GPS	Global Positioning System
HSM	Highway Safety Manual
IDOT	Illinois Department of Transportation
LaDOTD	Louisiana Department of Transportation and Development
LED	Light Emitting Diode
MoDOT	Missouri Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices
MVMT	Million Vehicle Miles Traveled
PSA	Public Service Announcement
RPM	Raised Pavement Markings
RSIP	Rural Safety Innovation Program
SE	Standard Error
SPF	Safety Performance Function
SVROR	Single Vehicle Run-off-Road
TDOT	Tennessee Department of Transportation
USDOT	United States Department of Transportation

Executive Summary

The Rural Safety Innovation Program (RSIP) is one of several key programs under the United States Department of Transportation's (USDOT) Rural Safety Initiative. The goal of the initiative is to improve safety on rural roads. The objective of this research project was to evaluate the effectiveness of highway safety improvement projects implemented under the Rural Safety Innovation Program – Delta Region Transportation Development Program (RSIP-DRTDP) toward reducing fatalities and injuries on rural roads. Nine agencies implemented a range of safety improvement projects as part of RSIP-DRTDP. Several levels of safety evaluations were performed as part of this research. Three projects were selected for detailed quantitative evaluation. One project lent itself to a simpler quantitative analysis, and two projects were more suited to a qualitative, rather than quantitative, analysis, focusing on lessons learned by the agencies during implementation. Three projects were not included in the evaluation due to insufficient data and/or the ability to link the necessary data for analysis purposes.

Many of the safety improvement projects implemented as part of the RSIP-DRTDP were able to achieve the overall goal of the Rural Safety Initiative of improving safety on rural highways. In Mississippi (RSIP Project 27), installation of centerline rumble strips on rural two-lane roads, where shoulder rumble strips were already present, resulted in a decrease in single vehicle run-off-road (SVROR), sideswipe-opposite direction, and head-on crashes. The dual application of centerline and shoulder rumble strips on rural two-lane roads resulted in a 35-percent reduction (SE=10.5) in total target crashes and a 40-percent reduction (SE=12.3) in fatal and all injury (FI) target crashes. In Louisiana (RSIP Project 37), improved signing and pavement markings at rural stop-controlled intersections reduced total and FI intersection and intersection-related crashes. The improved signing and pavement marking treatments resulted in crash reductions between 30- and 67-percent at stop-controlled intersections on rural two-lane roads. In Arkansas (RSIP Project 33), the safety evaluation of cable median barrier installed on rural interstates indicated a 49-percent reduction in fatal and serious injury (FS) crashes that was marginally significant at the 88-percent confidence level.

Lessons learned in Tennessee (RSIP Project 25) and Missouri (RSIP Project 32) in developing a sign inventory system and installing dynamic message signs and closed-circuit video, respectively, will also benefit other agencies interested in implementing similar programs. From a qualitative perspective, the RSIP projects implemented in Tennessee and Missouri were a success and benefitted the respective highway agency.

For the RSIP projects for which the safety evaluation yielded unreliable estimates (RSIP Project 36) or the safety effectiveness could not be completed due to insufficient data (RSIP Projects 28, 31, and 34), there is insufficient evidence at this time to reliably determine treatment effectiveness.

The knowledge gained from the evaluation of the RSIP-DRTDP projects can benefit other highway agencies when making funding decisions concerning future safety improvement projects and programs.

Chapter 1. Introduction

Background

The Rural Safety Innovation Program (RSIP) is one of several key programs under the United States Department of Transportation's (USDOT) Rural Safety Initiative. The goal of the initiative is to improve safety on rural roads, resulting in a decrease in the loss of lives and injuries. As part of the RSIP, nine highway agencies in the Delta Region of the United States received funds to implement highway safety improvements towards the achievement of this overall goal. The objective of this research project was to evaluate the effectiveness of the RSIP projects implemented by the nine highway agencies toward achieving this goal of reducing fatalities and injuries on rural roads. By quantitatively estimating the safety effectiveness of specific countermeasures (or combinations of countermeasures) and by presenting "lessons learned" by agencies through their experiences of implementing specific countermeasures, the knowledge gained from the evaluations can benefit other highway agencies when making funding decisions concerning future safety improvement projects and programs.

The RSIP includes several elements. This evaluation of the RSIP focuses on the Delta Region Transportation Development Program (DRTDP). Nine agencies implemented a range of safety improvement projects as part of the RSIP-DRTDP. Table 1 lists the agencies that received safety funding through the DRTDP and the types of countermeasures implemented with those funds. In general, it can be assumed that the respective agencies identified high-risk locations (e.g., roadway segments, curves, or intersections) for safety improvement based on crash data and local knowledge and selected countermeasures for implementation based on the anticipated effectiveness of the countermeasures and their applicability to a systematic approach to implementation. The types of safety programs implemented by the agencies differ with respect to the types of countermeasures implemented and the related collision types targeted for remediation.

Table 1. Agencies and Countermeasures Involved in the RSIP-DRTDP

RSIP Project No./Agency	Countermeasure/Improvement Types	General Site Attributes
RSIP Project 25: Tennessee Department of Transportation (TDOT)	Signing inventory/assessment system	Rural state highways
RSIP Project 27: Mississippi Department of Transportation (MDOT)	Centerline rumble strips and clear zone restoration	Rural two-lane roads
RSIP Project 28: Hinds County, MS	Signing, striping, and rumble strips	Rural two-lane roads
RSIP Project 31: Grant Parish, LA	Striping, rumble strips, raised pavement markers, flashing beacon warning signs, large arrow signs, chevrons, and other warning signs	Rural two-lane roads
RSIP Project 32: Missouri Department of Transportation (MoDOT)	Dynamic message signs on Interstate highways	Rural interstates
RSIP Project 33: Arkansas State Highway and Transportation Department (AHTD)	Cable median barrier on an Interstate highway	Rural interstates
RSIP Project 34: Rapides Parish, LA	Striping, rumble strips, raised pavement markers, flashing beacon warning signs, large arrow signs, chevrons, and other warning signs	Rural two-lane roads
RSIP Project 36: Illinois Department of Transportation (IDOT)	Advance curve warning signs, speed plates, chevrons, and raised pavement markings	Horizontal curves on rural two-lane roads
RSIP Project 37: Louisiana Department of Transportation and Development (La DOTD)	Signing and marking improvements at intersections	Intersections on rural roads

Objective and Scope

The objective of this research project was to evaluate the effectiveness of the highway safety improvement projects implemented under the RSIP-DRTDP toward reducing fatalities and injuries on rural roads. Due to the availability of data and the nature of the projects, several levels of safety evaluations were performed. Three projects were selected for detailed quantitative evaluation. One project lent itself to a simpler quantitative analysis rather than a rigorous statistical analysis because it lacked a sufficient number of treatment sites (and mileage), and two projects were more suited to a qualitative, rather than quantitative, analysis, focusing on lessons learned by the agencies during implementation of their program. Finally, three projects were not included in the evaluation due to insufficient data and/or the ability to link all of the necessary crash, traffic volume, and roadway inventory data for analysis purposes. Table 2 shows the level of analysis performed for each RSIP project, as part of this research, and the projects selected for the analyses.

Table 2. Levels of Evaluation and Agencies Involved

RSIP Project No./Agency	Level of Evaluation
RSIP Project 25: Tennessee Department of Transportation (TDOT)	Qualitative evaluation
RSIP Project 27: Mississippi Department of Transportation (MDOT)	Detailed quantitative evaluation
RSIP Project 28: Hinds County, MS	Not evaluated
RSIP Project 31: Grant Parish, LA	Not evaluated
RSIP Project 32: Missouri Department of Transportation (MoDOT)	Qualitative evaluation
RSIP Project 33: Arkansas State Highway and Transportation Department (AHTD)	Simpler quantitative evaluation
RSIP Project 34: Rapides Parish, LA	Not evaluated
RSIP Project 36: Illinois Department of Transportation (IDOT)	Detailed quantitative evaluation
RSIP Project 37: Louisiana Department of Transportation and Development (La DOTD)	Detailed quantitative evaluation

Research Approach

At the beginning of the project, the research team contacted the nine highway agencies involved in the RSIP-DRTDP to discuss implementation and evaluation of their projects. The first task was for the research team to gain a detailed understanding of each RSIP project. Through a series of teleconferences, the research team gathered detailed information on each of the projects, identified the specific evaluation opportunities for each project, discussed the availability of data for use in the analyses, and identified key contacts within the highway agencies for data requests.

Following the teleconferences, the research team developed an evaluation plan for each project. Where practical, the research team conducted an observational before/after evaluation of the differences in crash frequency and severity for specific countermeasures or combinations of countermeasures using the Empirical Bayes (EB) method. Two advantages of the EB method over other analysis approaches are that the EB method can compensate for regression-to-the-mean bias and that existing safety performance functions (SPFs) can be used in the analyses rather than developing new SPFs for each evaluation. Existing SPFs from the *Highway Safety Manual* (HSM; AASHTO, 2010) and *Safety Analyst* were calibrated and used as appropriate in this type of analysis. Crash, traffic volume, roadway inventory, and countermeasure data were obtained for the analyses from discussions with project personnel, electronic databases, review of aerial mapping tools, and field visits. For projects that did not lend themselves to a detailed quantitative before/after evaluation using the EB method, either a simpler comparison of crashes before and after installation of the countermeasures was performed, or a qualitative evaluation was performed by gathering data from available reports and interviews with project personnel.

Outline of Report

The remainder of this report is organized as follows:

- Chapter 2 – Detailed Quantitative Evaluations
- Chapter 3 – Simpler Quantitative Evaluation
- Chapter 4 – Qualitative Evaluations
- Chapter 5 – Conclusions
- Chapter 6 – References

Chapter 2. Detailed Quantitative Evaluations

Detailed quantitative evaluations of the safety effectiveness of countermeasures or countermeasure combinations were performed for three RSIP projects. The specific countermeasures or countermeasure combinations that were evaluated included:

- RSIP Project 27 – MDOT: Dual application of centerline and shoulder rumble strips
- RSIP Project 36 – IDOT: Improved signing and delineation at horizontal curves
- RSIP Project 37 – La DOTD: Improved signing and pavement markings at intersections

The results of each safety evaluation are provided below. For each evaluation, a description of the RSIP project is provided, followed by descriptive statistics, analysis approach, analysis results, and interpretation of results. A summary of the evaluations of the three projects is presented at the end of this chapter.

RSIP Project 27

Agency: Mississippi Department of Transportation (MDOT)

Focus of Evaluation: Dual Application of Centerline and Shoulder Rumble Strips

Project Background

MDOT received funding through the RSIP to implement two types of safety improvements along rural state highways: the installation of centerline rumble strips and a clear zone restoration project. These improvements focused on reducing the number and severity of lane departure crashes.

The total project cost for both safety improvements was approximately $2,407,480. In 2009, MDOT spent $1,602,700 on the installation of centerline rumble strips. The remaining funds were spent on the clear zone restoration project which included removal of roadside objects, regrading of side slopes, and installation of cable barrier, covering about 5 mi of roadway.

Table 3 shows the highways, counties, and beginning and end points for the centerline rumble strips installed as part of the RSIP project. The total project covered approximately 468 mi of rural two-lane roads, but centerline rumble strips were not installed along the entire lengths of highways listed in Table 3. It was estimated that approximately 350 miles of centerline rumble strips were installed through the RSIP project. At many of the locations where centerline rumble strips were installed, shoulder rumble strips were already present and, in many cases, recently installed (i.e., within a year or two of installation of the centerline rumble strips).

After assessing the overall safety improvements implemented through the RSIP project, it was determined that the focus of this safety evaluation should be on the locations where centerline rumble strips were installed on the same routes where shoulder rumble strips were present. It was further decided that the improvements from the clear zone restoration project covered only a few miles of roadway so an evaluation of this project by itself would likely yield unreliable results. Also, the improvements were unique from the centerline rumble strip installations and other improvements implemented through other RSIP projects, so the safety effectiveness of the clear zone project was not investigated.

Table 3. RSIP Project 27: Approximate Locations of Centerline Rumble Strip Installations from the RSIP in Mississippi

Route	Counties	Begin Termini	End Termini	Mileage
MS 1	Washington and Bolivar	Washington-Issaquena County Line	Bolivar-Coahoma County Line	90
MS 7	Humphreys, Leflore, Carroll, Grenada, Yalobusha, Lafayette, Marshall	Northern city limits of Belzoni	Marshall-Benton County Line	125
MS 8	Grenada	Leflore-Grenada County Line	Grenada-Calhoun County Line	40
MS 18	Rankin	Louis Wilson Road (Old MS 18)	Shell Oil Road	5
MS 27	Warren, Hinds, Copiah	Interstate 20	Northern city limits of Georgetown	60
MS 178	Marshall	Desoto-Marshall County Line	Western city limits of Holly Springs	15
MS 587	Lawrence, Marion	Sand Road	MS 586	25
US 49E	Holmes, Leflore	Yazoo-Holmes County Line	Southern city limits of Greenwood	38
US 61	Warren, Issaquena, Sharkey, Washington	Yazoo River Bridge	Beginning of 4-lane section, south of Leland, MS	70

Thus, treatment sites considered in this safety evaluation included sites on rural two-lane roads where the centerline and shoulder rumble strips were both installed. The centerline rumble strips were installed as part of the RSIP project, and the shoulder rumble strips were installed separately as part of a previous safety improvement within a few years of the installation of the centerline rumble strips. Table 4 shows the beginning and ending locations of routes used as treatment sites in the analysis.

Table 4. RSIP Project 27: Location of Treatment Sites Used in Analysis of Dual Application of Centerline and Shoulder Rumble Strips in Mississippi

Site No.	Route	Begin Termini			End Termini			Length (mi)
		Latitude	Longitude	Landmark	Latitude	Longitude	Landmark	
1	MS 1	33.86895	-91.01989	50 yds N of Rosedale Co Line	33.93449	-90.95056	Gunnison Corp. City Limit S	6.1
2	MS 1	33.94861	-90.93738	Gunnison Corp. City Limit N	33.98915	-90.90062	150 ft North of Bunge Rd	3.5
3	MS 7	33.48773	-90.32449	Ita Bena Corp City Limit/0.1 mi S of CR 514	33.39170	-90.31304	CR 511	7.1
5	MS 7	34.11651	-89.64865	0.8 mi N of CR 7	33.95933	-89.69366	0.6 mi N of CR 71(Mount Grove MB Church)	11.3
6	MS 7	34.72965	-89.46450	400 ft from MS 4	34.65681	-89.45878	550 ft N of Old MS 7	5.0
7	MS 8	33.78049	-89.76070	Grenada City Limit	33.76251	-89.50726	Grenada County Line	15.0
8	MS 27	31.97157	-90.25718	Beginning of NB passing lane	31.87526	-90.16793	500 ft N of MS 28 int.	8.6
9	US 61	33.09747	-90.88234	Sharkey County Line	32.97977	-90.82761	Anguilla Corp City Limit (Northern)	9.0
10	US 61	32.91724	-90.86683	Rolling Fork City Limit	32.96519	-90.82597	Anguilla Corp City Limit (Southern)	4.1
11	MS 587	31.34344	-89.97349	Ranch Rd	31.31425	-89.92480	Near Morgantown	4.0
12	MS 587	31.31175	-89.91358	Ballpark Ln	31.23504	-89.87185	W Division St	6.4

Nontreatment sites included in the analysis had similar characteristics to the treatment sites but had no rumble strips of any type present during the entire analysis period. All nontreatment sites were rural two-lane highways that had similar geometrics and traffic volumes as the treatment sites, but no rumble strips. Table 5 shows the beginning and ending locations of routes used as nontreatment sites in the analysis.

Table 5. RSIP Project 27: Location of Nontreatment Sites Used in Analysis of Dual Application of Centerline and Shoulder Rumble Strips in Mississippi

Site No.	Route	Begin Termini			End Termini			Length (mi)
		Latitude	Longitude	Landmark	Latitude	Longitude	Landmark	
N1	MS 1	34.12048	-90.82658	Bolivar/ Coahoma County Line	34.21038	-90.71105	MS 322	9.1
N2	MS 3	32.84168	-90.43389	Rinalto Rd	32.70342	-90.52300	Edgeline rumble strips present	11.1
N3	MS 8	33.76251	-89.50726	Grenada County Line	33.81016	-89.34944	MS 9	9.8
N4	MS 8	33.80710	-90.88254	None	33.74943	-90.74514	Bishop Rd.	8.9
N5	MS 14	32.99576	-90.58855	JCT 149	32.97409	-90.82049	Anquilla Corp City Limit (Eastern)	14.0
N6	US 49	33.00318	-90.32137	Yazoo Co Line	32.90033	-90.38420	Coker Rd	8.8
N7	MS 149	32.86546	-90.45191	Carter Rd	33.09863	-90.49826	MS 49	23.6
N8	MS 587	31.52922	-90.09777	Emanuel Peyton Ln	31.34724	-89.97308	Centerline rumble strips present	16.4

Objective

Considerable research has been conducted on the safety effects of both centerline and shoulder rumble strips installed by themselves on separate roadways. Current state of the practice recommends that the safety effectiveness of countermeasures, when implemented in combination, should be estimated by multiplying their effectiveness together. This approach assumes that the safety effects of the individual countermeasures are independent, which may not be accurate. The objective of this evaluation was to estimate the safety effectiveness of centerline and shoulder rumble strips installed in combination on rural two-lane roads based on available crash data. Only one recent study (Olson et al., 2013) was found that evaluated the safety effectiveness of centerline and shoulder rumble strips installed along the same roadway.

Descriptive Statistics

A total of 19 sites—11 treatment and 8 nontreatment sites covering approximately 80.1 mi and 101.7 mi of roadway, respectively—were identified for inclusion in the analysis. All sites, both treatment and nontreatment, were on rural two-lane roads.

For this analysis, the "before-period" years include only those years prior to the installation of either shoulder or centerline rumble strips, and the "after-period" years include the years after installation of the centerline rumble strips. Crash data were generally available from 2005 to 2012; crashes occurring during the treatment installation year or years were excluded from analysis. Typically, for treatment sites, the before period was from 2005 to 2008, and the after period was from 2010 to 2012. Years in which shoulder rumble strips were present prior to the installation of the centerline rumble strips were not included in the analysis, so that the dual application of rumble strips could be compared to a base condition of no rumble strips. All centerline rumble strips were installed in 2009, so depending upon the installation year of the shoulder rumble strips, the number of years in the before period differed slightly for treatment sites. As a result, the number of years of available data varied by site--from 1 to 4 years of data per site in the before period but always 3 years per site in the after period. For the nontreatment sites, the number of years of available data was 7 years per site for each site over the entire study period.

Crash types considered in this safety analysis are those expected to be impacted by the installation of both centerline and shoulder rumble strips, namely:

- Single vehicle run-off-road (SVROR) crashes (right or left)
- Sideswipe-opposite direction crashes
- Head-on crashes

Three crash severity levels—total crashes (i.e., all severities), fatal and all injury crashes (FI), and fatal and serious injury crashes (FS)—were used and analyzed separately. Table 6 summarizes the treatment site data used in the analysis, separately for each period (before and after) and site. The table shows the number of segments within each site [corresponding to a change in average annual daily traffic (AADT) along the site]; the total site length; the number of years in the specific period; the average AADT for that period; and crash counts by severity level (total, FI, and FS)—these crash counts represent the combined SVROR, sideswipe-opposite direction, and head-on crash counts. The AADT for each site and year was calculated as the average AADT of the segments within each site-year. These average AADTs were then averaged over the before and after years, respectively, for each site.

Table 7 summarizes the corresponding data for nontreatment sites across the entire study period.

Table 6. RSIP Project 27: Summary Statistics for the Before and After Periods for Treatment Sites in Mississippi

Site No.	Number of Segments per Site	Total Site Length (mi)	Before Period					After Period				
			Number of Years	Average AADT	Total Crashes	FI Crashes	FS Crashes	Number of Years	Average AADT	Total Crashes	FI Crashes	FS Crashes
1	3	6.1	4	1,742	3	3	1	3	1,333	2	2	2
2	1	3.5	4	2,000	0	0	0	3	1,300	0	0	0
3	3	7.1	4	1,567	11	10	1	3	1,589	5	4	1
4	4	11.3	4	3,338	16	10	4	3	2,792	5	1	1
5	2	5.0	3	4,633	10	7	4	3	4,333	3	1	0
6	4	15.0	1	2,650	13	8	1	3	3,050	14	7	0
7	2	8.6	4	2,338	9	6	0	3	2,267	3	0	0
8	2	9.0	1	2,700	3	1	1	3	1,850	5	4	4
9	1	4.1	1	3,500	0	0	0	3	3,000	0	0	0
10	1	4.0	4	238	7	5	0	3	190	6	4	0
11	2	6.4	4	1,413	24	12	1	3	1,417	20	12	2
Total	N/A	80.1	N/A	N/A	96	62	13	N/A	N/A	63	35	10

Note: Crash types include: SVROR crashes (right or left), sideswipe-opposite direction crashes, and head-on crashes only.

Table 7. RSIP Project 27: Summary Statistics for Entire Study Period for Nontreatment Sites in Mississippi

Site No.	Number of Segments per Site	Total Site Length (mi)	Study Period				
			Number of Years	Average AADT	Total Crashes	FI Crashes	FS Crashes
N1	1	9.1	7	1,131	10	7	0
N2	2	11.1	7	1,629	14	5	1
N3	6	8.9	7	3,612	19	13	2
N4	3	9.8	7	1,819	18	7	0
N5	6	14.0	7	1,439	12	11	2
N6	2	8.8	7	2,579	11	6	0
N7	10	23.6	7	1,841	22	16	4
N8	3	16.4	7	301	21	14	2
Total	N/A	101.7	N/A	N/A	127	79	11

Note: Crash types include: SVROR crashes (right or left), sideswipe-opposite direction crashes, and head-on crashes only.

Analysis Approach

The safety effectiveness of this treatment was evaluated using the EB before/after method as outlined in the 14-step procedure of Appendix 9A in Chapter 9 of the HSM. The general procedure is as follows:

EB Estimation of the Expected Average Crash Frequency in the Before Period

Step 1 – Using the applicable SPF, calculate the predicted average crash frequency for site type *x* during each year of the before period. For roadway segments, the predicted average crash frequency will be expressed as crashes per site per year.

Step 2 – Calculate the expected average crash frequency for each site *i*, summed over the entire before period. For roadway segments, the expected average crash frequency will be expressed as crashes per site.

EB Estimation of the Expected Average Crash Frequency in the After Period in the Absence of the Treatment

Step 3 – Using the applicable SPF, calculate the predicted average crash frequency for each site *i* during each year *y* of the after period.

Step 4 – Calculate an adjustment factor to account for the differences between the before and after periods in duration and traffic volume at each site *i*.

Step 5 – Calculate the expected average crash frequency for each site *i*, over the entire after period in the absence of the treatment.

Estimation of Treatment Effectiveness

Step 6 – Calculate an estimate of the safety effectiveness of the treatment at each site *i* in the form of an odds ratio.

Step 7 – Calculate the safety effectiveness as a percentage crash change at site *i*.

Step 8 – Calculate the overall effectiveness of the treatment for all sites combined, in the form of an odds ratio.

Step 9 – The odds ratio calculated in Step 8 is potentially biased. Calculate an adjustment to obtain an unbiased estimate of the treatment effectiveness in terms of an adjusted odds ratio.

Step 10 – Calculate the overall unbiased safety effectiveness as a percentage change in crash frequency across all sites.

Estimation of the Precision of the Treatment Effectiveness

Step 11 – Calculate the variance of the unbiased estimated safety effectiveness, express as an odds ratio.

Step 12 – To obtain a measure of the precision of the odds ratio, calculate its standard error as the square root of its variance.

Step 13 – Calculate the standard error of the safety effectiveness measure from Step 10.

Step 14 – Assess the statistical significance of the estimated safety effectiveness.

Note that all predicted crashes for each site-year were estimated on a per site basis by multiplying the SPF by site length in the above calculations.

Prior to implementing the EB method, the following points were addressed:

1. *Selecting an appropriate SPF:* It was decided to use the SPFs for total and FI severity levels for rural two-lane roads from S*afety Analyst*. The *Safety Analyst* SPFs predict crashes for all collision types combined.
2. *Obtaining the proportion of target crashes relevant to RSIP Project 27 evaluation (PR_1):* The proportions of both total and FI severity levels for the target crashes (SVROR, sideswipe-opposite direction, and head-on) were obtained from Table 10-4 in Chapter 10 of the HSM.
3. *Obtaining the proportion of FS out of FI crashes for this project (PR_2):* The proportion of FS out of FI crashes was calculated from the FI and FS crashes that occurred on all the nontreatment sites and the before treatment sites combined in the project database (a total of 90 site-years).
4. *Calibrating the SPFs to the local jurisdiction:* Calibration was performed separately for total and FI crashes using all the nontreatment sites and the before treatment sites combined in the project database (a total of 90 site-years).

The Safety Analyst SPFs for rural two-lane roads for total and FI severity levels have the general form:

$$\text{Predicted crashes/mi/yr} = \exp[a + b(\log_{10}\text{AADT})]$$

Figure 1. Equation 1 - General form of Safety Analyst SPF for rural two-lane roads for total and fatal and all injury severity levels.

where a and b are regression coefficients shown in Table 8 for each severity level (Total and FI).

Calibration factors (Cr) and proportions of target crashes are then used to adjust for local conditions as follows:

$$\text{Predicted crashes/mi/yr} = \{\exp[a + b(\log_{10}\text{AADT})]\} \times PR_1 \times PR_2 \times C_r$$

Figure 2. Equation 2 - General form of Safety Analyst SPF for rural two-lane roads adjusted for crash type and local conditions.

where PR1, PR2, and Cr are provided in Table 8 for each severity level.

Table 8. RSIP Project 27: SPF Coefficients, Target Crash Proportions, and Calibration Factors Used for Mississippi Data

Severity Level	Number of Site-Years[a]	Intercept (a)[b]	log_{10}AADT Coefficient (b)[b]	Overdispersion Parameter[b]	Proportion of Target Collision Type (PR_1)[c,d]	Proportion of FS/FI Crashes (PR_2)[a]	Calibration Factor (C_r)[a]
Total	90	-3.56	0.55	0.45	0.563	1.00	0.25
FI	90	-4.89	0.53	0.45	0.606	1.00	0.64
FS	90	-4.89	0.53	0.45	0.606	0.17	0.64

[a] Calculated from RSIP Project 27 data.

[b] From *Safety Analyst.*

[c] From HSM Chapter 10.

[d] Crash types include: SVROR crashes (right or left), sideswipe-opposite direction crashes, and head-on crashes only.

Note that PR2 is simply set equal to 1 for Total and FI crashes since it does not apply to that severity level. The SPF for FS crashes is based on that for FI crashes with the additional PR2 multiplier (17 percent of FI crashes were FS crashes in the database used for analysis—see point No. 3 above).

Analysis Results

The EB method was applied to estimate the safety effectiveness of the dual application of centerline and shoulder rumble strips in reducing target collision types including SVROR, sideswipe-opposite direction, and head-on crashes. Analyses were performed separately for total, FI, and FS severity levels. The analyses were based upon before and after crash data from 11 treatment sites, crash data from the 8 nontreatment sites, and Safety Analyst SPFs for rural two-lane roads. The analysis results are shown in Table 9. The statistics shown for each crash severity are:

- Number of treatment sites
- Total site length (miles)
- Percent change due to installation of dual application of centerline and shoulder rumble strips: estimate and standard error
- An indication of whether the treatment had a statistically significant effect on the crash severity level of interest at the 95-percent confidence level

Table 9. RSIP Project 27: Safety Effectiveness of Dual Application of Centerline and Shoulder Rumble Strips on Target Crashes in Mississippi

Crash Severity	Number of Treatment Sites	Total Site Length (mi)	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
Total	11	80.1	-35.0	10.5	Significant at 95% CL
FI	11	80.1	-39.6	12.3	Significant at 95% CL
FS	11	80.1	12.3	39.4	Not significant at 90% CL

Note: Crash types include: SVROR crashes (right or left), sideswipe-opposite direction crashes, and head-on crashes only.

The safety effectiveness estimates, which showed a reduction in total and FI target crashes, were statistically significant at the 95-percent confidence level, while the safety effectiveness estimate showed a resultant increase in FS target crashes that was not statistically significant at the 90-percent confidence level. However, there were only 13 FS target crashes in the before period and 10 FS target crashes in the after period. This small number of FS target crashes observed on the treatment sites contributed to the large standard error of the treatment effect, resulting in a non-statistically significant result for FS target crashes.

Interpretation of the Results

A comparison of the analysis results from this research to the estimated safety effectiveness of centerline and shoulder rumble strips from previous research and to the current state of practice for estimating the safety effectiveness of countermeasure combinations provides further insight into the reliability of all the results and current state of practice for safety evaluations. Previous studies (Torbic et al., 2009; Persaud et al., 2003) estimated the safety effectiveness of centerline rumble strips on rural two-lane roads. Torbic et al. estimated that the installation of centerline rumble strips on rural two-lane roads can be expected to reduce all severities (total) of head-on and opposite-direction sideswipe crashes (i.e., target crashes) by 30 percent (Crash Modification Factor; CMF = 0.70) and FI target crashes by 44 percent (CMF = 0.56). The expected safety effectiveness estimates for centerline rumble strips provided by Torbic et al. were based on the combined results of their research and that of Persaud et al. Similarly, previous studies (Torbic et al., 2009; Patel et al., 2007) quantified the safety effectiveness of shoulder rumble strips on rural two-lane roads. Torbic et al. estimated that the installation of shoulder rumble strips on rural two-lane roads can be expected to reduce all severities of SVROR crashes by 15 percent (CMF = 0.85) and FI SVROR crashes by 29 percent (CMF = 0.71). The expected safety effectiveness estimates for shoulder rumble strips provided by Torbic et al. were based on the combined results of their research and that of Patel et al. Only one recent study (Olson et al., 2013) was identified that investigated the safety effectiveness of the dual application of centerline and shoulder rumble strips on the same roadway. Based on a simple comparison of crash rates before and after treatment, Olson et al. estimated that the dual application of centerline and shoulder rumble strips reduced all severities of lane departure crashes by 66 percent (CMF = 0.34) and fatal and serious injury (FS) crashes by 56 percent (CMF = 0.44).

Based on the results of this research, the safety effectiveness of the dual application of centerline and shoulder rumble strips on target crashes (combined SVROR, sideswipe-opposite direction, and head-on crashes) on rural two-lane roads is estimated as follows:

- 35-percent reduction in total target crashes (SE = 10.5)
- 40-percent reduction in FI target crashes (SE = 12.3)
- 12-percent increase in FS target crashes (SE = 39.4); not statistically significant

The analysis results for total target crashes are in close agreement with current state of practice; however, there is considerable discrepancy between the two in the results for FI target crashes. For example, as mentioned earlier, the current state of practice recommends that the safety effectiveness of countermeasure combinations should be estimated by multiplying their effectiveness together. This approach suggests that the dual application of centerline and shoulder rumble strips would be expected to reduce total target crashes (i.e., all severity levels) by 40 percent based on the combined CMFs from Torbic et al. (2009). The combined CMF for the dual application of centerline and shoulder rumble strips would be calculated by multiplying the CMF for centerline rumble strips (CMF = 0.7) by the CMF for shoulder rumble strips (CMF = 0.85) to obtain a combined CMF of 0.60, which translates to an estimated 40-percent reduction in target crashes. Similarly, the combined CMF for target FI crashes equals 0.40 (0.56×0.71) which translates to an estimated 60-percent reduction in target FI crashes. Thus, for total target crashes there is a relatively small difference of -5 percent (35 - 40 percent) between the two safety effectiveness estimates, while for FI target crashes there is a larger difference of -20 percent (40 - 60 percent) between the two safety effectiveness estimates. It is interesting to note that for both severity levels, the results of this analysis estimated a smaller reduction in target crashes as compared to the safety effectiveness estimates calculated for countermeasure combinations using current state of practice procedures. This suggests that the current state of practice approach for estimating the safety effectiveness of countermeasure combinations may overestimate the effectiveness of countermeasure combinations.

When comparing the analysis results to the results of the recent study by Olson et al (2013), it is only reasonable to compare results for FI crashes. As indicated above, so few FS target crashes occurred on the treatment sites that the safety effectiveness estimate for FS target crashes was not statistically significant, and Olson et al. did not perform an analysis for all severity levels combined (i.e., total). Therefore, when comparing results for FI target crashes, there is a relatively large difference of -26 percent (40 - 66 percent) between the two safety effectiveness estimates. Part of the difference between the results can likely be attributed to differences in analysis approaches. In this research, the EB before/after method was used to estimate the percentage change in crash frequency, while Olson et al. compared crash rates before and after installation of the treatment.

It is also interesting to note that the analysis results provided by Olson et al. (2013) for FI target crashes (i.e., 66-percent reduction in FI target crashes) are very similar to the safety effectiveness estimate calculated for countermeasure combinations using current state of practice procedures (i.e., 60-percent reduction in FI target crashes).

RSIP Project 36

Agency: Illinois Department of Transportation (IDOT)

Focus of Evaluation: Delineation and Signing at Horizontal Curves

Project Background

IDOT developed a systematic, low-cost initiative to reduce crashes at high-risk curves on local roads in four Illinois counties in the Delta Region. Of the 16 Delta Region counties in Illinois, Franklin, Jackson, Randolph, and Williamson counties had the highest total fatal and serious injury curve-related crashes during a five-year analysis period prior to the RSIP project. Improvements planned for implementation through the RSIP project for these counties aimed at reducing roadway departure crashes on curves to reduce serious injuries and fatalities.

IDOT partnered with the four counties to identify high-risk curves based on crash data and local knowledge. Countermeasures were chosen by local agencies with the assistance of IDOT. The total project cost for the safety improvements was $430,000. Table 10 shows the types of countermeasures implemented in the four counties, the number of curves improved, and the cost of the improvements by county. At some locations, new signs were installed, while at other locations older signs were upgraded. The safety improvements were completed during calendar years 2009 and 2010.

Table 10. RSIP Project 36: RSIP Safety Improvements in Illinois by County

County	Countermeasures	Number of Curves Improved	Cost
Franklin	Advanced curve warning signs, speed plates, and chevrons	17[a]	$74,000
Jackson	Advanced curve warning signs, speed plates, and chevrons	9	$44,000
Randolph	Advanced curve warning signs, speed plates, chevrons, and raised pavement markings (RPMs)	21	$63,000
Williamson	Advanced curve warning signs and chevrons	37[b]	$249,000
Total			$430,000

[a] At two of the curves, some tree trimming and tree removal took place. At another curve, some existing guardrail was extended.

[b] At three curves, paved shoulders were to be installed.

As described in the Research Approach in Chapter 1, the research team conducted field visits to confirm the types of safety improvements completed at each treatment site. During the data collection trip to Illinois, the research team could not confirm that the safety improvements were completed at curves in Williamson County. Therefore, only the safety improvements implemented at curves in Franklin, Jackson, and Randolph Counties are included in this evaluation of delineation and signing at horizontal curves. Table 11 shows the location of the treated curves and the types of safety improvements implemented at each curve included in the safety evaluation. It should be noted that the research team was unable to confirm the characteristics of the treatment sites prior to installation of the safety improvements. As a result, assumptions about existing conditions were made based on IDOT's treatment description for each site and on the research team's post-installation field inspection.

Table 11. RSIP Project 36: Location of Treatment Sites in Illinois and Types of Safety Improvements

County	Site No.	Route	Latitude	Longitude	Countermeasures
Franklin	1	FAS 2863 (Bessie Rd)	38.00388	-88.81216	Add advanced warning, speed plates and chevrons
	2	FAS 873 (Akin Blacktop)	37.98761	-88.71155	Upgrade advanced warning, add speed plates, add chevrons
	3	FAS 873 (Akin Blacktop)	37.98538	-88.85292	Upgrade advanced warning, add speed plates, add chevrons
	4	FAS 868 (Ewing Rd)	38.08746	-88.81339	Add advanced warning signs
	5	FAS 1878 (Deering Rd)	37.91333	-88.89322	Upgrade advanced warning, speed plates and chevrons
	6	FAS 1878 (Deering Rd)	37.90676	-88.89964	Upgrade advanced warning signs
	7	FAS 1886 (Number 9 Blacktop)	37.88872	-88.86073	Add advanced warning signs and chevrons
	8	FAS 1886 (Number 9 Blacktop)	37.88059	-88.80361	Upgrade advanced warning and add chevrons
	9	FAS 1877 (Yellowbanks Rd)	37.95015	-88.99392	Upgrade advanced warning and add chevrons
	10	FAS 1972 (Peach Orchard Rd)	38.05281	-89.01185	Upgrade advanced warning signs
	11	FAS 1873A (Orient Rd)	37.91231	-88.86084	Upgrade warning signs and add chevrons
	12	FAU 9496 (Country Club Rd)	37.87682	-88.95136	Add advanced warning signs and chevrons
	13	FAS 876 (Freeman Spur Rd)	37.86339	-89.00713	Add advanced warning signs and chevrons
	14	FAS 869 (Elkville Blacktop)	37.87685	-89.13827	Upgrade advanced warning signs
	15	FAS 869 (Elkville Blacktop)	37.87867	-89.14231	Upgrade advanced warning, add speed plates, add chevrons
Jackson	1	FAS 1916 (Elkville Road)	37.90647	-89.24431	Upgrade advanced warning and add chevrons
	2	FAS 1919 (Boskeydell Rd)	37.67128	-89.21367	Upgrade advanced warning and speed plates and add chevrons
	3	FAS 919 (Giant City Road)	37.65337	-89.16955	Upgrade advanced warning signs, speed plates and chevrons
	4	FAS 917 (Town Creek Rd)	37.74844	-89.35211	Upgrade advanced warning signs, speed plates and chevrons
	5	FAS 2912 (Marina Road)	37.77795	-89.40972	Upgrade advanced warning signs, speed plates and chevrons
	6	CH 10 (Big Lake Road)	37.75174	-89.52092	Upgrade advanced warning signs
	7	CH 10 (Big Lake Road)	37.76917	-89.52713	Add advanced warning and speeds plates, and update chevrons
	8	CH 10 (Big Lake Road)	37.77853	-89.53449	Add advanced warning and speeds plates, and update chevrons
	9	CH 9 (Neunert Road)	37.71667	-89.48951	Upgrade advanced warning signs, speed plates and chevrons
Randolph	1	CH 1 (FAS 849)	38.00805	-89.82202	Upgrade advanced warning and speed plates, add chevrons and RPMs
	2	CH 1 (FAS 849)	38.00846	-89.82399	Upgrade advanced warning and speed plates, add chevrons and RPMs
	3	CH 1 (FAS 849)	38.01405	-89.82511	Upgrade advanced warning and speed plates, add chevrons and RPMs
	4	CH 1 (FAS 849)	38.01714	-89.83398	Upgrade advanced warning and speed plates, add chevrons and RPMs
	5	CH 1 (FAS 849)	38.06551	-89.83324	Upgrade advanced warning and speed plates, add chevrons and RPMs
	6	CH 1 (FAS 849)	38.06721	-89.84531	Upgrade advanced warning and speed plates, add chevrons and RPMs
	7	CH 1 (FAS 849)	38.07847	-89.84699	Upgrade advanced warning and speed plates, add chevrons and RPMs
	8	CH 1 (FAS 849)	38.08107	-89.84923	Upgrade advanced warning and speed plates, add chevrons and RPMs
	9	CH 1 (FAS 849)	38.19741	-89.84601	Upgrade advanced warning, add chevrons and RPMs
	10	CH 1 (FAS 849)	38.21327	-89.84835	Upgrade advanced warning and speed plates, add chevrons and RPMs
	11	CH 1 (FAS 849)	38.21711	-89.85127	Upgrade advanced warning sign and add chevrons
	12	CH 4 (FAS 862)	38.08864	-89.82124	Upgrade advanced warning, add chevrons and RPMs
	13	CH 3 (FAS 859)	38.00854	-89.78905	Upgrade advanced warning, add chevrons and RPMs
	14	CH 3 (FAS 859)	38.00441	-89.79291	Upgrade advanced warning, add chevrons and RPMs
	15	CH 2 (FAS 853 & 1870)	37.99927	-89.74601	Upgrade advanced warning and speed plates, add chevrons and RPMs
	16	CH 2 (FAS 853 & 1870)	37.96921	-89.74239	Upgrade advanced warning, add chevrons and RPMs
	17	CH 2 (FAS 853 & 1870)	37.95559	-89.74092	Upgrade advanced warning and speed plates, add chevrons and RPMs

Nontreatment sites included in the analysis had similar characteristics to the treatment sites but did not have recently installed or improved delineation and/or signing present. Typically, nontreatment sites considered in before/after safety evaluations have similar characteristics to the treatment sites, but the countermeasure being evaluated is not present at the nontreatment sites. However, because the treatment sites were relatively sharp curves, it was not realistic to find similar curves without any type of delineation and/or signing. Also, in many cases, the safety improvements at treatment sites involved upgrading existing advance warning signs, so advance warning signs were present at the treatment sites prior to the safety improvement being implemented as part of the RSIP project. Therefore, it was considered appropriate that the nontreatment sites have the type of delineation and/or signing present at the treated curves prior to the implementation of the RSIP project. Typically, the delineation and signing at the nontreatment sites was older and did not have the retroreflectivity qualities of the newer delineation and/or signing at the treatment sites. Most of the nontreatment sites (18 out of 22) had advance warning signs present, while only a few of the nontreatment sites (6 out of 22) had chevrons present. None of the nontreatment sites had RPMs. Table 12 shows the locations of the curves used as nontreatment sites in the analysis.

Table 12. RSIP Project 36: Location of Nontreatment Sites in Illinois

County	Site No.	Route	Latitude	Longitude
Franklin	N1	No 9 Blacktop Rd	37.89244	-88.87569
	N2	No 9 Blacktop	37.87788	-88.79598
	N3	Deering Rd	37.95612	-88.90534
	N4	Deering Rd	37.94758	-88.89925
	N5	Ruembler Crossing	37.95071	-88.92388
	N6	Freeman Spur Blacktop	37.87421	-88.97537
Jackson	N1	Mt Joy Rd	37.79177	-89.39721
	N2	Stave Mill Rd	37.78477	-89.36497
	N3	Stave Mill Rd	37.78126	-89.36036
	N4	Town Creek Rd	37.74827	-89.40489
	N5	Neunert Rd	37.70826	-89.50093
Randolph	N1	CH 10	38.14087	-89.84501
	N2	CH 18	38.19713	-89.80132
	N3	CH 18	38.19119	-89.79772
	N4	CH 2	37.95649	-89.69036
	N5	CH 2	37.93442	-89.62605
	N6	CH 2	37.99148	-89.74746
	N7	CH 5	37.94118	88.67037
	N8	CH 1	38.13162	-89.94522
	N9	CH 10	38.11039	-89.96031
	N10	St Leo’s Rd	38.10404	-90.00241
	N11	St Leo’s Rd	38.09123	-90.00363

Objective

The objective of this evaluation was to quantify the safety effectiveness of combinations of roadway delineation and signing treatments in reducing total crashes and SVROR crashes at horizontal curves on rural two-lane highways. Treatments varied by site and included installation or upgrade of curve warning signs, speed plates, chevrons, and raised pavement markers.

Descriptive Statistics

A total of 41 treatment and 22 nontreatment sites are included in this safety evaluation. Treatments were installed in 2009 in Franklin (15 sites) and Jackson (9 sites) Counties and in 2010 in Randolph County (17 sites). All crashes at each site were located either within the curve (or curves) of interest or within a 0.1-mi buffer zone on each end of the curve since crashes in this buffer area are often related to the curve. Crash and traffic volume data were obtained for years 2004 through 2012 for the analysis; thus the before period was either five- or six-years long and the after period was either two- or three-years long.

The evaluation focused on quantifying the safety effectiveness of the delineation and signing treatments on total crashes (i.e., all collision types combined) and SVROR crashes. Analyses were performed separately for three crash severity levels: Total, FI, and FS crashes.

Table 13 summarizes the treatment site data used in the analysis, separately for each period (before and after) and treatment site. The table provides the length and radius of the curve (or curves), lane width and shoulder width, the average AADT in the specific period, and total (i.e., all collision types combined) and SVROR crash counts, each by severity level (Total, FI, and FS crashes). Table 14 provides similar statistics for the nontreatment sites across the entire study period. Note that Table 13 and Table 14 provide information on lane and shoulder widths for reporting purposes only. This information was not considered in the analysis.

Analysis Approach

The safety effectiveness of the treatment combinations was evaluated using the EB before/after method similar to that discussed in the evaluation of RSIP project 27. Prior to implementing the EB method, the following points were addressed:

1. *Selecting an appropriate SPF:* It was decided to use the SPF for total severity level (i.e., all severity levels combined) for rural two-lane roads from Chapter 10 of the HSM. The SPF predicts crashes for all collision types combined for tangent sections of rural two-lane roads.
2. *Obtaining the proportion of FI and FS crashes for this project (PR_2):* The proportions of FI and FS severity levels for all collision types combined were calculated from those crashes that occurred on all the nontreatment sites and the before treatment sites combined in the project database (a total of 398 site-years).
3. *Obtaining the proportion of target crashes for total, FI, and FS crashes for this project (PR_1):* The proportions of target crashes (SVROR) to all collision types for total, FI, and FS severity levels were calculated based on those crashes that occurred on all the

nontreatment sites and the before treatment sites combined in the project database (a total of 398 site-years).

4. *Calibrating the SPFs to the local jurisdiction:* Calibration was performed for total crashes using all the nontreatment sites and the before treatment sites combined in the project database (a total of 398 site-years). Since a single base SPF was used, that calibration factor applies to all severity levels considered.

Table 13. RSIP Project 36: Summary Statistics for the Before and After Periods for Treatment Sites in Illinois

County	Site No.	Curve Length (mi)	Curve Radius (ft)	Lane Width (ft)	Shoulder Width (ft)	Before Period								After Period									
						Number of Years	AADT	Total Crashes			SVROR Crashes			Number of Years	AADT	Total Crashes			SVROR Crashes				
								Total	FI	FS	Total	FI	FS			Total	FI	FS	Total	FI	FS		
Franklin	1	0.310	350	10	2	5	200	0	0	0	0	0	0	3	175	0	0	0	0	0	0		
	2	0.155	101	11	1	5	850	1	0	0	0	0	0	3	325	0	0	0	0	0	0		
	3	0.310	1,703	10	2	5	850	2	0	0	2	0	0	3	1,100	1	0	0	1	0	0		
	4	0.361	1,760	10	2	5	650	2	1	0	1	0	0	3	800	2	1	1	1	0	0		
	5	0.220	1,105	11	1	5	1,200	4	1	1	1	1	1	3	1,900	1	1	1	1	1	1		
	6	0.149	1,650	10.5	1	5	1,200	2	1	1	2	1	1	3	1,900	8	2	0	6	2	0		
	7	0.238	230	11	1	5	900	2	0	0	0	0	0	3	850	2	2	2	2	2	2		
	8	0.105	1,650	10	1	5	400	0	0	0	0	0	0	3	500	0	0	0	0	0	0		
	9	0.539	880	10	2	5	900	8	2	2	2	2	2	3	1,000	3	1	1	3	1	1		
	10	0.113	212	10	1	5	550	3	0	0	1	0	0	3	650	0	0	0	0	0	0		
	11	0.098	948	12	1	5	950	0	0	0	0	0	0	3	450	0	0	0	0	0	0		
	12	0.310	358	11	1	5	950	0	0	0	0	0	0	3	800	1	1	0	1	1	0		
	13	0.153	639	10.5	1	5	1,350	2	1	0	2	1	0	3	1,350	0	0	0	0	0	0		
	14	0.180	398	10	5	5	1,400	16	4	0	1	0	0	3	1,650	0	0	0	0	0	0		
	15	0.084	476	10	5	5	1,400	1	0	0	0	0	0	3	1,650	1	0	0	0	0	0		
Jackson	1	0.170	952	11	2	5	1,700	1	0	0	0	0	0	3	1,550	0	0	0	0	0	0		
	2	0.516	352	10	2	5	2,000	10	3	1	3	2	0	3	1,500	3	1	0	3	1	0		
	3	0.217	1,120	11	2	5	1,950	6	3	1	3	3	1	3	1,800	7	1	0	3	0	0		
	4	0.196	588	12	1	5	2,550	0	0	0	0	0	0	3	2,350	6	1	0	2	1	0		
	5	0.083	219	10.5	1	5	400	1	1	0	0	0	0	3	600	2	1	0	2	1	0		
	6	0.140	81	10	1	5	75	0	0	0	0	0	0	3	50	0	0	0	0	0	0		
	7	0.180	144	10	1	5	225	0	0	0	0	0	0	3	250	0	0	0	0	0	0		
	8	0.297	268	10	1	5	225	0	0	0	0	0	0	3	250	2	1	0	2	1	0		
	9	0.240	683	10.5	1	5	325	2	0	0	0	0	0	3	275	0	0	0	0	0	0		

Table 13. RSIP Project 36: Summary Statistics for the Before and After Periods for Treatment Sites in Illinois (Continued)

County	Site No.	Curve Length (mi)	Curve Radius (ft)	Lane Width (ft)	Shoulder Width (ft)	Before Period								After Period							
						Number of Years	AADT	Total Crashes			SVROR Crashes			Number of Years	AADT	Total Crashes			SVROR Crashes		
								Total	FI	FS	Total	FI	FS			Total	FI	FS	Total	FI	FS
Randolph	1	0.165	453	11	2	6	550	1	1	0	0	0	0	2	500	1	0	0	1	0	0
	2	0.128	440	11	2	6	550	2	0	0	0	0	0	2	500	1	0	0	1	0	0
	3	0.190	538	11	3	6	550	0	0	0	0	0	0	2	500	0	0	0	0	0	0
	4	0.240	510	11	2	6	550	5	2	1	2	2	1	2	650	1	1	1	1	1	1
	5	0.190	615	11	3	6	650	4	0	0	2	0	0	2	700	0	0	0	0	0	0
	6	0.180	543	11	3	6	650	2	1	1	0	0	0	2	650	0	0	0	0	0	0
	7	0.158	796	11	3	6	700	1	1	1	1	1	1	2	650	0	0	0	0	0	0
	8	0.152	903	11	3	6	700	2	1	1	1	1	1	2	650	0	0	0	0	0	0
	9	0.250	1,471	11	3	6	2,050	5	1	1	3	1	1	2	2,450	2	1	1	0	0	0
	10	0.193	1,687	11	3	6	1,150	5	1	1	2	1	1	2	1,650	2	1	0	1	0	0
	11	0.194	1,203	11	3	6	1,150	0	0	0	0	0	0	2	1,650	1	1	0	1	1	0
	12	0.160	1,290	10.5	2	6	1,150	8	4	2	2	2	2	2	1,275	2	0	0	0	0	0
	13	0.310	1,123	10.5	3	6	950	2	0	0	1	0	0	2	1,050	2	1	1	1	1	1
	14	0.440	1,626	10	3	6	950	4	2	2	1	1	1	2	1,050	0	0	0	0	0	0
	15	0.380	470	9.5	2	6	550	5	2	2	1	2	2	2	600	1	1	0	1	1	0
	16	0.290	947	12	4	6	950	0	0	0	0	0	0	2	1,100	0	0	0	0	0	0
	17	0.290	888	10	4	6	750	0	0	0	0	0	0	2	1,100	1	0	0	0	0	0
All	N/A	9.274	N/A	N/A	N/A	N/A	N/A	109	33	18	34	21	15	N/A	N/A	53	19	8	34	15	6

Table 14. RSIP Project 36: Summary Statistics for the Entire Study Period for Nontreatment Sites in Illinois

County	Site No.	Curve Length (mi)	Curve Radius (ft)	Lane Width (ft)	Shoulder Width (ft)	Number of Years	Entire Study Period						
							AADT	Total Crashes			SVROR Crashes		
								Total	FI	FS	Total	FI	FS
Franklin	N1	0.078	260	10	1	8	931	1	0	0	0	0	0
	N2	0.136	1,586	9	1	8	438	1	0	0	1	0	0
	N3	0.177	682	10.5	2	8	1,000	14	2	0	6	2	0
	N4	0.072	425	10.5	3	8	1,000	13	6	3	9	5	2
	N5	0.066	87	10.5	0	8	275	4	2	1	2	1	1
	N6	0.249	920	10.5	1	8	1,025	5	1	0	2	1	0
Jackson	N1	0.083	165	9	1	8	278	0	0	0	0	0	0
	N2	0.045	116	9	2	8	519	2	0	0	0	0	0
	N3	0.044	85	10	1	8	519	1	0	0	0	0	0
	N4	0.263	700	10.5	2	8	1,206	14	4	1	6	3	1
	N5	0.199	907	10.5	1	8	306	3	2	2	3	2	2
Randolph	N1	0.254	1,007	11.5	2	8	838	1	1	0	1	1	0
	N2	0.159	457	10.5	2	8	475	0	0	0	0	0	0
	N3	0.149	536	12	2	8	475	0	0	0	0	0	0
	N4	0.234	908	11	4	8	688	2	1	0	1	1	0
	N5	0.129	1,113	11	3	8	1,450	5	3	1	3	2	1
	N6	0.185	859	9.5	3	8	563	0	0	0	0	0	0
	N7	0.317	977	9	0	8	381	0	0	0	0	0	0
	N8	0.264	716	11.5	2	8	269	1	0	0	1	0	0
	N9	0.214	910	11	2	8	250	0	0	0	0	0	0
	N10	0.309	792	9.5	1	8	463	4	1	1	1	0	0
	N11	0.451	930	9.5	2	8	463	1	0	0	0	0	0
All		4.077	N/A	N/A	N/A	N/A	N/A	72	23	9	36	18	7

The HSM SPF for rural two-lane roads for all severity levels combined (total) has the general form:

$$\text{Predicted crashes/site/yr} = \text{AADT} \times \text{Lc} \times 365 \times 10^{-6} \times e^{(-0.312)}$$

Figure 3. Equation 3 - General form of HSM SPF for rural two-lane roads for all severity levels combined (total).

where AADT is the average annual daily traffic (veh/day) and Lc is the length of roadway segment in miles.

The value of the overdispersion parameter (k) associated with the SPF for rural two-lane roadway segments is a function of the roadway segment length and is calculated as:

$$k = \frac{0.236}{Lc}$$

Figure 4. Equation 4 - Overdispersion parameter.

The CMF for horizontal curvature (CMF_{HC}), calibration factors, and crash proportions are used to adjust the base SPF for local conditions as follows for selected severity levels:

$$\text{Predicted crashes/site/yr} = [AADT \times Lc \times 365 \times 10^{-6} \times e^{(-0.312)}] \times PR_1 \times PR_2 \times CMF_{HC} \times C_r$$

Figure 5. Equation 5 - General form of HSM SPF for rural two-lane roads adjusted for crash type, horizontal curvature, and local conditions.

where PR_1, PR_2, and C_r are provided in Table 15 for each collision type and severity level.

Table 15. RSIP Project 36: Target Crash Proportions and Calibration Factors Used for Illinois Data

Collision Type	Severity Level	Number of Site-Years[a]	Number of Crashes	Proportion of Target Collision Type (PR_1)[a,b]	Proportion of Crashes (PR_2)[a,c]	Calibration Factor (C_r)[a]
All	Total	398	181	1.00	1.00	6.7
	FI	398	56	1.00	0.31	
	FS	398	27	1.00	0.15	
SVROR	Total	398	70	0.39	1.00	
	FI	398	39	0.70	0.31	
	FS	398	22	0.81	0.15	

From RSIP 36 data—control sites and before-period treatment sites.
[b] Proportion of SVROR crashes out of corresponding all-collision crashes.
[c] Proportion of FI and FS crashes relative to total crashes based on all-collision crashes only.

CMFHC adjusts the crash prediction to horizontal curves and was developed to represent the manner in which crash experience on curved alignments differs from that of tangents. CMF3r is calculated as a function of curve length and curve radius using Equation (10-13) in HSM Chapter 10:

$$CMF_{HC} = \frac{(1.55xL_C + \left(\frac{80.2}{R}\right) - (0.012xS)}{(1.55xL_C)}$$

Figure 6. Equation 6 - CMF for horizontal curves on rural two-lane highways.

By including the horizontal curve CMF in the crash prediction, the analysis approach accounts for the sharpness of each curve in the estimation of the expected safety effectiveness of the delineation and signing treatments.

Analysis Results

The EB before/after method was applied to estimate the safety effectiveness of combinations of roadway delineation and signing treatments. The analyses were based on before and after crash data from 41 treatment curves on rural two-lane roads, crash data from 22 nontreatment curves, and the HSM SPF for rural two-lane road segments. The EB before/after analysis was performed for the following combinations:

- Curves on rural two-lane roads
  - Total crashes, all collision types combined
  - FI crashes, all collision types combined
  - FS crashes, all collision types combined
- Curves on rural two-lane roads
  - Total SVROR crashes
  - FI SVROR crashes
  - FS SVROR crashes

The analysis results for all collision types combined are shown in Table 16; those for SVROR crashes are shown in Table 17. The statistics shown in each table for each crash severity are:

- Number of treatment curves
- Total curve length (mi)
- Percent change in crash frequency due to a combination of roadway delineation and signing treatments: estimate and standard error
- An indication of whether the treatment had a statistically significant effect on the frequency of crash type and severity level of interest at the 95-percent confidence level

Table 16. RSIP Project 36: Safety Effectiveness of Horizontal Curve Delineation and Signing on Total Crashes in Illinois

Crash Severity	Number of Treatment Sites	Total Curve Length (mi)	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
Total	41	9.274	-9.9	12.85	Not significant at 90% CL
FI	41	9.274	6.9	25.25	Not significant at 90% CL
FS	41	9.274	-6.0	33.77	Not significant at 90% CL

Table 17. RSIP Project 36: Safety Effectiveness of Horizontal Curve Delineation and Signing on SVROR Crashes in Illinois

Crash Severity	Number of Treatment Sites	Total Curve Length (mi)	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
Total SVROR	41	9.274	68.7	30.40	Significant at 95% CL
FI SVROR	41	9.274	27.8	33.94	Not significant at 90% CL
FS SVROR	41	9.274	-14.4	35.39	Not significant at 90% CL

The results in Table 16 and Table 17 show two or three prevalent trends. First, the direction of the safety effectiveness values is not consistent across the severity types and, in some cases, is counterintuitive. The analyses of total, FS, and FS SVROR crashes suggest that the delineation and signing treatment combinations resulted in a decrease in crashes, while the analyses of FI, total SVROR, and FI SVROR crashes suggest that the delineation and signing treatments resulted in an increase in crashes. Second, only one of the results (total SVROR) suggests a statistically significant change in crashes occurred at the 90-percent confidence level. None of the other estimates of the safety effectiveness of the delineation and signing treatment combinations were statistically significant at the 90-percent confidence level. Third, the standard error of the treatment effect was large compared to the estimate in all analyses, directly resulting in non-statistically significant results.

Interpretation of the Results

The analysis does not provide reliable estimates of the safety effectiveness of the delineation and signing treatment combinations installed on curves on rural two-lane highways in Illinois as part of the RSIP project. The analysis results vary and in some cases are counterintuitive. A number of reasons may explain the varying trends from the analysis results, including:

1. Because the safety improvements were installed on relatively short segments of roadway, the overall length of roadways included in the analysis that were improved was relatively small. Thus, the overall number of curves, length of roadway, and associated crash data were insufficient to reliably estimate the safety effectiveness of the delineation and signing treatments installed as part of this project.
2. Many of the treatment combinations involved upgrading existing advance warning signs. Because advance warning signs were present in the before condition, it is likely that upgrading signs has a smaller incremental safety effect than adding new signs. Estimates of smaller incremental effects on safety are more difficult to quantify than larger effects.
3. A wide range of treatment combinations were installed at different curves. Because the same types of treatment combinations were not applied at each site, this likely added to the variability in the results.
4. Because there was a wide range of treatment combinations installed, it was difficult to determine the appropriate characteristics to use in defining and selecting appropriate nontreatment sites for calibration purposes. Several of the nontreatment sites had advance warning signs present, and a few of the nontreatment sites had chevrons presents. This too could have contributed to the variability in the data. It is possible that the delineation and signing treatments provided drivers with a false sense of security to be able to negotiate the curves at higher speeds, and thus resulted in an increase in crashes; but this does not completely explain why the results for total (all collisions combined) and SVROR crashes differ across the three severity levels (i.e., for some severity levels the results indicate a reduction in crashes, while for other severity levels the results indicate an increase in crashes).

The lack of reliable estimates of the safety effectiveness of the delineation and signing treatments based on this study does not indicate that the treatment combinations are ineffective at reducing crashes at horizontal curves on rural two-lane roads, but rather that there is insufficient evidence at this time to determine their effectiveness.

RSIP Project 37

Agency: Louisiana Department of Transportation and Development (La DOTD)

Focus of Evaluation: Improved Signing and Pavement Markings at Intersections

Project Background

LaDOTD developed a strategic plan to reduce crashes at high-crash intersections throughout rural Louisiana. Low-cost safety improvements were targeted for installation at 89 stop-controlled intersections and 15 signalized intersections. At the stop-controlled intersections, the primary safety improvements included oversized stop signs, oversized intersection warning signs, route signs, junction auxiliary signs, and new stop bars. At the signalized intersections, the primary safety improvements included installation of back plates for the signal heads, 12-in LED lens, retiming of clearance intervals, elimination of flashing operation during night conditions, intersection warning signs, and route marker signs. The total cost of the safety improvements implemented under the RSIP was $1,000,653. All of the safety improvements were completed during 2010.

This safety evaluation focused on estimating the safety effectiveness of treatments implemented at rural stop-controlled intersections in reducing intersection and intersection-related crashes. Of the 89 stop-controlled intersections improved as part of the RSIP project, 36 treatment sites were included in the safety evaluation based on the geographical locations of the improved intersections and availability of treatment type, traffic volume, and crash data for the analysis. Table 18 shows the locations of the treated intersections and the type of improvements installed.

Seven nontreatment sites included in the analysis had similar characteristics to the treatment sites, but none of the sites had oversized signs, and only one site had route marker signs present on the major road.

Objective

The objective of this evaluation was to quantify the safety effectiveness of combinations of treatments installed in reducing total crashes and target collision types including angle, rear-end, and turning crashes at rural stop-controlled intersections. Treatments varied by intersection and included oversized stop signs, oversized intersection warning signs, route signs, junction auxiliary signs, and new stop bars.

Descriptive Statistics

A total of 36 treatment and 7 nontreatment sites are included in the safety evaluation.

All treatments were installed in 2010. Crash and traffic volume data were obtained for years 2006 through 2012 for analysis. For all treatment sites, the before period is from 2006 through 2009. The after period consists of two years—2011 and 2012.

All crash types were considered in the analysis, as well as target crashes which included rear-end, right-angle, and turning crashes. Analyses were performed separately for two crash severity levels: total and FI. No severity information was available to identify FS crashes.

Table 19 summarizes the treatment site data used in the analysis, separately for each period (before and after) and treatment intersection. The table provides the average major- and minor-route AADTs in the specific period, and crash counts (total and FI crashes; all collision types combined) for each intersection. Table 20 provides similar statistics for total and FI crashes (all collision types combined) for the nontreatment intersections across the entire study period. Similarly, Table 21 summarizes target crash counts for the treatment sites in the before and after periods, and Table 22 summarizes target crash counts for the nontreatment sites across the entire study period.

Table 18. RSIP Project 37: Location of Treatment Sites in Louisiana and Types of Safety Improvements

Site No.	Number of Legs	Roadway Type	Major Route	Minor Route	Major Route: Intersection Warning Signs	Major Route: Route Marker Signs	Minor Route: Intersection Warning Signs	Minor Route: Stop Sign	Minor Route: Stop Bar
1	3	2-lane	LA 1	LA 3170	na	New	Oversized	Oversized double stop signs	New
2	3	Multilane	US 61[a]	LA 626	na	na	Oversized	Oversized	na
3	3	Multilane	US 61	LA 628	na	New	Oversized	na	New
4	3	Multilane	LA 3127	LA 3160	na	New	Oversized	na	New
5	3	Multilane	LA 3127	LA 3142	Na	New	Oversized	na	New
6	3	2-lane	LA 18[a]	LA 20	Oversized	New	Oversized	na	New
7	3	2-lane	LA 20	LA 643	Oversized	New	Oversized	Oversized	
8	3	2-lane	LA 20	LA 644	Oversized	New	Oversized	Oversized	New
9	3	2-lane	LA 3125	LA 3214	Oversized	New	Oversized	Oversized	New
10	3	2-lane	LA 182	LA 358	Oversized double advanced warning in one direction	New	Oversized	Oversized	na
11	3	Multilane	US 190	LA 103 SB	na	New	Oversized	na	na
12	4	2-lane	LA 76	LA 411	na	New	Oversized	Oversized	na
13	3	2-lane	LA 20	LA 307	Oversized advanced warning with LED beacon in both directions	New	Oversized	Oversized	New
14	3	2-lane	LA 84	LA 459	Oversized	New	Oversized	Oversized	New
15	4	2-lane	US 165[a]	LA 124	na	New	Oversized	Oversized	New
16	3	2-lane	LA 16	LA 22	Oversized	New	Oversized	Oversized	na
17	3	2-lane	LA 16	LA 444	na	New	Oversized	Oversized	na
18	3	2-lane	LA 16	LA 42	na	New	Oversized	Oversized	na
19	3	2-lane	LA 16	LA 447	Oversized advanced warning with LED beacon in both directions	New	Oversized	Oversized	New
20	4	2-lane	LA 42	LA 63	Oversized	New	na	Oversized	New
21	4	2-lane	LA 43[a]	LA 442	Oversized	New	Oversized	Oversized	New
22	4	2-lane	LA 10	LA 67	na	New	Oversized	Oversized	na
23	3	2-lane	US 167	LA 748	Oversized	New	Oversized	Oversized	New
24	3	2-lane	LA 85	LA 674	na	New	Oversized	Oversized	New
25	3	Multilane	LA 70	LA 3120	Oversized double advanced warning	New	na	Oversized	na
26	3	2-lane	US 71[a]	LA 1177	na	New	Oversized	Oversized	na
27	4	2-lane	LA 10[a]	LA 67	na	New	na	Oversized	na
28	3	2-lane	LA 22[a]	LA 70	na	New	na	Oversized	na
29	4	2-lane	LA 44	LA 941	na	New	Oversized	Oversized	na
30	4	Multilane	US 190	LA 741	Oversized (one direction)	New	Oversized	Oversized	na
31	3	2-lane	LA 31	LA 355	na	New	na	na	na
32	4	2-lane	LA 182[a]	Duchamp RD	na	New	Oversized	Oversized	na
33	3	2-lane	LA 10	LA 25	na	New	Oversized	Oversized	na
34	3	2-lane	LA 25[a]	LA 430	Oversized	New	Oversized	Oversized	na
35	4	2-lane	LA 25	LA 438	Oversized	New	Oversized	Oversized	na
36	4	2-lane	LA 62[a]	LA 436	Oversized	New	Oversized	Oversized	na

[a] Overhead flashers present facing all directions/approaches.
na = information not available.

Table 19. RSIP Project 37: Summary Statistics for the Before and After Treatment Periods for Treatment Intersections in Louisiana—All Collision Types

Site No.	Major Route	Minor Route	Before Period: 4 years (2006-2009)				After Period: 2 years (2011-2012)			
			Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes	Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
1	LA 1	LA 3170	2,287	6,151	1	0	1,672	5,680	0	0
2	US 61	LA 626	32,126	3,734	19	7	31,440	3,084	2	0
3	US 61	LA 628	26,704	1,305	2	1	27,374	1,774	1	0
4	LA 3127	LA 3160	13,145	2,083	6	2	13,743	1,851	1	0
5	LA 3127	LA 3142	6,544	5,471	5	1	7,586	5,441	2	0
6	LA 18	LA 20	2,679	6,129	4	0	2,977	4,435	1	1
7	LA 20	LA 643	6,654	3,461	6	1	7,381	3,148	0	0
8	LA 20	LA 644	6,654	4,234	16	5	7,381	4,024	9	5
9	LA 3125	LA 3214	4,618	2,908	4	1	4,917	2,673	0	0
10	LA 182	LA 358	25,476	2,493	6	2	21,358	1,926	1	1
11	US 190	LA 103 SB	16,908	7,205	1	1	17,030	6,586	0	0
12	LA 76	SIDNEY (LA 411)	732	2,620	4	3	701	2,855	0	0
13	LA 20	LA 307	6,654	2,748	7	1	7,381	2,757	2	0
14	LA 84	LA 459	4,142	1,051	8	3	3,608	859	0	0
15	US 165	LA 124	4,977	961	7	4	4,425	784	0	0
16	LA 16	LA 22	6,450	7,041	3	2	7,106	7,892	1	1
17	LA 16	LA 444	5,104	2,790	2	0	5,627	2,972	0	0
18	LA 16	LA 42	5,104	5,273	4	2	5,627	5,956	0	0
19	LA 16	LA 447	4,992	6,606	19	9	5,623	6,173	3	1
20	LA 42	LA 63	3,414	4,723	3	1	4,603	6,167	0	0
21	LA 43	LA 442	5,407	2,709	6	5	5,610	2,704	1	0
22	LA 10	LA 67 (E JCT) S.	3,073	4,515	6	3	5,590	4,217	0	0
23	US 167	LA 748	15,438	1,857	6	2	17,133	2,068	0	0
24	LA 85	LA 674	596	3,257	5	1	641	3,627	1	0
25	LA 70	LA 3120	17,375	2,748	1	1	21,422	3,138	4	3
26	US 71	LA 1177	4,155	328	0	0	4,533	291	0	0
27	LA 10	LA 67 (W JCT) N.	4,124	9,162	4	2	4,613	8,784	1	0
28	LA 22	LA 70	16,241	16,188	114	34	18,438	16,315	41	14

Table 19. RSIP Project 37: Summary Statistics for the Before and After Treatment Periods for Treatment Intersections in Louisiana—All Collision Types (Continued)

Site No.	Major Route	Minor Route	Before Period: 4 years (2006-2009)				After Period: 2 years (2011-2012)			
			Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes	Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
29	LA 44	LA 941	9,333	3,470	18	9	10,362	3,188	1	0
30	US 190	LA 741	12,718	1,318	12	9	12,842	1,102	7	2
31	LA 31	LA 355	2,039	4,008	3	0	2,151	4,497	2	2
32	LA 182	DUCHAMP RD	12,500	3,519	19	11	13,278	3,856	18	9
33	LA 10	LA 25	4,648	9,922	2	2	3,311	7,228	0	0
34	LA 25	BENE (LA 430)	4,984	5,166	4	1	3,465	3,665	0	0
35	LA 25	LA 438	2,479	805	7	3	1,888	724	0	0
36	LA 62	LA 436	2,185	1,149	3	1	2,234	978	1	0
Total	N/A	N/A	N/A	N/A	337	130	N/A	N/A	100	39

Table 20. RSIP Project 37: Summary Statistics for the Entire Study Period for Nontreatment Intersections in Louisiana—All Collision Types

Site No.	Number of Legs	Roadway Type	Major Route	Minor Route	Entire Study Period: 6 years (2006-2012 excluding 2010)			
					Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
N1	3	Multilane	US 165	LA 112	5,956	997	5	2
N2	3	2-lane	LA 29	LA 1161	7,239	2,613	18	7
N3	3	Multilane	LA 3127	LA 3141	6,891	1,803	6	3
N4	3	2-lane	LA 31	LA 354	2,076	926	5	3
N5	3	2-lane	LA 31	LA 341	3,842	1,877	6	3
N6	3	2-lane	LA 31	LA 351	6,618	3,029	4	2
N7	3	Multilane	US 71	US 167	3,841	1,175	2	2
Total	N/A	N/A	N/A	N/A	N/A	N/A	46	22

Table 21. RSIP Project 37: Summary Statistics for the Before and After Treatment Periods for Treatment Intersections in Louisiana—Target Crashes

Site No.	Major Route	Minor Route	Before Period: 4 years (2006-2009)				After Period: 2 years (2011-2012)			
			Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes	Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
1	LA 1	LA 3170	2,287	6,151	1	0	1,672	5,680	0	0
2	US 61	LA 626	32,126	3,734	9	5	31,440	3,084	1	0
3	US 61	LA 628	26,704	1,305	2	1	27,374	1,774	0	0
4	LA 3127	LA 3160	13,145	2,083	2	1	13,743	1,851	0	0
5	LA 3127	LA 3142	6,544	5,471	3	1	7,586	5,441	0	0
6	LA 18	LA 20	2,679	6,129	1	0	2,977	4,435	1	1
7	LA 20	LA 643	6,654	3,461	2	0	7,381	3,148	0	0
8	LA 20	LA 644	6,654	4,234	9	3	7,381	4,024	6	2
9	LA 3125	LA 3214	4,618	2,908	2	1	4,917	2,673	0	0
10	LA 182	LA 358	25,476	2,493	2	0	21,358	1,926	1	1
11	US 190	LA 103 SB	16,908	7,205	0	0	17,030	6,586	0	0
12	LA 76	SIDNEY (LA 411)	732	2,620	2	1	701	2,855	0	0
13	LA 20	LA 307	6,654	2,748	6	1	7,381	2,757	1	0
14	LA 84	LA 459	4,142	1,051	5	2	3,608	859	0	0
15	US 165	LA 124	4,977	961	5	3	4,425	784	0	0
16	LA 16	LA 22	6,450	7,041	0	0	7,106	7,892	0	0
17	LA 16	LA 444	5,104	2,790	0	0	5,627	2,972	0	0
18	LA 16	LA 42	5,104	5,273	3	1	5,627	5,956	0	0
19	LA 16	LA 447	4,992	6,606	6	5	5,623	6,173	3	1
20	LA 42	LA 63	3,414	4,723	1	0	4,603	6,167	0	0
21	LA 43	LA 442	5,407	2,709	5	4	5,610	2,704	0	0
22	LA 10	LA 67 (E JCT) S.	3,073	4,515	3	1	5,590	4,217	0	0
23	US 167	LA 748	15,438	1,857	4	2	17,133	2,068	0	0
24	LA 85	LA 674	596	3,257	1	0	641	3,627	0	0
25	LA 70	LA 3120	17,375	2,748	0	0	21,422	3,138	2	1
26	US 71	LA 1177	4,155	328	0	0	4,533	291	0	0
27	LA 10	LA 67 (W JCT) N.	4,124	9,162	3	2	4,613	8,784	1	0
28	LA 22	LA 70	16,241	16,188	81	25	18,438	16,315	37	14

Table 21. RSIP Project 37: Summary Statistics for the Before and After Treatment Periods for Treatment Intersections in Louisiana—Target Crashes (Continued)

Site No.	Major Route	Minor Route	Before Period: 4 years (2006-2009)				After Period: 2 years (2011-2012)			
			Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes	Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
29	LA 44	LA 941	9,333	3,470	10	6	10,362	3,188	1	0
30	US 190	LA 741	12,718	1,318	10	8	12,842	1,102	7	2
31	LA 31	LA 355	2,039	4,008	0	0	2,151	4,497	1	1
32	LA 182	DUCHAMP RD	12,500	3,519	16	8	13,278	3,856	14	9
33	LA 10	LA 25	4,648	9,922	0	0	3,311	7,228	0	0
34	LA 25	BENE (LA 430)	4,984	5,166	4	1	3,465	3,665	0	0
35	LA 25	LA 438	2,479	805	6	2	1,888	724	0	0
36	LA 62	LA 436	2,185	1,149	2	1	2,234	978	0	0
Total	N/A	N/A	N/A	N/A	206	85	N/A	N/A	76	32

Table 22. RSIP Project 37: Summary Statistics for the Entire Study Period for Nontreatment Intersections in Louisiana—Target Crashes

Site No.	Major Route	Minor Route	Entire Study Period: 6 years (2006-2012 excluding 2010)			
			Average $AADT_{major}$	Average $AADT_{minor}$	Total Crashes	FI Crashes
N1	US 165	LA 112	5,956	997	2	1
N2	LA 29	LA 1161	7,239	2,613	13	6
N3	LA 3127	LA 3141	6,891	1,803	3	2
N4	LA 31	LA 354	2,076	926	2	1
N5	LA 31	LA 341	3,842	1,877	3	2
N6	LA 31	LA 351	6,618	3,029	3	2
N7	US 71	US 167	3,841	1,175	1	1
Total	N/A	N/A	N/A	N/A	27	15

Analysis Approach

The 43 Louisiana intersections were located on either rural two-lane roads or multilane highways and had either 3 or 4 legs; their breakdown by those characteristics is shown in Table 23.

Table 23. RSIP Project 37: Breakdown of Louisiana Intersections by Facility Type and Number of Legs

Intersection Type	Facility Type and Number of Legs				All Intersections
	Rural Two-Lane Roads		Rural Multilane Roads		
	3 Legs	4 Legs	3 Legs	4 Legs	
Treatment	19	10	6	1	36
Nontreatment	4	0	3	0	7
All Intersections	23	10	9	1	43

Based on the site distribution by facility type and number of legs shown above, the safety evaluation was performed for the following three combinations:

- Three-leg intersections on rural two-lane roads
- Four-leg intersections on rural two-lane roads
- Three-leg intersections on multilane highways

No safety evaluation was performed based on the single four-leg intersection on a multilane highway (Site No. 30).

The safety effectiveness of the treatment combinations was evaluated using the EB before/after method similar to that discussed in the evaluation of RSIP project 27. Prior to implementing the EB method, the following points were addressed:

1. *Selecting appropriate SPFs:* The SPFs for intersections on rural two-lane roads and multilane highways from Chapters 10 and 11 of the HSM were selected for total and FI crashes. The coefficients of these SPFs vary by facility type and number of intersection approach legs.
2. *Obtaining the proportion of target crashes (PR_1) relevant to RSIP Project 37 evaluation:* The proportions of both total and FI severity levels for the target crashes (rear-end, right-angle, and turning crashes) were calculated based on the total and FI crashes (all collision types combines and target crashes only) that occurred on all nontreatment sites and the before treatment sites combined in the project database. These proportions were calculated separately for each facility type and intersection number of legs, with one exception.
3. *Obtaining the proportion of FI out of total crashes (PR_2) for this project for two-lane roads, separately for three-leg and four-leg intersections:* Where needed, the proportion of FI out of total crashes (all collision types combined) was calculated from the total and FI crashes that occurred on all the nontreatment sites and the before treatment sites combined in the project database (a total of 125 site-years for three-leg intersections and 52 site-years for four-leg intersections on rural two-lane roads).

4. *Calibrating the SPFs to the local jurisdiction:* Calibration was performed separately for total and FI crashes (all collision types combined), facility type, and number of intersection legs, using all the nontreatment intersections and the before treatment intersections combined in the project database.

The HSM SPFs for intersections on rural two-lane and rural multilane roads for total and FI severity levels have the general form:

$$\text{Predicted crashes/yr} = \exp[a + b(\log_{10}AADT_{Major}) + c(\log_{10}AADT_{Minor})]$$

Figure 7. Equation 7 - Equation 6. General form of HSM SPF for intersections on rural two-lane and rural multilane roads for total and fatal and all injury severity levels.

where a, b, and c are regression coefficients shown in Table 24. These coefficients apply to base conditions and vary by facility type and number of intersection legs, separately for each severity level (total and FI).

CMFs, calibration factors, and proportions of target crashes are then used to adjust for local conditions as follows:

$$\text{Predicted crashes/yr} = \{\exp[a + b(\log_{10}AADT_{Major}) + c(\log_{10}AADT_{Minor})]\} \times PR_1 \times PR_2 \times CMF_{Combined} \times C_r$$

Figure 8. Equation 8 - General form of HSM SPF for intersections on rural two-lane and rural multilane roads adjusted for crash type, combined CMFs, and local conditions.

where PR_1, PR_2, and C_r are provided in Table 24 for combination of facility type, number of legs, and severity level; and $CMF_{Combined}$ is provided in Table 25. Table 26 provides the combined crash modification factors for nontreatment sites.

Note that PR_2 is equal to 1 for total and FI crashes in those cases where a specific SPF is provided in the HSM for that severity level. The $CMF_{Combined}$ is the product of the CMFs from Chapters 10 and 11 of the HSM for intersection lighting, skew angle, number of major-road left-turn lanes, and number of major-road right-turn lanes for a particular intersection.

Table 24. RSIP Project 37: SPF Coefficients, Target Crash Proportions,and Calibration Factors Used for Louisiana Intersection Data

Facility Type	Number of Legs	Number of Site-Years[a]	Severity Level	Intercept (a)[b]	$log_{10}AADT_{Major}$ Coefficient (b)[b]	$log_{10}AADT_{Minor}$ Coefficient (c)[b]	Overdispersion Parameter[b]	Proportion of Target Collision Type (PR_1)[a,c]	Proportion of FI/Total Crashes (PR_2)[a,d]	Calibration Factor (C_r)[a]
Two-Lane Road	3	125	Total	-9.86	0.79	0.49	0.54	0.60	1	0.70
		125	FI	-9.86	0.79	0.49	0.54	0.64	0.33	0.70
	4	52	Total	-8.56	0.6	0.61	0.24	0.69	1	0.39
		52	FI	-8.56	0.6	0.61	0.24	0.67	0.55	0.39
Multilane Highway	3	48	Total	-12.526	1.204	0.236	0.46	0.47	1	0.64
		48	FI	-12.664	1.107	0.272	0.569	0.60	1	0.72
	4	6	Total	-10.008	0.848	0.448	0.494	0.62	1	1.25
		6	FI	-11.554	0.888	0.525	0.724	0.75	1	2.15

Calculated from RSIP Project 37 data.

[b] From HSM, Chapters 10 and 11.

[c] Target crash types include: rear-end, right-angle, and turning crashes only.

[d] Crash types include all collision types.

Table 25. RSIP Project 37: Combined Intersection CMFs Used for Louisiana Treatment Intersections

Site No.	Roadway Type	Number of Legs	Lighting	Skew Angle	Number of Major-Road Left-Turn Lanes	Number of Minor-Road Right-Turn Lanes	Combined CMF[a]	
							Total Crashes	FI Crashes
1	2-lane	3	No	0	1	0	0.6	0.6
2	Multilane	3	Yes	45	1	0	0.7	0.6
3	Multilane	3	Yes	0	1	0	0.5	0.4
4	Multilane	3	No	0	1	0	0.6	0.5
5	Multilane	3	No	0	1	0	0.6	0.5
6	2-lane	3	Yes	0	0	0	0.9	0.9
7	2-lane	3	Yes	45	0	0	1.1	1.1
8	2-lane	3	Yes	15	0	0	1.0	1.0
9	2-lane	3	No	0	0	0	1.0	1.0
10	2-lane	3	No	0	1	0	0.6	0.6
11	Multilane	3	Yes	0	1	0	0.5	0.4
12	2-lane	4	Yes	15	0	0	1.0	1.0
13	2-lane	3	Yes	60	0	0	1.2	1.2
14	2-lane	3	Yes	0	0	0	0.9	0.9
15	2-lane	4	Yes	0	0	0	0.9	0.9
16	2-lane	3	Yes	0	0	1	0.8	0.8
17	2-lane	3	No	0	0	0	1.0	1.0
18	2-lane	3	No	30	0	1	1.0	1.0
19	2-lane	3	No	30	0	1	1.0	1.0
20	2-lane	4	No	0	0	0	1.0	1.0
21	2-lane	4	Yes	0	0	2	0.7	0.7
22	2-lane	4	Yes	0	0	0	0.9	0.9
23	2-lane	3	No	0	0	1	0.9	0.9
24	2-lane	3	No	0	0	0	1.0	1.0
25	Multilane	3	Yes	0	1	1	0.4	0.3
26	2-lane	3	Yes	30	0	1	0.9	0.9
27	2-lane	4	Yes	0	0	0	0.9	0.9
28	2-lane	3	Yes	0	0	0	0.9	0.9
29	2-lane	4	Yes	0	0	0	0.9	0.9
30	Multilane	4	Yes	0	2	0	0.5	0.4
31	2-lane	3	Yes	45	0	0	1.1	1.1
32	2-lane	4	Yes	0	0	0	0.9	0.9
33	2-lane	3	No	0	0	1	0.9	0.9
34	2-lane	3	Yes	0	0	1	0.8	0.8
35	2-lane	4	Yes	0	0	0	0.9	0.9
36	2-lane	4	Yes	0	0	2	0.7	0.7

[a] Combined CMF to account for lighting, skew angle, number of major-road left-turn lanes, and number of minor-road right-turn lanes

Table 26. RSIP Project 37: Combined Intersection CMFs Used for Louisiana Nontreatment Intersections

Site No.	Roadway Type	Number of Legs	Lighting	Skew Angle	Number of Major-Road Left-Turn Lanes	Number of Minor-Road Right-Turn Lanes	Combined CMF[a]	
							Total Crashes	FI Crashes
N1	Multilane	3	No	0	1	0	0.6	0.5
N2	2-lane	3	Yes	15	0	0	1.0	1.0
N3	Multilane	3	No	0	1	0	0.6	0.5
N4	2-lane	3	No	30	0	0	1.1	1.1
N5	2-lane	3	Yes	0	0	0	0.9	0.9
N6	2-lane	3	Yes	20	0	1	0.8	0.8
N7	Multilane	3	Yes	0	1	1	0.4	0.3

[a] Combined CMF to account for lighting, skew angle, number of major-road left-turn lanes, and number of minor-road right-turn lanes

Analysis Results

The EB before/after method was applied to estimate the safety effectiveness of the combination of improvements at rural stop-controlled intersections. The analyses were based on before and after crash data from 35 treatment intersections, crash data from 7 nontreatment intersections, HSM SPFs for three-leg intersections on rural two-lane roads and multilane highways, and HSM SPFs for four-leg intersections on rural two-lane roads. The EB before/after analysis was performed for the following combinations:

- Three-leg stop-controlled intersections on rural two-lane roads
  - Total crashes, all collision types combined
  - FI crashes, all collision types combined
  - Total target crashes
  - FI target crashes
- Four-leg stop-controlled intersections on rural two-lane roads
  - Total crashes, all collision types combined
  - FI crashes, all collision types combined
  - Total target crashes
  - FI target crashes
- Three-leg stop-controlled intersections on multilane highways
  - Total crashes, all collision types combined
  - FI crashes, all collision types combined
  - Total target crashes
  - FI target crashes

Target crashes included rear-end, right-angle, and turning crashes.

The analysis results for three-leg stop-controlled intersections on rural two-lane roads are shown in Table 27; those for four-leg stop-controlled intersections on rural two-lane roads are shown in

Table 28; and those for three-leg stop-controlled intersections on multilane highways are shown in Table 29 . The statistics shown in each table for each crash severity are:

- Number of treatment intersections
- Percent change due to a combination of intersection improvements: estimate and standard error
- An indication of whether the treatment had a statistically significant effect on the crash severity level of interest at the 95-percent confidence level

Table 27. RSIP Project 37: Safety Effectiveness of Combination Intersection Improvements on Total and Target Crashes in Louisiana—Three-Leg Stop-Controlled Intersections on Rural Two-Lane Roads

Collision Type	Crash Severity	Number of Treatment Intersections	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
All	Total	19	-67.4	4.3	Significant at 95% CL
	FI	19	-56.3	8.9	Significant at 95% CL
Target	Total	19	-30.3	10.3	Significant at 95% CL
	FI	19	-13.2	20.2	Not significant at 90% CL

Note: Target crash types include: rear-end, right-angle, and turning crashes only.

Table 28. RSIP Project 37: Safety Effectiveness of Combination Intersection Improvements on Total and Target Crashes in Louisiana—Four-Leg Stop-Controlled Intersections on Rural Two-Lane Roads

Collision Type	Crash Severity	Number of Treatment Intersections	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
All	Total	10	-52.8	10.3	Significant at 95% CL
	FI	10	-63.9	12.2	Significant at 95% CL
Target	Total	10	-32.9	17.3	Significant at 90% CL
	FI	10	-26.3	25.1	Not significant at 90% CL

Note: Target crash types include: rear-end, right-angle, and turning crashes only.

Table 29. RSIP Project 37: Safety Effectiveness of Combination Intersection Improvements on Total and Target Crashes in Louisiana—Three-Leg Stop-Controlled Intersections on Multilane Highways

Collision Type	Crash Severity	Number of Treatment Intersections	Safety Effectiveness (%)	Standard Error of Treatment Effect (SE, %)	Significance
All	Total	6	-54.9	14.5	Significant at 95% CL
	FI	6	-66.1	19.8	Significant at 95% CL
Target	Total	6	-52.5	28.0	Significant at 90% CL
	FI	6	-71.0	29.3	Significant at 95% CL

Note: Target crash types include: rear-end, right-angle, and turning crashes only.

Interpretation of Results

For three-leg stop-controlled intersections on rural two-lane roads, the analysis results indicate that the combinations of intersection improvements reduced all types of intersection and intersection-related crashes for both total and FI severity levels. The results show a 67-percent reduction in total crashes and a 56-percent reduction in FI crashes, both statistically significant at the 95-percent confidence level. For target crashes, the results show a 30-percent reduction in total crashes, statistically significant at the 95-percent confidence level. The results indicate a 13-percent reduction in target FI crashes, however, this reduction is not statistically significant at the 90-percent confidence level. Looking at all severity levels (i.e., total), the results indicate a higher percent reduction in all crash types combined (67-percent reduction) as compared to target crashes (30-percent reduction).

The safety effectiveness estimates differ between three- and four-leg stop-controlled intersections, but the general trends are the same. The results for FI target crashes were not statistically significant, and the safety effectiveness estimates for all severity levels (total) indicate a higher percent reduction in all crash types combined compared to target crashes.

For three-leg stop-controlled intersections on rural multilane roads, the results indicate that the combinations of intersection improvements reduced all types of intersection and intersection-related crashes and all target crashes for both total and FI severity levels; however, only six treatment sites were available for analysis, so these results should be interpreted with caution.

When comparing the combination of improvements implemented at the treatment sites, the primary treatment that likely has the greatest impact on alerting drivers to the presence of an intersection is the installation of oversized signs, whether they be oversized advance warning signs or oversized stop signs. The other types of treatments evaluated, including the installation of new route marker signs and new stop bars, probably could be considered secondary treatments to the oversized signs. From the analysis results, the incremental effect of adding oversized advanced warning signs and/or oversized stop signs cannot be distinguished from the incremental effects of adding new route marker signs and stop bars. However, based on the characteristics of the treatment, it is likely that the oversized advanced warning signs and/or oversized stop signs contributed more to the reduction in crashes that was found as compared to the impact of the secondary treatments including new route marker signs and stop bars.

Summary

Detailed quantitative analyses were performed to estimate the safety effectiveness of safety improvements implemented as part of three separate RSIP projects, including RSIP Projects 27, 36, and 37. The analyses focused on estimating safety effectiveness of the following treatment combinations:

- RSIP Project 27: Dual application of centerline and shoulder rumble strips
- RSIP Project 36: Improved signing and delineation at horizontal curves

- RSIP Project 37: Improved signing and pavement markings at stop-controlled intersections

Two of the three detailed quantitative analyses (RSIP Project 27 and RSIP Project 37) found a statistically significant reduction in crashes due to installation of the safety improvements.

The results indicate that the dual application of centerline and shoulder rumble strips is effective at reducing total and FI target crashes, which included SVROR, sideswipe-opposite direction, and head-on crashes. The safety effectiveness of the dual application of centerline and shoulder rumble strips on target crashes on rural two-lane roads is estimated as follows:

- 35-percent reduction in total target crashes (SE = 10.5)
- 40-percent reduction in FI target crashes (SE = 12.3)

The results also indicate that improved signing and pavement markings at stop-controlled intersections on rural two-lane roadways and multilane highways are effective at reducing crashes. The combination of signing and pavement markings that were evaluated included installation of oversized advance warning signs, oversized stop signs, new route marker signs, and new stop bars. Based upon the characteristics of the treatments, the oversized advanced warning signs and oversized stop signs are considered the primary treatments, and the new route marker signs and stop bars are considered the secondary treatments. The most reliable estimates of safety effectiveness of the improved signing and pavement markings treatments at stop-controlled intersections for all intersection and intersection related crashes and for target crashes which included rear-end, right-angle, and turning crashes are as follows:

- Three-leg stop-controlled intersections on rural two-lane roads
  - 67-percent reduction in total crashes (SE = 4.3)
  - 56-percent reduction in FI crashes (SE = 8.9)
  - 30-percent reduction in total target crashes (SE = 10.3)
- Four-leg stop-controlled intersections on rural two-lane roads
  - 53-percent reduction in total crashes (SE = 10.3)
  - 64-percent reduction in FI crashes (SE = 12.2)
  - 33-percent reduction in total target crashes (SE = 17.3)

Similar trends were seen in the safety effectiveness of the signing and pavement marking improvements at three-leg stop-controlled intersections on multilane roadways; but the analysis only included data from six treatment sites so the results are not considered as reliable.

The analysis results did not provide reliable information to quantify the safety effects of the delineation and signing treatment combinations installed on horizontal curves on rural two-lane roads. Treatment combinations varied by site and included installation or upgrade of curve warning signs, speed plates, chevrons, and RPMs. The lack of reliable estimates on the safety effectiveness of the delineation and signing treatments does not indicate that the treatment combinations are ineffective at reducing crashes at horizontal curves on rural two-lane roads, but rather that there is insufficient evidence at this time to determine their effectiveness.

Chapter 3. Simpler Quantitative Evaluation

A simpler quantitative evaluation of the safety effectiveness of countermeasures was performed for one RSIP project. The specific countermeasure that was evaluated included:

- RSIP Project 33 – AHTD: Cable median barrier

A description of the RSIP project is provided below, followed by the results of the safety evaluation, including, descriptive statistics, analysis approach, and analysis results.

RSIP Project 33

Agency: Arkansas State Highway and Transportation Department (AHTD)

Focus of Evaluation: Cable Median Barrier

Project Background

AHTD received funding through the RSIP to extend an existing median cable barrier along I-55 from near Jericho to the Highway 63 Interchange near Lake David, approximately an 11-mi section of rural interstate. This section of highway was selected for improvement based upon a high frequency of crossover crashes. Prior to the RSIP project, AHTD had previously installed median cable barrier along an adjacent section of I-55 and along a section of I-40.

The roadway characteristics of the highway section where the cable median barrier was installed are as follows:

- Number of lanes: 4 (2 per direction)
- Lane width: 12 ft
- Paved inside shoulders: 4-6 ft
- Median type: grass median
- Average median width: 25 ft
- Speed limit: 70 mph

Shoulder rumble strips are present on both the inside and outside shoulders of this section of interstate.

The type of work involved in this project included:

- Earthwork (involved little change to the median cross slope, if any)
- Modifying drop inlets to provide adequate safety slopes
- Paving ditches
- Installing cable system (in the middle of the median)

Construction dates for installing the median cable barrier were from April 2009 through March 2010.

Because the cable median barrier installed as part of the RSIP project covered a limited number of miles and because AHTD had recently installed cable median barrier along two similar sections of rural interstates, it was decided to include in the analysis the safety experience from all three sections of rural interstates where AHTD had installed cable median barrier. The approximate locations of the cable median barrier and the installation dates are as follows:

- I-55, Section 11, log miles 12.62 to 23.87 (installed in 2009 through 2010 using RSIP funds)
- I-55, Section 11, log miles 8.75-12.62 (installed 2007)
- I-40 Sections 42 /43, log miles 204.5-213.0 (installed 2005)

Objective

The objective of this evaluation was to estimate the safety effectiveness of installing cable median barrier on rural interstates.

Descriptive Statistics

Three sections of rural interstates, covering approximately 23.6 miles, where cable median barrier was installed are included in the analysis.

Crash and traffic volume data were obtained for years 2004 through 2011 for the analysis. The number of before and after years varied among the three sites, and for two of the sites, only one year of data was available in one of the periods.

All crash types were considered in the analysis. Although cable median barrier would be expected to reduce cross median crashes and potentially increase SVROR crashes to the left, these crash types represented such a small percentage of the total crashes along such a short section of highway, that it was not reasonable to consider such crashes types in the analysis (e.g., 9 head-on crashes occurred in the before period and 10 in the after period, 5 sideswipe opposite direction crashes occurred in the before period and 10 in the after period, no distinction could be made between SVROR to the left vs. to the right). Therefore, the analysis focused on all crash types combined. Three crash severity levels were considered in the evaluation: total, FI, and FS crashes. Table 30 provides the years included in the before period and a summary of crash counts and crash rates [crashes/million vehicle miles traveled (MVMT)] during the before period for each of the treatment sites included in the analysis. Similarly, Table 31 provides the years included in the after period and a summary of crash counts and crash rates (crashes/MVMT) during the after period for each of the treatment sites included in the analysis.

Table 30. RSIP Project 33: Summary Statistics for the Before Period for Treatment Sites in Arkansas

Site No.	Route	Section No.	Segment Length (mi)	Number of Before Years (years)	Average AADT	Total Crashes	FI Crashes	FS Crashes	Total (crashes/ MVMT)	FI (crashes/ MVMT)	FS (crashes/ MVMT)
1	I-55	110	11.25	5 (2004-2008)	27,982	250	112	28	0.44	0.19	0.05
2	I-55	110	3.87	3 (2004-2006)	28,235	213	147	13	1.78	1.23	0.11
3	I-40	420/430	8.5	1 (2004)	31,100	31	14	6	0.32	0.15	0.06
Total	N/A	N/A	23.62	N/A	N/A	494	273	47	N/A	N/A	N/A

Table 31. RSIP Project 33: Summary Statistics for the After Period for Treatment Sites in Arkansas

Site No.	Route	Section No.	Segment Length (mi)	Number of After Years (years)	Average AADT	Total Crashes	FI Crashes	FS Crashes	Total (crashes/ MVMT)	FI (crashes/ MVMT)	FS (crashes/ MVMT)
1	I-55	110	11.25	1 (2011)	24,500	78	18	4	0.78	0.18	0.04
2	I-55	110	3.87	4 (2008-2011)	24,915	181	64	5	1.29	0.45	0.04
3	I-40	420/430	8.5	6 (2006-2011)	31,150	226	89	16	0.39	0.15	0.03
Total	N/A	N/A	23.62	N/A	N/A	485	171	25	N/A	N/A	N/A

Analysis Approach

The analysis approach for this RSIP project differs from that for the three previous ones because the same sites were considered both before and after treatment installation, in other words, each site served as its own control. It also differs in that yearly crash counts were analyzed rather than crash counts summed over a given period, that is, site-years rather than sites were the basis for analysis. This approach thus required a special treatment of the data in the modeling approach: each "after site" was paired with its "before site" and the temporal correlation in crash frequencies at a given site from year to year was taken into account. The safety analysis of this treatment therefore consisted of a simple paired before/after comparison where each site served as its own control. A generalized linear model (GLM) with a negative binomial distribution and a log link was used to model the yearly crash rates (crashes/MVMT). A repeated measures correlation structure was included to account for the relationship in crash rates at a given site across years (temporal correlation). A compound symmetry covariance structure was used. General estimating equations (GEE) within PROC GENMOD in SAS were used to estimate the final regression parameters. For the three sites combined, a total of 20 site-years were considered for analysis.

The model for each crash type has the following form:

$$\text{Predicted crashes/MVMT} = \exp(a + b \times I_{Period})$$

Figure 9. Equation 9 - General model to calculate predicted crashes.

where:

I_{Period} = Indicator variable for period; 0 for before period; 1 for after period
a,b = Regression coefficients to be estimated

Analysis Results

The regression results are shown in Table 32 and include the following statistics for the three severity levels:

- The number of sites and site-years in Columns 2 and 3
- The estimates of a and b, their standard error, and associated p-value in Columns 5-7
- The percent change in crash rates due to treatment installation (i.e., before to after change): estimate and lower and upper 95-percent confidence limits in Columns 8-10
- The type 3 p-value associated with the treatment effect in Column 11

Table 32. RSIP Project 33: Regression Results and Treatment Effects by Crash Severity

Crash Rate by Severity (per MVMT)	Number of Sites	Number of Site-Years	Regression Coefficient	Estimate	Standard Error	P-Value	Percent Change in Crash Rate (Before to After)			Type 3 P-Value
							Estimate (%)	Lower 95% Confidence Limit (%)	Upper 95% Confidence Limit (%)	
Total	3	20	a	-0.16	0.47	0.73	N/A	N/A	N/A	N/A
			b	-0.13	0.22	0.54	-13	-43	35	0.59
FI	3	20	a	-0.61	0.55	0.27	N/A	N/A	N/A	N/A
			b	-0.75	0.25	0.0032	-53	-71	-22	0.31
FS	3	20	a	-2.82	0.18	<.0001	N/A	N/A	N/A	N/A
			b	-0.68	0.21	0.0012	-49	-66	-23	0.12

Note: an empty cell indicates that the statistic is not applicable.

Interpretation of Results

The negative percent change in crash rate (Column 8) indicates that the crash rate decreased due to the installation of the cable median barrier for all three severity levels (conversely, a positive change would indicate an increase in crash rate). The 95-percent confidence limits of the percent change provide an assessment of whether the change, positive or negative, is statistically significant at the 95-percent confidence level: if the interval contains zero, then the change is not statistically significant (i.e., not different from zero) at the 95-percent confidence level; if the interval does not contain zero, then the change is statistically significant (i.e., different from zero) at the 95-percent confidence level.

The Type 3 p-values in the last column of Table 32 also provide an indication of whether cable median barriers have a significant effect on crash rates. These p-values correspond to the score statistics produced in the Type 3 GEE analysis and are generally more conservative than the p-values associated with the computation of the 95-percent confidence limits which are computed with the Wald statistic. Generally, these two p-values are in agreement with each other; however, when the two disagree, the Type 3 p-value should be the one on which to base conclusions.

For total crash rates, the Type 3 p-value (0.59) is close to the p-value associated with the confidence limits (0.54), both indicating that the percent change in total crash rates is not statically significantly different from zero. For FI and FS crash rates, however, the discrepancy between the two types of p-values is large; in both cases, the p-values associated with the confidence limits (0.0032 and 0.0012, respectively) indicate statistical significant at the 95-percent confidence level while the type 3 p-values (0.31 and 0.12) show no statistical significance at the 95-percent confidence level. Note, however, that the type 3 p-value (0.12) associated with the percent change in FS crash rate would indicate statistical significance at approximately 90-percent level.

In summary, the analysis showed the following:

- The installation of cable median barriers had a beneficial effect on total, FI and FS crash rates based on the negative percent changes in these crash rates: -13 percent for total, -53 percent for FI, and -49 percent for FS crash rates.
- There is insufficient evidence, however, to conclude that the treatment had a statistically significant effect on crash rates at the 95-percent confidence level.
- The installation of cable median barrier had a marginally significant effect in reducing FS crashes; the reduction is -49 percent and is statistically significant at the 88-percent confidence level.

Chapter 4. Qualitative Evaluations

This section presents qualitative evaluations of two RSIP projects:

- RSIP Project 25 – TDOT: Development of a Sign Inventory System
- RSIP Project 32 – MoDOT: Implementation of Dynamic Message Signs and Closed-Circuit Video

RSIP Project 25

Agency: Tennessee Department of Transportation (TDOT)

Focus of Evaluation: Development of Sign Inventory System

Project Background

County governments in Tennessee expressed interest in meeting the retroreflectivity standards in the Manual on Uniform Traffic Control Devices (MUTCD; FHWA, 2009). Recognizing that better sign retroreflectivity increases safety, especially at night (motorists are more likely to notice and follow brighter, more visible signs), the counties were interested in decreasing crashes through the low-cost, system-wide implementation of more retroreflective signs. The counties sought to develop a project that included the creation of a sign inventory and retroreflectivity measurements for signs in the inventory. This would provide the necessary information for a data-driven sign replacement program. In addition, in 2007 FHWA published a final rule stating that public agencies with jurisdiction over roadways should have an assessment method for determining sign retroreflectivity and maintaining it above minimum standards. The 2009 MUTCD provides guidance for being compliant with this rule.

Through the RSIP project, Tennessee Department of Transportation (TDOT) implemented a pilot program for the development of a sign inventory system that focused on rural state routes in the 21 counties in the Delta region (TDOT's Region 4). TDOT partnered with a consulting firm and a manufacturer of sign sheeting to develop the sign inventory and process for conducting retroreflectivity and other sign quality measurements.

The goal of the project was to evaluate all the signing on state routes in the Delta region, develop an inventory system, record retroreflectivity measurements and general condition of the signs, assign a latitude and longitude (i.e., location) to all signs, and implement a program to identify, prioritize, and replace signs that do not meet MUTCD standards or other defined criteria. The inventory system was to include a web-based application accessible by anyone in the agency without the need for special software.

TDOT planned to expand the sign inventory system to other counties and local routes in the future if this project was found to be successful.

Project Deployment

The project included five primary tasks:

- *Task 1—Project Initialization and Management*. This task included coordinating administrative issues between TDOT, the consulting firm, and sign manufacturer, as well as obtaining and formatting the GIS centerline data and ortho-photography for the routes and counties involved in the project.
- *Task 2—Data Collection*. This task included the initial collection of the global positioning system (GPS) position and digital image of signs. This information was collected by vehicles equipped with GPS units, digital cameras, and mobile computers.
- *Task 3—Data Post Processing.* Data collected in Task 2 was processed to record sign attributes such as MUTCD code and description, sign placement location (right, left, overhead), sign face orientation to nearest cardinal direction, county, route, log mile, sign dimension, sign substrate material, and support type and material. This was all determined from the digital images. In addition, each sign was given a preliminary assessment rating from good to critical based on characteristics such as fading, deterioration, and alignment. This post-processing included a quality control element during which reviewers selected random records to determine the accuracy of the entered attribute data.
- *Task 4—Sign Assessment and Engineering.* This task included both a nighttime retroreflectivity assessment of the sign sheeting and a daytime engineering assessment of each sign in the inventory developed in Task 3. For the nighttime assessment trained personnel evaluated each sign from a moving vehicle and recorded the assessment rating for retroreflectivity. The daytime assessment was used to evaluate sign application and recommend changes such as adding additional signs, replacing with larger signs, raising the sign or changing its location, or other recommended maintenance tasks to make the signs comply with MUTCD standards. The sign database was updated to reflect the nighttime and daytime assessments, observations, and recommendations.
- *Task 5—Deliverables and Documentation.* The final deliverables for this project included:
    - Four laptop computers with the mobile database software program
    - Half-day training session for TDOT staff on the functionality and use of the software
    - Staff support for developing a program to interface with TDOT's log-mile system

The overall cost of the RSIP sign inventory project was $813,500.

Treatment Application

The sign inventory program included all signs on state routes in the 21 rural counties in the Delta region of Tennessee. The program enables TDOT staff to systematically evaluate all the signs in their inventory for compliance with MUTCD standards including retroreflectivity, and to prioritize and schedule the replacement of signs that do not meet standards without unnecessarily replacing signs that still meet criteria. The program allows TDOT to focus resources on identified needs.

The following summary statistics describe the extent of the project:

- 62,311 signs were recorded in the inventory and evaluated
- Approximately 2 percent of the signs were assessed as having critical retroreflectivity
- Approximately 3 percent of signs were recorded as requiring maintenance action
- Approximately 2,000 signs were recommended or proposed for addition to the system

Lessons Learned

Several benefits, challenges, and lessons learned from the project include the following:

- The initial capture of sign assets in the field using digital cameras was a quick way to develop the initial sign inventory database, but there were some limitations. There were situations in which signs were blocked by obstructions or foliage, or the digital image was not clear due to sun glare or weather conditions.
- The initial mobile image capturing effort took longer than anticipated due to the fact that TDOT maintains regulatory signs on non-state route approaches to intersections with state routes. This meant that to record stop signs at intersections with non-state routes, the data collection vehicle had to turn onto the minor route and make a U-turn to face the stop sign of the minor route, cross the state route and make another U-turn on the opposing leg to capture that sign, and then turn back onto the state route to continue.
- Agencies must anticipate the storage space required to save digital images of thousands of signs. In addition, a plan must be developed to transfer images taken in the field to office computers for post-processing and inclusion in the inventory database. For this project, external hard drives were used to transfer images.
- Post-processing in the office of the images was labor-intensive and time consuming. While image recognition technology can be used to some extent to recognize standard signs, custom and non-standard signs require a human interface. Additional sign attributes also require human evaluation. However, the initial level of effort to develop the inventory would not be required for subsequent updates, which would focus only on ongoing maintenance needs or changes made to the inventory.
- Sign attributes such as sign dimensions and offset distance were approximated in the office using the digital images rather than measured in the field. This provided a substantial time savings and was found to provide measurements within tolerable thresholds.
- Nighttime data collection must be completed during hours of complete darkness, so summer nights provide fewer working hours than winter nights. Condensation, fog, frost and other weather and temperature-related factors that can obstruct retroreflectivity measurements should be considered when scheduling the time of year to conduct the assessment.
- The sign inventory system was specifically developed to allow field staff to update sign attributes after routine maintenance in an easy-to-use web-based tool. The web-based

tool makes it convenient to update the inventory system and keep it current so that it can be used to manage sign assets.

Future Implementations

At this time, the sign inventory system has not been expanded to other areas or regions of Tennessee; however, state officials have considered options, scenarios, and funding to expand the system to other areas of the state.

RSIP Project 32

Agency: Missouri Department of Transportation (MoDOT)

Focus of Evaluation: Implementation of Dynamic Message Signs and Closed-Circuit Video

Project Background

In 2005, MoDOT began the Smooth Roads Initiative, which included many thousands of miles of improvements to the state’s most heavily traveled roadways. To help manage the many construction projects, MoDOT used 40 portable changeable message signs along two major Interstates. Recognizing the benefits of these signs, MoDOT decided to seek a more permanent solution for providing real-time information to the traveling public. For this reason, they began a program of installing dynamic message signs (DMSs) and closed circuit television cameras (CCTVs) around the state. In case of an incident, the CCTVs can be used to verify the location and severity of the crash and help to reduce emergency response times. The DMSs can also be used to warn motorists and direct them to bypass routes when incidents block major routes.

MoDOT received funding through the RSIP to install six DMSs, upgrade fiber optic connectivity between the signs, and install 13 CCTVs to relay information to the traffic management center in St. Louis. The DMSs and CCTVs were installed along I-57, I-55, and US 60 in the Delta Region. The project was designed to complement DMS installations already programmed around the state. Total project costs were estimated at approximately $1,000,000, broken down as follows:

- $500,000 to design and install six new DMSs in the Delta Region
- $30,000 for a research project to evaluate and quantify benefits of DMSs and CCTVs
- $370,000 for telecomm upgrades
- $100,000 to design and install camera equipment.

Construction and installation began 2009 and was completed in 2010.

Project Deployment

The successful deployment of DMSs on I-70 and I-44, following the 2005 Smooth Roads Initiative, became a springboard for providing DMSs on other rural interstates, particularly in northwest and southeast Missouri. Prior to the RSIP project, MoDOT had already decided to install some DMSs along I-55 in southeast Missouri. When the RSIP was initiated, MoDOT identified six new locations in the Mississippi Delta Region eligible for RSIP funding at which to install additional equipment that would complement the already planned DMS installation. Those sites were along the I-55, I-57, and US 60 corridors. The signs were located prior to key decision points so that customers would have time to make a decision and change their travel plans based on the information, if necessary. For example, signs were installed on US 60/I-57 just before a motorist would get to I-55. Likewise, DMS further west on US 60 were installed just before US 67 and US 63.

Some of the devices installed as part of the RSIP project are connected by fiber. A telecommunication company owns the fiber that was utilized. MoDOT has an agreement in place to access the fiber under certain circumstances. Devices not connected by fiber rely on cellular communications. While MoDOT did not install the devices, they have taken care of general maintenance for the devices since the completion of the project.

Treatment Application

MoDOT reported that they use the CCTVs and DMSs in a variety of ways. The DMSs are used to display a message 24/7. If appropriate, the DMSs may be used to provide information about an incident, a work zone, detours, AMBER alerts, weather conditions, or other emergency information. If no such messages are needed at a given DMS, then that DMS will display a public service announcement (PSA) message related to highway safety, such as PLEASE BUCKLE UP, ARRIVE ALIVE, or PLEASE DO NOT TEXT AND DRIVE. MoDOT utilizes a pre-approved rotation of these PSA safety messages, and operators utilize this list of messages to provide motorists with a variety of information so that the same message is not continuously displayed for days and days. The PSA safety messages never take priority over messages about incidents, work zones, weather or other operational and safety issues specific to the route at that time. Because travel time information is not currently available in the rural parts of the state, the DMSs installed as part of the RSIP project display a relatively high proportion of the PSA safety messages. In addition to the general PSA safety messages, the DMSs may also be used for special campaigns such as Click It or Ticket, Drive Sober or Get Pulled Over, and Work Zone Awareness Week. A number of campaigns have taken advantage of the DMS to spread the word, and MoDOT's transportation safety partners are appreciative of this avenue for spreading their messages during highway safety campaigns. An excerpt from the message log of one of the DMSs is shown in Figure 10.

MESSAGE	POST TIME
DSE IS 55 N DMS 16.60 (SIGN ID 67)	
Drive Safe In Work Zones MoDOT Cares	04/18/2013 5:32:19AM
Turn Off Cruise [fo4]During Wet [fo]Conditions	04/18/2013 9:25:34PM
152 Road Deaths In MO This Year 55% Unbuckled	04/19/2013 12:52:35AM
Drive Safe In Work Zones MoDOT Cares	04/19/2013 5:51:15AM
[fo]Motor Carriers [fo4]Hands-Free Only [fo]On Cell Phones	04/20/2013 6:04:31PM
[fo]Motor Carriers [fo4]Hands-Free Only [fo]On Cell Phones	04/21/2013 7:43:54PM
[fo4]For Emergencies [fo]Dial *55 For [fo4]Highway Patrol	04/21/2013 11:00:54PM
[fo]Motor Carriers [fo4]Hands-Free Only [fo]On Cell Phones	04/22/2013 8:10:41PM
[fo4]For Emergencies [fo]Dial *55 For [fo4]Highway Patrol	04/23/2013 3:24:46AM
*** UNKNOWN MESSAGE ***	04/23/2013 11:05:31PM
163 Road Deaths In MO This Year 53% Unbuckled	04/23/2013 11:06:31PM
Travel Info[nl4][fo4]www.modot.org	04/24/2013 11:40:51AM
Travel Info[nl4][fo4]www.modot.org	04/24/2013 11:40:59AM
Travel Info[nl4][fo4]www.modot.org	04/24/2013 11:41:34AM
163 Road Deaths In MO This Year 53% Unbuckled	04/24/2013 12:36:58PM
I-155 CLOSED AT MISS RIVER USE ALT ROUTEEXPECT DELAY	04/25/2013 6:29:53AM
I-155 CLOSED AT MISS RIVER USE ALT ROUTEALL TRAFFIC MUST EXIT AT MM 272REDUCE SPEED	04/25/2013 6:31:29AM
I-155 CLOSED AT MISS RIVER USE ALT ROUTEALL TRAFFIC MUST EXIT AT MM 272REDUCE SPEED	04/25/2013 6:32:10AM
I-155 CLOSED AT MISS RIVER USE ALT ROUTE	04/25/2013 6:36:32AM
[fo4]For Emergencies [fo]Dial *55 For [fo4]Highway Patrol	04/25/2013 8:32:22AM
[fo]Please Do Not Text and Drive MoDOT Cares	04/25/2013 9:02:49AM
[fo]Motor Carriers [fo4]Hands-Free Only [fo]On Cell Phones	04/25/2013 8:13:10PM
Reduce Speed During Wet Conditions	04/26/2013 12:01:19PM
Turn Off Cruise [fo4]During Wet [fo]Conditions	04/26/2013 5:30:12PM
[fo4]Stay Alert Buckle Up [fo]MoDOT Cares	04/28/2013 1:19:15AM
[fo]Motor Carriers [fo4]Hands-Free Only [fo]On Cell Phones	04/28/2013 6:48:25PM
[fo4]Keep Right Except to Pass [fo]MoDOT Cares	04/29/2013 10:14:21AM
[fo]Move Over For [fo4]Emerg Vehicles [fo]MoDOT Cares	04/29/2013 11:28:11PM

Source: MoDOT Staff

Figure 10. RSIP Project 32: Excerpt of Message Log from One DMS

The CCTVs provide a continuous source of system surveillance utilized by MoDOT staff across the state. They provide staff with real-time field conditions related to traffic flow, incident management, and weather. On a day-to-day basis, the cameras are preset at positions to provide general surveillance of the transportation system. When other events take place, the cameras are used to monitor activities and status of specific events. Such events include crashes that adversely impact traffic flow or block a lane(s). Likewise, the cameras may be used to monitor the impact of a work zone on traffic flow. The other critical service the cameras provide is a visual assessment of field conditions during adverse weather. The cameras can be used to verify road conditions during storm events, thus providing confirmation to operators and customer service representatives that are providing customers with real-time traveler information. In addition, the camera feeds are made directly available to the general public through MoDOT's Traveler Information Map and mobile application. The camera feeds can also be shared with local media for inclusion on local traffic reports. The cameras are also used for incident response in the rural areas. Typically incidents are not first identified on the camera (so response time is not necessarily affected by the cameras), but the cameras allow for better monitoring of the situation and, ultimately, more efficient clearing of the incident. The cameras also provide the ability for customers to evaluate the route and check for incidents and work zones from a computer at home or work before choosing their travel route.

Project Evaluation

MoDOT hired researchers at the University of Missouri-Columbia to conduct a formal evaluation of some of the DMS used in the region of the RSIP project. The final report titled *Evaluating the Benefits of Dynamic Message Signs on Missouri's Rural* Corridors (Edara et al., 2012) is available on MoDOT's website. The evaluation consisted of three separate studies. The first was an in-person survey of motorists in the study corridor (conducted at a gas station and at an exit near the regional airport) asking about sign visibility, message clarity and accuracy, the perceived impact of the signs on safety, and whether the driver took action (such as slowing or changing route) based on the sign message. Responses were categorized by trip purpose (work or recreation), vehicle type (truck or private), residency (local or visitor), and gender of respondent for analysis. In all categories, the responses were overwhelmingly positive.

The second study was a measure of speed change between a location upstream and downstream of a DMS at two locations, each with a different message being displayed. In the first case, the DMS read "ROAD WORK AT MM 117 EXPECT DELAYS", and in the second it read, "TWO WAY TRAFFIC AHEAD USE CAUTION". For both cars and trucks, statistically significant speed reductions between the upstream locations and the downstream locations ranged from about 1 mph to about 4 mph.

The third study evaluated the impact of the DMSs on diverting traffic to a detour route during a full freeway closure. I-57 was closed for four days at the Missouri-Illinois border for repairs on the Mississippi River bridge. The researchers measured evening peak traffic flow at 15 points along the detour route both before and during the bridge closure for comparison and found a significant increase in traffic along the detour route. Traffic flow was modeled in simulation software to estimate the delay savings realized by taking the detour route suggested by the DMS compared to traveling along the intended route until seeing the static bridge closure signs and making a U-turn to travel back to the detour route turn-off. Several scenarios were modeled which each assumed a different percentage of drivers were aware of the freeway closure prior to beginning their trip. The research team estimated a delay savings between 35 and 400 hours for the three-day closure studied, depending on the assumption regarding the percent of drivers who would be aware of the detour route even without the DMS. This translates to a savings of between $5,000 and $55,000 per similar event. Researchers noted that in rural areas the treatments do not provide as much travel time savings as in urban areas simply because of lower traffic volumes. However, since fewer alternate routes tend to be available in rural areas, drivers have a greater need to be informed of an available detour.

As part of the third study, researchers also surveyed drivers at a truck stop near Cape Girardeau, a town along I-55, which was part of the 38-mile detour route. Respondents were asked whether they saw the DMS with the bridge closure information, if they were previously aware of the bridge closure, if they trusted the accuracy of the signs, and if the signs provided sufficient detour information. The surveys revealed that while several travelers reported knowing of the closure from radio and newspaper, about 40 percent listed the DMS as their only source of information regarding the closure. The researchers found that, overall, drivers were satisfied with the DMSs and trusted the detour route information provided. Commercial truck drivers gave slightly higher ratings than drivers of passenger cars.

MoDOT staff has found motorists to be very appreciative of information regarding incidents, work zones, detours, road conditions and other emergencies. The PSA messages that are also posted on DMSs have not been formally evaluated, though drivers sometimes contact MoDOT regarding those messages. Usually, driver feedback is in the form of suggestions for specific messages. Drivers also often request travel time information, similar to what is available on systems managed in a traffic management center in the more urban areas, but this feature is not available in the rural deployments at this time.

While a formal benefit/cost ratio has not been conducted on the CCTVs and DMSs, MoDOT believes them to be cost effective. To date, the maintenance costs have been minimal, and the range of benefits include continued system surveillance, provision of valuable information to travelers, monitoring of traffic incidents and work zones in real time, and verifying weather and pavement conditions.

Lessons Learned

MoDOT did not identify any major roadblocks to successful implementation of the CCTV cameras and DMSs, but one issue related to utilities was identified:

> *Coordination with electric co-ops in the area shouldn't be underestimated. This project impacted 6 different electric co-ops across the state. Each of these entities has their own policies and procedures, so working out power requests and response times can vary from one company to the next. Depending on the cooperation of these electric companies, design work can hit a snag at different points during the process.*

Future Implementations

MoDOT reported that some additional DMSs and CCTVs have been installed since the completion of the RSIP project. These installations have typically been to fill a gap in a region with existing traffic monitoring equipment, such as outside of St. Louis and in the Springfield area. While these deployments were not added as direct results of the RSIP project, the success of the RSIP project provided additional support and justification for the installations. MoDOT staff indicated that if the RSIP project had not produced the benefits seen in the rural regions, the effort to fill in gaps on the major roadway system might have been weaker. While MoDOT is filling in gaps on the major system, a large-scale rural deployment of CCTVs and DMS in the near future is neither planned, nor likely to take place.

Chapter 5. Conclusions

Many of the safety improvement projects implemented as part of the RSIP-DRTDP were able to achieve the overall goal of USDOT's Rural Safety Initiative to improve safety on rural highways by decreasing loss of lives and injuries.

In Mississippi (RSIP Project 27), the installation of centerline rumble strips on rural two-lane roads, where shoulder rumble strips were already present, resulted in a decrease in SVROR (right or left), sideswipe-opposite direction, and head-on crashes. The dual application of centerline and shoulder rumble strips on rural two-lane roads resulted in a 35-percent reduction (SE=10.5) in total target crashes and a 40-percent reduction (SE=12.3) in FI target crashes. The results highlight the need for additional research on quantifying the safety effectiveness of individual treatments installed in combination. The results from this research suggest that the current state of practice approach for estimating the safety effectiveness of countermeasure combinations (i.e., multiplying together CMFs of individual countermeasures to estimate the combined CMF) may overestimate the effectiveness of countermeasure combinations.

In Louisiana (RSIP Project 37), improved signing and pavement markings at rural stop-controlled intersections effectively reduced total and FI intersection and intersection-related crashes. The improved signing and pavement marking treatments resulted in the following crash reductions at the respective intersection types:

- Three-leg stop-controlled intersections on rural two-lane roads
  - 67-percent reduction in total crashes (SE = 4.3)
  - 56-percent reduction in FI crashes (SE = 8.9)
  - 30-percent reduction in total target crashes (SE = 10.3)
- Four-leg stop-controlled intersections on rural two-lane roads
  - 53-percent reduction in total crashes (SE = 10.3)
  - 64-percent reduction in FI crashes (SE = 12.2)
  - 33-percent reduction in total target crashes (SE = 17.3)

Target crashes included rear-end, right-angle, and turning crashes. When comparing the combination of improvements implemented at the treatment sites, the primary treatment that likely had the greatest effect on reducing crashes was the installation of oversized advance warning signs or oversized stop signs. Secondary treatments including new route marker signs and stop bars likely contributed less to the safety improvements.

In Arkansas (RSIP Project 33), the safety evaluation of cable median barrier installed on rural interstates was able to demonstrate beneficial effects on all crash types and severities. In particular, following installation of cable median barrier on rural interstates, the results showed a 49-percent reduction in FS crashes that was marginally significant at the 88-percent confidence level.

For the RSIP projects for which the safety evaluation yielded unreliable estimates (RSIP Project 36) or the safety effectiveness could not be completed due to insufficient data (RSIP Projects 28, 31, and 34), there is insufficient evidence at this time to reliably determine treatment effectiveness.

Finally, highlights of the lessons learned by TDOT (RSIP Project 25) and MoDOT (RSIP Project 32) in developing a sign inventory system and installing dynamic message signs and closed-circuit video, respectively, will benefit other agencies interested in similar programs. In particular, knowing of the logistical difficulties encountered by TDOT during data collection and post-processing of the sign inventory data will help other agencies during the planning stage of implementing a similar project within their jurisdictions. Also, the need to coordinate with electric companies early in the planning and project development phases is important information for other agencies planning to implement projects that involve installation of DMSs and CCTVs. From a qualitative perspective, the RSIP projects implemented by TDOT and MoDOT were a success and benefitted the respective agency. The knowledge gained from the evaluation of the RSIP-DRTDP projects can benefit other highway agencies when making funding decisions concerning future safety improvement projects and programs.

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