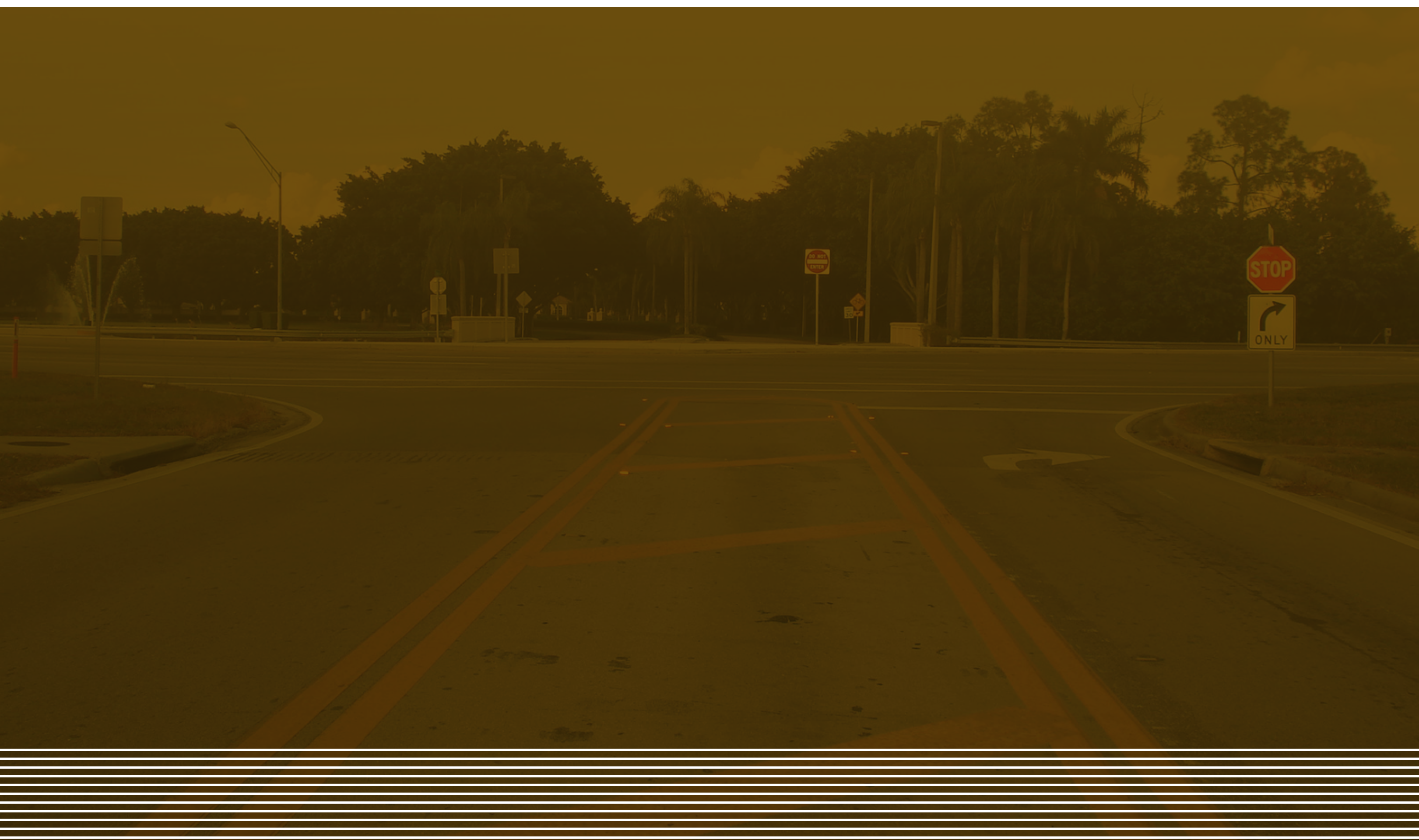
Road Safety Audits:

AN EVALUATION OF RSA PROGRAMS AND PROJECTS



U.S. Department of Transportation
Federal Highway Administration

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FHWA-SA-12-037

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16. Abstract

Road Safety Audits (RSAs) are an effective tool for proactively improving the future safety performance of a road project during the planning and design stages and for identifying safety issues in existing transportation facilities. To demonstrate the effectiveness of RSAs, the Federal Highway Administration (FHWA) Office of Safety sponsored an evaluation of RSAs at the program and project levels. The aim of these evaluations is to provide State, local, Federal, and Tribal agencies with examples of RSA programs and quantifiable results from specific RSA projects that can help in implementing RSAs and further their growth and success.

Six jurisdictions were reviewed for their unique ability to sustain an RSA program at the State, regional, or local level. Key strategies underpinning the success of these RSA programs are described in this document. At the project level, five RSAs were evaluated to quantify the safety benefit of specific improvements that were implemented as a result of the RSAs. Statistical analyses were conducted using observational before-after methods. Costs of conducting the RSA and of implementing countermeasures are also presented and used in conjunction with the before-after analysis to determine the benefit/cost (B/C) ratio of each project.

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SUMMARY

Road Safety Audits (RSAs) are an effective tool at addressing safety for all users. This document provides the evaluation results of RSAs at both the ***program*** and ***project level***. As part of this study, nine jurisdictions were reviewed for their unique ability to sustain an RSA program at the State, regional, or local level (see Table 1). These jurisdictions were selected based on the presence of an RSA program and their willingness to share their experiences. The key strategies underpinning these successful RSA programs are described in this document.

Table 1. Summary of RSA Programs Evaluated.

Agencies	Focus	Benefit
Rhode Island Department of Transportation (RIDOT)	Low-Cost, High-Benefit Safety and Mobility	Rapid deployment of RSA team and implementation of recommendations.
Nevada Department of Transportation (NDOT)	Establish RSA Champions and Stakeholder Relations	Trained over 60 transportation professionals on the basic and advanced techniques for conducting RSAs.
Kansas Department of Transportation (KDOT)	Recurring System-wide RSA Program	Efficient use of personnel and consistent updating of traffic control devices.
Massachusetts Department of Transportation (MassDOT)	Linking RSAs to Highway Safety Improvement Program	RSAs linked to funding and projects are programmed quickly.
Montgomery County, Maryland Department of Transportation (MCDOT)	Improving Pedestrian and Bicycle Safety	Crash data and observations in the field used to understand and address pedestrian and bicyclist safety.
Arizona Department of Transportation (ADOT)	Collaborative and Proactive Approach to Statewide Safety	Findings from RSAs have been used to update DOT policies and standards.
Tennessee DOT (TDOT)	Formalized and uniform RSA process	RSAs are conducted in a more efficient and cost-effective manner.
Collier County, Florida	Adoption of an RSA policy including a RSA requirement for design permits	Improvements to design result in savings over the life of a project.
South Jersey Transportation Planning Organization (SJTPO)	Creating a comprehensive site selection processes.	The process was able to identify locations for quick, low-cost improvements that would lead to the highest reduction in severe crashes.

At the project level, five areas (four roadways and one intersection projects) were reviewed to quantify the safety benefits of specific improvements that were implemented as a result of an RSA. These projects were selected based on having implemented safety measures suggested as part of the RSA, as well as the availability of data for similar “comparison” sites within the agency’s jurisdiction. Statistical analyses were conducted using observational before-after methods. As shown in Table 2, there was a significant reduction in crashes as a result of the suggestions implemented from the five RSAs. Total crash reductions ranged from 10 to 50 percent. For most RSA projects, benefit/cost (B/C) ratios—which compare the benefits derived from crash reduction to the cost of conducting the RSA and implementing the countermeasures—were calculated as an additional measure of the project’s success. All of the evaluated RSA projects had a B/C ratio greater than 1.0, meaning the project benefits outweighed the project costs. Many of these RSA projects were also discussed in the context of the overall RSA program for each location.

Table 2. Summary of RSA Projects Evaluated.

Location	Results
Bullhead Parkway *Bullhead City, Arizona*	• 54% reduction in total crashes • 50% reduction in fatal / incapacitating injury crashes • 30% reduction in intersection-related crashes • B/C ratio of 20:1 (total crashes)
State Route 101 (Peavine Road) *Cumberland County, Tennessee*	• 13.7% reduction in total crashes • 31.3% reduction in injury crashes • B/C ratio of 51:1 (total crashes)
Intersection of Collier Boulevard and Golden Gate Parkway *Collier County, Florida*	• 11% reduction in total crashes, two intersections • B/C ratio of 5:1 (total crashes, two intersections)
Immokalee Road *Collier County, Florida*	• 10.8% reduction in total crashes
Ninth Street *Ocean City, New Jersey*	• 25.6% reduction in total crashes • B/C ratio of 1.2:1 (total crashes)

The RSA programs and projects reviewed for this report represent a small sample of RSA activity throughout the U.S. Many Federal, State, local, and Tribal agencies have experience conducting RSAs and are creating or have created RSA programs. Moving forward, more agencies will be implementing safety measures as a result of RSAs, which will, in turn, provide more opportunities to evaluate the effectiveness of these measures in addressing safety.

INTRODUCTION

BACKGROUND

Road Safety Audits (RSAs) are an effective tool for proactively improving roadway safety. The RSA process may be employed on any type of facility and during any stage of the project development process, including existing facilities that are open to traffic. A decade ago, few States had experience in conducting RSAs. Now, almost every State has had some experience with the RSA process.

The Federal Highway Administration (FHWA) defines an RSA as a "formal safety performance evaluation of an existing or future road or intersection by an independent, multidisciplinary team." The primary focus of an RSA is safety, while working within the context of other aspects, such as mobility, access, surrounding land use, and aesthetics. An RSA conducted by a team that is independent of the design and operations of the facility can address safety through a thorough review of roadway, traffic, environmental, and human factors conditions. By using an unbiased and multidisciplinary team to perform a comprehensive review and an evaluation of physical, operational, and human-factors-related safety issues for a given study area, RSAs make sure that safety is adequately considered.

RSAs typically follow the procedures outlined in the *FHWA Road Safety Audit Guidelines* document (Publication Number FHWA-SA-06-06). The procedures involve an eight-step RSA process that is shown in Figure 1 and can be done at any stage in a project's life:

- A *pre-construction RSA (planning and design stages)* examines a road before it is built, either at the planning/feasibility stage or the design (preliminary or detailed design) stage. An RSA at this stage identifies potential safety issues before crashes occur. The earlier a preconstruction RSA is conducted, the more potential it has to efficiently remedy possible safety concerns.
- *Construction RSAs (work zone, changes in design during construction, and preopening)* examine temporary traffic management plans associated with construction or other roadwork and changes in design during construction. RSAs at this stage can also be conducted when construction is completed, but before the roadway is opened to traffic.
- A *post-construction or operational RSA (existing road)* examines a road that is operating and is usually conducted to address a demonstrated crash problem.

Figure 1. Typical RSA Process.

The multidisciplinary RSA team is typically composed of at least three members having expertise in road safety, traffic operations, and road design. Other potential team members may have a background in (but not limited to) enforcement, emergency medical services, maintenance, human factors analysis, transportation planning, pedestrian safety, and bicyclist safety. It is important that members of the RSA team are independent of the design and operations of the facility being assessed. The RSA team's independence assures two things: 1) there is no bias in the assessment, and 2) the project is reviewed with "fresh eyes."

PURPOSE

The purpose of this document is to provide State, local, Federal, and Tribal agencies with examples of RSA programs and quantifiable results from RSA projects that can help in implementing RSAs and further their growth and success. This project evaluated nine sustained RSA programs and the improvements implemented as a result of five specific RSA projects. The RSA programs (shown in Table 3) were reviewed from a programmatic perspective to identify key factors for success, and the RSA projects were evaluated to quantify the safety effectiveness of the improvements suggested through the RSAs in reducing crashes. Table 4 provides a brief summary of the characteristics of the specific RSA projects evaluated. The evaluation consisted of a rigorous before-after analysis to measure the project's success through the development of benefit/cost (B/C) ratios, which describe the benefits derived from crash reduction versus the cost of conducting the RSA and implementing the recommended countermeasures. The methodology used in the analysis is described in Appendix A. Appendix B includes a project description, a summary of key findings and suggestions, and photographs to illustrate before and after conditions of each of the RSA projects evaluated. Specifics about why RSAs were initiated are also discussed.

Table 3. RSA Programs Evaluated.

Agencies	Program Level	Focus
Rhode Island Department of Transportation (RIDOT)	State	Low-Cost, High-Benefit Safety and Mobility
Nevada Department of Transportation (NDOT)	State	Establish Champions
Kansas Department of Transportation (KDOT)	State	Recurring System-wide RSA Program
Massachusetts Department of Transportation (MassDOT)	State	Linking RSAs to Highway Safety Improvement Program
Montgomery County Department of Transportation (MCDOT- Montgomery County, Maryland)	County	Improving Pedestrian and Bicycle Safety
Arizona Department of Transportation (ADOT)	State	Collaborative and Proactive Approach to Statewide Safety
Tennessee DOT (TDOT)	State	Formalized and uniform RSA process
Collier County, Florida	County	Adoption of an RSA policy including a RSA requirement for design permits
South Jersey Transportation Planning Organization (SJTPO)	Regional	Creating a comprehensive site selection processes.

Table 4. RSA Projects Evaluated.

Location	RSA Stage	Project Description
Bullhead Parkway *Bullhead City, Arizona*	Existing roadway	• 10.2-mile section • Paved, four-lane divided rural roadway • 4 signalized intersections, 13 unsignalized intersections • AADT: 10,000 – 15,000 vehicles per day (2007) • 50 mph posted speed limit
State Route 101 (Peavine Road) *Cumberland County, Tennessee*	Existing roadway	• 3.84-mile section • Paved, two-lane rural roadway • Two unsignalized intersections • AADT: 12,860 vehicles per day (2007) • 45 mph posted speed limit
Collier Boulevard at Golden Gate Parkway *Collier County, Florida*	Existing roadway	• Three-legged signalized intersection • Paved, four-lane divided roadway • Adjacent unsignalized intersection at Collier County Boulevard and 25th Avenue • AADT: 18,000 – 24,000 vehicles per day (2005) • 45 mph posted speed limit
Immokalee Road *Collier County, Florida*	Design stage	• 3.25-mile section • Paved, four-lane divided roadway (existing) • Paved, six-lane divided roadway (planned) • Six signalized intersections • AADT: 45,488 vehicles per day (2005) • 45 mph posted speed limit
Ninth Street *Ocean City, New Jersey*	Existing roadway	• 0.47-mile section • Paved, four-lane arterial roadway • 6 signalized intersections, 1 unsignalized intersection • AADT: 13,870 vehicles per day (2007) • 25 mph posted speed limit

NOTEWORTHY RSA PROGRAMS

RSA programs were reviewed to understand the key strategies underpinning successful program implementation at the State, regional, or local level. The RSA programs reviewed as part of this project were selected based on the presence of an RSA program that has resulted in multiple RSAs and the parent agencies' willingness to share their experiences. The key strategies underpinning the following noteworthy RSA programs are described in this document:

- State of Rhode Island.
- State of Nevada.
- State of Kansas.
- Commonwealth of Massachusetts.
- Montgomery County, Maryland.

- State of Arizona.
- State of Tennessee.
- Collier County, Florida.
- South Jersey Transportation Planning Organization.

RHODE ISLAND DOT: FOCUS ON HIGH-BENEFIT, LOW-COST SAFETY AND MOBILITY IMPROVEMENTS

The Rhode Island Department of Transportation (RIDOT) initiated its RSA Program through *RI*STARS*—Rhode Island's Strategically Targeted Affordable Roadway Solutions. This program borrows from a Federal program in the 1970s and the Virginia Department of Transportation's similarly-named *STARS* program. Traditionally, the transportation planning process has focused on long-term, high-cost capital improvements for the transportation system. RI*STARS is focused on rapidly delivering high-benefit, low-cost safety and mobility improvements in response to today's safety, mobility, and funding challenges.

Funding for RI*STARS is included in the Transportation Improvement Program (TIP), which is its own line item under the RIDOT Traffic Safety Program. The program is funded $1,000,000 a year for study, design, and near-term construction. Construction of additional near-term and intermediate term recommendations may utilize other safety dollars, as well, such as Highway Safety Improvement Program (HSIP) funds.

RI*STARS was piloted on Aquidneck Island, which is made up of the Towns of Portsmouth and Middletown and the City of Newport. Aquidneck Island was selected for the pilot because of the significant amount of data available from the recently-started Aquidneck Island Transportation Study (AITS)- this was a regional, comprehensive, multimodal transportation planning study that evaluated roadway, transit, and pedestrian and bicycle travel. During the pilot effort, "hot spots" were identified in each of the three municipalities based on data that were compiled as part of the AITS, including crash data, congestion mapping, and input from public and local municipalities. Potential locations were then ranked based on crash history (including frequency and severity) and delay to identify 50 candidate locations exhibiting the greatest safety and/or congestion concerns. Candidates that were already under construction were dropped from further consideration, resulting in 17 ”hot spot” corridors and intersections.

RSAs were conducted by an interdisciplinary RSA Team consisting of engineers and officials from the municipalities, RIDOT, the Rhode Island Statewide Planning Program, law enforcement, and FHWA. The team identified crash contributing factors and developed strategies to address these factors for each “hot spot.” These strategies were comprehensive- covering the 4 E's of safety (engineering, enforcement, education, and emergency services)- and grouped into near-term, intermediate term, and long-term implementation time frames. Planning-level order-of-magnitude construction cost estimates were developed for the recommended improvements, as were crash reduction benefits. B/C ratios were then calculated to evaluate the economic feasibility and effectiveness of the proposed safety improvements at each location.

Once the RI*STARS team reviewed all countermeasures and developed a list of recommendations, the team developed a list of implementation mechanisms to be used for the identified recommendations. RIDOT Traffic Engineering will be implementing all the optimized signal timings in the field. RIDOT Maintenance will be responsible for addressing issues such as silted catch basins and missing signal head hoods. Recommendations at four locations are being incorporated into the design stage of identified projects. All remaining improvements will be implemented through two separate design-bid-build construction contracts. The first contract will focus on improvements not requiring permitting, such as basic signing, striping, and pedestrian facility enhancements. The second contract will cover the remaining improvements that may require permitting or input from the municipality or general public. The first contract was advertised for construction in March 2012 and the second is scheduled to be advertised at the end of 2012. Enforcement and education recommendations were developed in conjunction with appropriate stakeholders to maximize the opportunity for successful implementation.

An aerial view of the City of Newport Rotary with enhanced pavement marking plan.

One example of a recommended improvement from RI*STARS that will be implemented within a year is the retrofit of the City of Newport Rotary. As illustrated in the photograph at left, the nondelineated rotary will be enhanced with modern roundabout features, primarily by implementing low-cost measures like signing, striping, and minor curbing. In addition to enhancing safety, the retrofitted rotary is projected to operate with less delay than it does under existing conditions. However, this retrofit is an interim measure, as the intermediate-range plan is to reconstruct the intersection into a modern roundabout as part of an adjacent bridge project. Another example of a recommended improvement is the conversion of a four-lane roadway to two lanes with a two-way-left-turn-lane and shoulders that can be used by cyclists.

An aerial view of the four-lane to two-lane roadway conversion concept.

The successes of the RI*STARS program hinges upon the rapid implementation of the proposed countermeasures. This is critical in gaining momentum for the program and maintaining support from stakeholders (i.e., municipalities, community groups, and first responders). This pilot program has a goal to implement most near-term improvements within one year from the issuance of the final report and less than two years from the time the RSAs were conducted. Other improvements being included in planned projects will be implemented over the next few years, as those specific projects go to construction.

NEVADA DOT: ESTABLISH RSA CHAMPIONS

The Nevada DOT (NDOT) has a well-established RSA Program. NDOT Safety Engineering established a dedicated RSA Coordinator to implement the RSA program statewide. To supplement these efforts, NDOT developed guidelines for RSAs of new transportation project plans (i.e., preconstruction RSAs) such as capacity projects at various design stages, as well as for RSAs along existing roads (i.e., post-construction RSAs) that are undergoing safety improvements or resurfacing-restoration-rehabilitation (3-R) projects. In starting its program, NDOT leveraged the National Highway Institute (NHI) and FHWA RSA courses to train over 60 transportation professionals in the basic and advanced techniques in conducting RSAs. RSA teams focus on providing low-cost, crash-reducing improvements that can often be put into place by maintenance crews. NDOT also starts the RSA process in the prescoping phase of design projects such that safety improvements have the best chance for inclusion. NDOT also utilizes consulting firms to perform RSAs.

KANSAS DOT: RECURRING SYSTEMWIDE RSA PROGRAM

The Kansas DOT (KDOT) conducts county-wide RSAs on the entire State highway system. With a goal of completing a comprehensive RSA every five years on each State route, U.S. route, and the Interstate system. The RSA is comprised of three components: an office review, a field review, and a final report. It provides a proactive process to recognize issues immediately and to take corrective action. The RSA process also allows for the responsible engineer to meet with local officials and KDOT personnel to gain additional insight to improve safety. KDOT found that a well-managed RSA program can achieve more efficient use of personnel, as well as promote the consistent and up-to-date use of traffic control devices across the State.

MASSACHUSETTS DOT: LINKING RSAS TO HSIP

There are multiple benefits to linking an RSA program to the Highway Safety Improvement Program (HSIP). The RSA program can identify high quality, affordable, multi-modal safety projects and be used as a tool to advance HSIP implementation efforts and reduce fatalities and serious injuries within a jurisdiction. The Massachusetts DOT (MassDOT) considers RSA programs to be a “low-cost opportunity to make significant safety improvements” and uses them at all stages of a facility’s life-cycle, an approach that stemmed from its Strategic Highway Safety Plan (SHSP). MassDOT’s HSIP is linked to its RSA program by requiring that "all HSIP candidate locations will require an accompanying RSA report, or an engineering or planning report to determine eligibility." For example, roadway departure crashes were identified as an SHSP emphasis area and high severe crash locations were identified as part of the HSIP. The RSA program studied severe crossover median crashes and recommended and prioritized low-cost median treatments at these locations. MassDOT is looking to expand its RSA program to cover non-motorized high-crash locations as a result of the successful RSA median program.

MONTGOMERY COUNTY, MARYLAND: IMPROVING PEDESTRIAN AND BICYCLE SAFETY

Montgomery County DOT is leading an RSA program for pedestrians and bicyclists for the County. A consultant-led team identifies candidate locations for the pedestrian and bicycle safety assessments through the County’s High Incident Area (HIA) Program. Up to four HIAs are selected for evaluation each year, usually on major corridors throughout the County. Once study areas are defined, a multidisciplinary team is assembled that includes representatives from the Maryland State Highway Administration (MD SHA), neighboring local agencies, community members, and Montgomery County DOT staff. During the course of the assessment, the RSA team analyzes data, conducts site visits, and examines the issues and preliminary findings, which are discussed among the various stakeholders. A report is produced documenting the issues, and the RSA team presents it to the key stakeholders and roadway owners, a group that typically includes the County, MD SHA, and local/regional transit agencies. The RSA team coordinates improvements with each agency and monitors and pursues actions to implement improvements, such as completing preliminary designs, developing cost estimates, and completing work orders.

Arizona DOT: Collaborative and Proactive Approach to Statewide Safety

Program details can be found in Appendix B.

Tennessee DOT: Formalized and Uniform RSA Process

Program details can be found in Appendix B.

Collier County, Florida: Adoption of RSA Policy Including Design Permit Requirement

Program details can be found in Appendix B.

South Jersey Transportation Planning Organization: Comprehensive Site Selection Processes

Program details can be found in Appendix B.

THE EFFECTIVENESS OF RSA PROJECTS

BACKGROUND

The RSA project costs and benefits must be understood to determine the effectiveness of an RSA in improving safety. This section discusses basic techniques to compare RSA project costs and benefits to determine a project B/C ratio and provides programmatic guidance when selecting a location to conduct an RSA.

RSA COSTS

Three main factors contribute to the cost of an RSA:

- RSA team costs.
- Design team and owner costs.
- Implementation costs.

The *RSA team costs* reflect the size of the team and the time required for the RSA, which in turn are dependent on the complexity of the RSA project. In the RSA projects evaluated as part of this project, the team size may have been larger than necessary to expose more professionals to the RSA process.

The *design team and owner costs* reflect the time required for staff to attend the start-up and preliminary findings meetings and to subsequently read the RSA report and respond to its findings. In addition, staff time is required to compile project or site materials for the RSA team.

The final cost component is *implementation costs*. These are the costs resulting from the design and construction of measures suggested as part of the RSA. These can range from low-cost measures (e.g., signing and pavement markings) to higher-cost measures that require design and construction. Measures suggested for each of the RSAs reviewed for this project are included in Appendix B.

RSA BENEFITS

The primary benefit of RSAs is the reduction in crashes as road safety is improved. The U.S. Department of Transportation's[1] estimated costs of automotive crashes are shown below:

[1] Duvall, Tyler D. Memorandum to Secretarial Officers, Modal Administrators, U.S. Department of Transportation Office of the Assistant Secretary for Transportation Policy, "Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses". 5 Feb. 2008.

- $6,000,000 for a traffic fatality (category K).
- $4,422,500 for a critical injury (category A1).
- $1,087,500 for a severe injury (category A2).
- $333,500 for a serious injury (category B1).
- $89,900 for a moderate injury (category B2).
- $11,600 for a minor injury (category C).
- $6,500 for property damage only (PDO).

The process for determining whether a measure or project is effective at reducing crashes is a B/C analysis that compares the total expected benefits of a measure or project to the total expected costs for a specific measure or project. The output of the analysis, called a B/C ratio, is the cost savings from the reduction in crashes (achieved through the safety measures) divided by the cost of the safety reviews and safety measures implemented (in dollars). A B/C ratio greater than 1.0 represents the project benefits outweighing the project costs. Table 5 illustrates how the cost of various types of safety reviews can be justified for an existing location based on crash history. The table indicates the number of crashes of moderate-(B2), minor-(C), or PDO-(O) severity that need to be reduced as a result of the safety review to achieve a B/C ratio of at least 1.0 based on the average cost of the safety review alone. It is assumed that each type of safety review has a service life of three years. As such, the statistics in Table 5 refer to the number of crashes in a three-year period. The table highlights that, by addressing a few moderate to property-damage-only crashes, an agency can justify the cost of a simple to complex RSA.

Table 5. Type of Safety Review Based on Number of Crashes.

Type of Safety Review (Existing Roadway)	Average Cost	B2	C	O
		Moderate	Minor	PDO
		Associated Crash Cost		
		$89,900	$11,600	$6,500
Traditional Safety Review	$1,000	1	1	1
RSA - Simple	$10,000	1	1	2
RSA - Intermediate	$15,000	1	2	3
RSA - Complex	$25,000	1	3	4
Detailed Safety Review	$50,000	1	5	8

Notes: Any type of safety review can achieve a B/C over 1.0 if there is just one moderate or more severe injury. Each study type is assumed to have a three-year service life. A traditional safety review is typically a quick review of a project conducted by a transportation agency with in-house staff. A detailed safety review refers to a more expansive form of traditional safety review.

In the past, it was difficult to quantify the benefits of design-stage RSAs, especially on new facilities that have no crash record, since they aim to prevent crashes from occurring. Now, through the use of the Highway Safety Manual (HSM) and related tools such as the Interactive Highway Safety Design Model (IHSDM), there are methods to estimate the expected crashes for a new facility based on its design and operational characteristics. The benefits of RSAs on improved facilities and existing roads can be quantified based on observed pre- and post-improvement collision histories, but there are potential biases related to simple before-after comparisons. The HSM identifies methods for incorporating the average crash history at similar sites with the observed crashes at the location of interest to address the potential biases associated with before-after evaluations.

Whether design-stage or existing-stage, when compared to the high cost of automotive crashes, changes implemented from an RSA only need to prevent a few moderate- or high-severity crashes to be cost effective. Table 6 illustrates how different project implementation levels can achieve a favorable B/C ratio for various crash severities. The table indicates the number of crashes (by severity) that need to be reduced over the service life of the project to achieve a B/C ratio of at least 1.0 based on project implementation cost. It is assumed that maintenance projects have a service life of three years and HSIP projects have a service life of 10 years. For example, a low-level maintenance project would prove to be beneficial given at least one PDO crash is eliminated. A medium-level HSIP candidate project would prove to be beneficial if at least one serious injury or three moderate injury crashes were eliminated. Capital projects addressing highway safety issues without the guidance of an RSA may be similarly beneficial, but RSAs provide an opportunity to address multiple issues and coordinate safety-related projects to optimize costs and improve the potential effectiveness in reducing crashes and severity.

There are many other benefits that can be realized from conducting an RSA or safety review other than relying completely on achieving a B/C ratio greater than 1.0. Other benefits of RSAs include reduced life-cycle project costs (i.e., the total cost over the life of a project that includes activities like design and engineering, land acquisition, construction, reconstruction and rehabilitation, and preservation and routine maintenance).[2] This can be attributed to the fact that, as crashes are reduced and there is less need to make changes to the roadway or project, a greater awareness of safety is realized through the development of good safety engineering and design practices within an agency, including consideration of potential multimodal safety issues and integrating human factors into the design, operations, and maintenance of roads.

[2] Economic Analysis Primer
http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer04.cfm

Table 6. Type of Project Based on Number of Crashes.

Project Type	Average Cost	K	A1	A2	B1	B2	C	O
		Killed	Critical	Severe	Serious	Moderate	Minor	PDO
		Associated Crash Cost						
		$6,000,000	$4,422,500	$1,087,500	$333,500	$89,900	$11,600	$6,500
Maintenance – Low[1]	$1,000	1	1	1	1	1	1	1
Maintenance – Medium[1]	$10,000	1	1	1	1	1	1	2
Low-Cost Safety Improvement[2]	$10,000	1	1	1	1	1	1	2
Maintenance – High[1]	$100,000	1	1	1	1	2	9	16
HSIP – Medium[2]	$250,000	1	1	1	1	3	22	39
HSIP – Med/High[2]	$500,000	1	1	1	2	6	44	77
HSIP – High[2]	$1,000,000	1	1	1	3	12	87	154

Strong Candidate for RSA and Countermeasures
Likely Candidate for RSA and Countermeasures
Questionable Candidate for RSA and Countermeasures
Weak Candidate for RSA and Countermeasures

Notes:

1. Assumes a 3-year service life.

2. Assumes a 10-year service life.

Through safety management activities, one should strive for the greatest concentration of severe crashes to target for an effective RSA. The number of crashes shown is the absolute minimum to achieve a positive benefit/cost ratio (i.e., greater than 1.0).

RSA Projects Evaluated

Five RSAs were selected for detailed quantitative evaluations as part of this project, based on having implemented safety measures suggested as part of the RSA, as well as the availability of data for similar "comparison" sites within the agency's jurisdiction. The RSA sites selected for detailed evaluation include the following:

- Bullhead Parkway – Bullhead City, Arizona.
- State Route 101 – Cumberland County, Tennessee.
- Collier Boulevard at Golden Gate Parkway – Collier County, Florida.
- Immokalee Road – Collier County, Florida.
- Ninth Street – Ocean City, New Jersey.

The information presented for each RSA was gathered through direct communication with the responsible RSA agency. The specific objective of the quantitative analysis was to estimate the safety effects of engineering improvements that were implemented as a result of conducting RSAs. The expected annual benefits were then compared to the annualized cost of the treatments, including the cost to conduct the RSA, to estimate a B/C ratio. Safety effects were measured with respect to total crashes. Specific crash types were considered whenever possible, based on the individual locations, availability of detailed data, and sample size.

Methodology

Three evaluation methods were employed in this study depending on the availability of data. All three methods were based on an observational before-after study design where a site was selected for study, an RSA was conducted, treatments were implemented based on the RSA findings, and the crash history of the site was compared before and after treatment.

There are several potential biases to account for in before-after studies for which one should account:

- **Regression-to-the-mean**. Regression-to-the-mean is the tendency for high crash frequency periods to be followed by a low crash frequency period and vice-versa.
- **Traffic volume**. Changes in traffic volume can affect the number of crashes on a roadway and, therefore, should be accounted for in the analysis.
- **Temporal trends**. Temporal trends are factors that may change from the before to the after period, such as weather, driver behavior, and crash reporting practices.

If these potential biases are not properly addressed (or at least dismissed), the results could over- or underestimate the safety effects of the treatment.

The following is a brief summary of primary attributes of each evaluation methodology used in the evaluation of RSA outcomes:

- **Empirical Bayes.** The empirical Bayes (EB) before-after method is used to estimate and compare the expected number of crashes without implementation of specific RSA treatments to the number of reported crashes after RSA treatments have been implemented. EB is the primary, and preferred, study design for this evaluation and is considered the state-of-the-practice for conducting observational before-after studies because it properly accounts for regression-to-the-mean and other potential sources of bias.
- **Comparison Group.** This method uses data from the RSA site (having implemented treatments) and a comparison group of untreated RSA sites (having similar characteristics and crash histories to the treated RSA site) to develop before/after comparisons of observed and expected crash incidence. This method can account for several potential sources of bias but does not effectively address regression-to-the-mean.
- **Naïve.** The naïve (or simple) before-after method uses before and after crash data only from the RSA site to compare observed and expected crash incidence. This method does not address regression-to-the-mean and is typically the last option for a before- after study; however, it can be useful to identify the general effectiveness of a treatment (i.e., substantial increase or decrease in crashes), particularly if the treatment effect is large.

A detailed overview of the attributes, advantages, and disadvantages of each evaluation method can be found in Appendix A. More details can be found in FHWA's *A Guide to Developing Quality Crash Modification Factors* (Gross et al., 2010).

Key Findings

Each of the five RSA sites evaluated exhibited an overall reduction in crashes as a result of the suggestions implemented from the RSAs. Reductions in total crashes ranged from 10 percent to 50 percent, with varying levels of statistical significance. Furthermore, each of the RSA sites for which project cost information was provided showed a B/C ratio greater than 1.0, meaning that the benefits of the treatments implemented as a result of the RSAs exceeded the total RSA and implementation costs. B/C ratios ranged from 1.2:1 to 116:1; the greater the B/C ratio, the greater the benefit compared to the project cost. Areas with high B/C ratios either had a high reduction in crashes (e.g., a reduction in total crashes of 50 percent) or had low project costs (e.g., implementing signing and pavement markings). Areas with lower B/C ratios typically had higher project costs.

Table 7 summarizes the safety improvement measures implemented as a result of the RSAs, the statistical evaluation methods applied, the project costs, and the safety benefits and resulting B/C ratios based on the analysis of the crash types addressed. Appendix A provides further details on the methodologies used to quantify RSA treatment benefits for each case study site. Further details about each RSA project site (i.e., a project description, summary of key findings and suggestions, photographs for each location, the methodology used in the evaluation, data, analysis, and findings) are included in Appendix B. If it was available, additional information is also provided about the agency's RSA procedures and experience outside of the specific RSA project considered for this effort.

Table 7. Quantitative Evaluation of RSA Outcomes.

Location & Measures	Primary Method: *Biases Addressed*	Results
Bullhead Parkway *Bullhead City, Arizona* • Roadside improvements • Guardrail • Signing and marking • Traffic signals • Drainage	Comparison Group: *Traffic volume changes, temporal changes*	• Total cost of $869,478 (plus several nominal fee projects) • $785,000 of additional projects scheduled • 54% reduction in total crashes • 50% reduction in fatal/incapacitating injury crashes • 30% reduction in intersection-related crashes • B/C ratio of 20:1 (total crashes) • B/C ratio of 16:1 (injury crashes) • B/C ratio of 2:1 (intersection- related crashes)
State Route 101 (Peavine Rd.) *Cumberland County, Tennessee* • Signing and marking • Sight distance enhancements • Vegetation removal	Empirical Bayes: *Regression-to-the-mean, traffic volume changes, temporal changes*	• Total cost of $35,000 • 13.7% reduction in total crashes • 31.3% reduction in injury crashes • B/C ratio of 51:1 (total crashes) • B/C ratio of 116:1 (injury crashes)
Intersection of Collier Boulevard and Golden Gate Parkway *Collier County, Florida* • Signing and marking • Geometric modifications • Vegetation removal • Pedestrian enhancements	Empirical Bayes: *Regression-to-the-mean, traffic volume changes, temporal changes*	• Total cost of $265,000 • 11% reduction in total crashes, both intersections • B/C ratio of 5:1 (total crashes, both intersections)
Immokalee Road *Collier County, Florida* • Access management • Pedestrian signals • Median fence • Geometric modifications • Bicycle facilities	Naïve (with adjustments): *Traffic volume changes, temporal changes, other changes (4- to 6-lane conversion)*	• 10.8% reduction in total crashes
Ninth Street *Ocean City, New Jersey* • Traffic signal improvements • Pedestrian signals	Comparison Group: *Traffic volume changes, temporal changes*	• Total cost of $921,000 • 25.6% reduction in total crashes • B/C ratio of 1.2:1 (total crashes)

APPENDIX A: DETAILED OVERVIEW OF EVALUATION METHODOLGIES

EMPIRICAL BAYES METHODOLOGY

The empirical Bayes (EB) method can be used to account for regression-to-the-mean bias in before-after studies. Other advantages are that it can be used to accomplish the following:

- Overcome the difficulties of using crash rates to normalize for differences in traffic volumes between the before and after periods.
- Reduce the level of uncertainty in the estimates of safety effect.
- Provide a foundation for developing guidelines for estimating the likely safety consequences of contemplated installations.
- Properly account for differences in crash experience and reporting practices.

The premise of the EB method is to estimate the *expected* number of crashes that would have occurred in the after period had the treatment not been implemented (π) and compare that with the number of *reported* crashes in the after period once the treatment is actually installed (λ). The number of crashes before a treatment by itself is not a good estimate of π because of changes in safety that may result from changes in traffic volume, regression-to-the-mean, and trends in crash reporting and other factors. Instead, π is estimated from an EB procedure where information from the treatment site and a group of similar reference sites are combined. The following steps are used to estimate π:

1. Identify a reference group of untreated sites that is otherwise similar to the treatment group.
2. Use the reference group data to estimate safety performance functions (SPFs) (i.e., mathematical equations that predict crash frequency by type/severity as a function of traffic volumes and other site characteristics). Typically, SPFs are negative binomial regression models that are estimated using generalized linear modeling (GLM).
3. Calibrate annual multipliers (time-related factors) to account for temporal trends (e.g., variations in weather, demography, and crash reporting).
4. Use the SPFs and annual multipliers to compute the *predicted* number of crashes in each year of the before period for each treatment site.
5. Use the *predicted* number of crashes in the before period (from step 4) and the observed crashes in the before period at each treatment site to estimate the *expected* number of crashes in the before period at each site. This step applies the EB weighting scheme to adjust for possible bias due to regression-to-the-mean.

6. Estimate π (i.e., the expected number of crashes in the after period had the treatment not been implemented) as the product of the expected number of crashes in the before period (from step 5) and the ratio of the sum of annual SPF predictions for the after period divided by the sum of these predictions for the before period.
7. The estimate of π is then summed over all sites in a treatment group of interest and compared with the count of crashes during the after period.

The estimate of π and its variance are then used, along with the crash counts after the implementation of the treatment, to estimate the treatment effect.

Comparison Group Methodology

The comparison group method does not effectively account for regression-to-the-mean but can be effective in accounting for other nontreatment effects, such as those due to changes in traffic volume and other temporal trends. This method makes use of a comparison group that is untreated and for which an RSA was not conducted but is otherwise similar to the treatment sites. The data from the comparison group are used to adjust the before period crash count at the treated site to reflect the length of after period (relative to the before period), as well as other extraneous factors. Implicit in the use of a comparison group is the assumption that the comparison group is subject to extraneous factors affecting crashes in a way that is sufficiently similar to the treatment sites. This can be tested by tracking the yearly crash counts at treatment and comparison sites.

Similar to the EB method, the premise of the comparison group method is to estimate the expected number of crashes that would have occurred in the after period had the treatment not been implemented (π) and compare that with the number of reported crashes in the after period once the treatment is actually installed (λ). The departure from the EB method is that π is based on the observed crashes in the before period at the treatment site. This estimate could be biased if sites are selected for treatment because of a randomly high observed crash count (i.e., regression-to-the-mean).

General temporal trends are accounted for using crash data from the comparison group. Specifically, the ratio of crashes after treatment to before treatment is computed for the comparison sites and multiplied by the observed crashes before treatment at the treatment site. This is generally insufficient to account for changes in traffic volume from the before period to the after period. To properly account for traffic volume changes, another factor is applied to the result of the previous step. The comparison group is first used to develop an SPF, and the factor is computed as the ratio of predicted crashes in the after period divided by the predicted crashes in the before period for the treatment sites.

NAÏVE METHODOLOGY

The naïve (or simple) before-after method does not effectively account for regression-to-the-mean and is also less effective than the EB and comparison group methods in accounting for other nontreatment effects, such as those due to changes in traffic volume and other temporal trends. This method does not utilize a reference or comparison group and simply uses before and after data from the treatment sites.

Similar to the previous two methods, the naïve before-after method estimates the expected number of crashes that would have occurred in the after period had the treatment not been implemented (π) and compares that with the number of reported crashes in the after period once the treatment is actually installed (λ). Similar to the comparison group method, π is based on the observed crashes in the before period at the treatment site, but there is no use of a comparison group to adjust this estimate. Again, this estimate could be biased if sites are selected for treatment based on a randomly high crash count (i.e., regression-to-the-mean).

The naïve before-after method accounts for the length of the before and after periods and roughly adjusts for changes in traffic volumes. There is no account for other temporal trends that could change from the before to the after period. To account for traffic volume changes, a simple linear relationship between crashes and traffic volume is often assumed. In this case, the ratio of traffic volume in the after period to the before period would be calculated. The ratio of years after treatment to years before treatment is also computed to adjust for the number of years in each period. The observed crash count before treatment is then multiplied by the two ratios to estimate π.

APPENDIX B: RSA CASE STUDIES

BULLHEAD PARKWAY: BULLHEAD CITY, ARIZONA

Road: Existing 10.2-mile section of paved, 4-lane, divided, rural roadway

RSA Sites:	• 4 signalized intersections, 13 unsignalized intersections • AADT: 10,000 – 15,000 vehicles per day (2007) • 50 mph posted speed limit
Environment:	☐ urban/urbanized ☐ suburban ☐ **rural**
Owners:	Bullhead City, Arizona

Road Safety Audit

Date of RSA:	23-25 October 2007
RSA Stage(s):	☐ planning/design stage ☐ **RSA of existing roads**
RSA Team:	5 members representing ADOT Traffic Safety, ADOT Traffic Design, ADOT Kingman District, FHWA, and the City of Yuma
RSA Cost:	$30,000
Implementation Cost:	$839,478
Crash Reduction:	54% total; 50% fatal / incapacitating; 30% intersection-related
Benefit / Cost Ratio:	20:1 total; 16:1 injury; 2:1 intersection-related

BACKGROUND

An RSA was conducted along a 10.2-mile section of Bullhead Parkway in Bullhead City, Arizona (Figure 2). Bullhead Parkway is a four-lane, divided, rural roadway with a posted speed limit of 50 mph for the entire length. Four signalized intersections are present along the Parkway. At the time of the RSA, the annual average daily traffic along the Parkway was reported to range between 10,000 and 15,000 vehicles per day (vpd).

The RSA was requested by the Bullhead City Department of Public Works. The Parkway appeared on Arizona's 2006 Five Percent Report. The section was also one of the City's top safety priority locations.

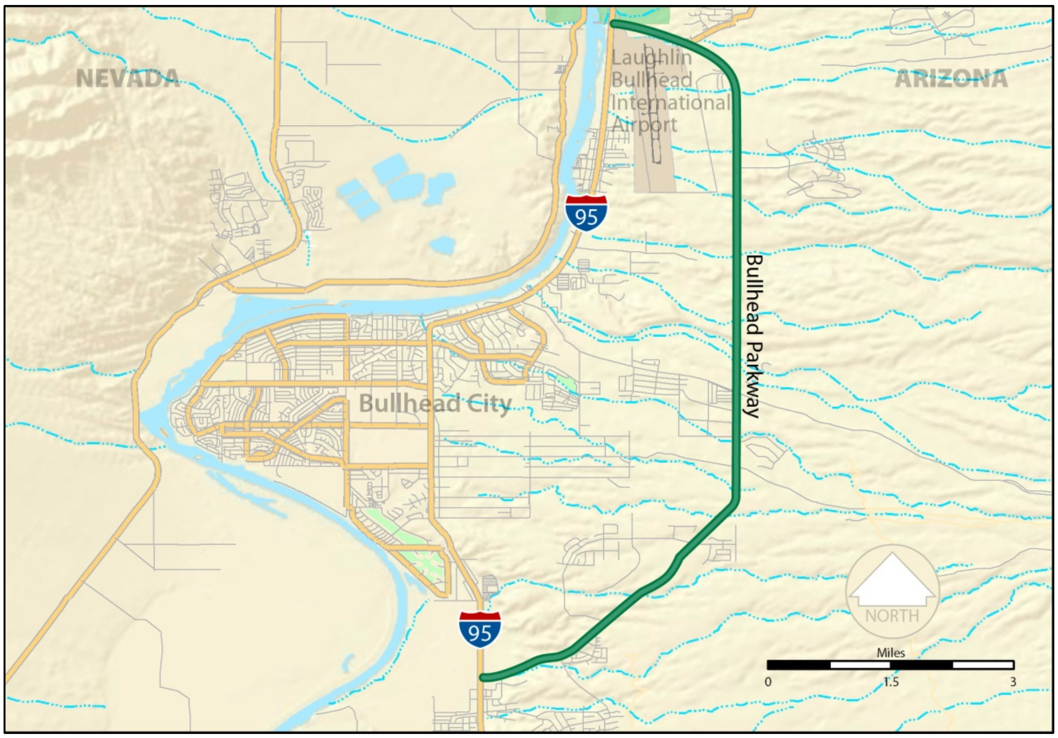


Figure 2. Aerial Map of Bullhead Parkway.

The RSA was conducted in October 2007. The RSA team was comprised of five members representing the Arizona Department of Transportation (ADOT) Traffic Safety, ADOT Traffic Design, ADOT Kingman District, City of Yuma, and Federal Highway Administration (FHWA).

Information used by the RSA team to conduct the review included the following:

- Crash data (August 1, 2003 – July 31, 2006) from the ADOT Motor Vehicle Division.
- Traffic data (2007 and 2009) from Bullhead City.
- Roadway data (lane, median, and shoulder widths).

For this RSA, 3.5 hours (total) were required to hold the opening and closing meetings. The RSA team spent 7 hours in the field reviewing the roadway segment. Analysis prior to and following the field review required 10 hours. Documenting the findings of the RSA required 12 hours. Four hours of travel each way were required to complete the RSA. In total, the RSA of Bullhead Parkway took 40.5 hours and cost $30,000.

Key Findings and Suggestions

The key findings and suggestions of the RSA are summarized in Table 8. Several of the measures were initiated in 2007, shortly after the completion of the RSA. A number of measures have since been implemented or are programmed for coming years. Out of all the measures suggested, only the flattening of roadside slopes is not being considered or evaluated further due to a lack of available right-of-way and cost issues.

Table 8. Summary of Safety Issues and Suggestions: RSA of Bullhead Parkway (part 1 of 3).

Suggestions		Implementation	Location/Extent	Cost
Roadside and Edge Drop-offs	Flatten embankment slopes to 4:1; lay back cut slopes	Not Implemented	N/A	N/A
	Install guardrail where embankment slopes are steeper than 4:1	Implemented (Jan to Jun 2008)	All over Parkway	Approx. $100,000
	Request that developers move concrete blocks	Implemented (Jan 2008)	North of Lauglin Ranch Boulevard	Nominal
	In addition to constructing 8-ft shoulders with rumble strips along the outside lanes, provide 4-ft shoulders with rumble strips along the median lanes; in interim, maintain and stabilize shoulders	Paving shoulders, inside and outside with rumble strips (May 2008)	All over Parkway	$565,228
Median	If median crossover crashes increase, consider median barrier, particularly on the southern end	Not implemented, crossover crashes have been zero	N/A	N/A
	At non-traversable median drains, raise the catch basin and provide a concrete apron with 6:1 slopes; then remove object markers and delineators	All center median storm drains raised to grade per ADOT standards; all posts and signs removed (Jan to Oct 2008)	All over Parkway	20 x $1,000 each $20,000
	Perform routine maintenance on catch basins, pipes, and grates	Being implemented (Jan through Dec 2008)	All over Parkway	Ongoing operational costs
	If landscaping median, use vegetation that grows no higher than 4 ft with mature trunk diameters no larger than 4 in	Decided not to landscape median	N/A	N/A

Table 8. Summary of Safety Issues and Suggestions:
RSA of Bullhead Parkway (part 2 of 3).

Suggestions		Implementation	Location/Extent	Cost
Median	Extend guardrail at locations where hazards are not adequately shielded	Guardrail installed in front of new traffic signals standards on East side (Mar 2008)	75-ft. on Montano Place	$5,000
	Remove unwarranted guardrail just south of Montano Place	Guardrail removed on W side (Feb 2008)	South of Montano Place	$500
	Stiffen guardrail in front of power pole just south of Montano Place	Double guardrail installed (Mar 2008)	South of Montano Place	$250
	Address erosion problems at guardrail sections near milepost 9	Implemented (Apr 2008)	Milepost 9	$1,000
	Remove unneeded curb sections	Still to be done	N/A	N/A
	Provide post block-outs at remaining curb/guardrail locations	Implemented (Jan thru Dec 2007/2008)	Several areas on Parkway	$5,000
	For future curb installations, use sloping curb no higher than 4 inches installed flush with or behind the guardrail	No more curb installed	N/A	N/A
	When replacing terminals, install energy-absorbing terminals	Replaced about 30 in 2008 - 2010, 20 planned for FY 2011 using HSIP Grant	All over Parkway	20 x $4,000 per terminal $80,000
Signage	Install hill signs showing percent grade with a 45 mph speed plaque on southbound section south of North Oatman Road	Still to be done	N/A	N/A
	Use 150-ft spacing for flexible delineators in curves	Implemented (May 2008)	300-ft spacing	$14,000
	Install two-direction large arrow signs on far side of T intersections	W1-7 sign installed at T intersections (Feb & Mar '08)	All over Parkway	$2,000
	Remove unnecessary intersection warning signs	D-3 signs installed for advance warning; all yellow advance warning signs removed (Jan to Oct 2008)	All over Parkway	Nominal
	Install advance street name signs in advance of side streets	Y- D-3 signs installed for advance warning; all yellow advance warning signs removed (Sep and Oct 2008)	All over Parkway	$1,500
	At southbound approach to Desert Hills Boulevard, replace the intersection warning sign with the existing signal ahead sign	Southbound signal ahead sign moved 150 ft north around curve (Jan 2008)	At Desert Foothills Boulevard	Nominal
	Where signs are closely spaced, move farther apart	Implemented (Feb 2009)	All over Parkway	Nominal
	Where signs are within 10 ft of the road, move farther away	All signs in shoulders moved to 8+ ft from travel lane (May 2008)	All over Parkway	Included in cost of shoulder work
	Install object markers at Circle K driveway island	Delineation installed on porkchop island (Jan 2008)	At Circle K on Adobe Road	Nominal
	When replacing signs, use higher intensity sheeting and next larger size	Started using current standard Jan 2009	All over Parkway	Nominal extra cost

Table 8. Summary of Safety Issues and Suggestions: RSA of Bullhead Parkway (part 3 of 3).

Suggestions		Implementation	Location/Extent	Cost
Markings	Extend the northbound right-turn lane at Adobe Road and the southbound right-turn lane at North Oatman Road	Right-turn lane EB to SB lengthened (Mar 2008)	At Adobe Road & North Oatman Road	$5,000
	Provide "dribble lines" for northbound right-turn lane at Adobe Road	White blocks installed across entrance to guide around curve (Mar 2008)	At Adobe Road	Nominal
	Update pavement markings and consider using thermoplastic markings and 6-inch wide edge and lane lines	Scheduled for 2010	All over Parkway	$300,000 HSIP Grant
	Install RPMs on the inside edge line (20-ft spacing) and on the lane lines (40-ft spacing)	Reflective RPMs will be installed on both sides of Parkway. Scheduled for 2010.	All over Parkway	$50,000 HSIP Grant
	Use grinding for future pavement marking eradication	None needed	N/A	N/A
	In the future, consider use of offsets for left-turn lanes	None needed	N/A	N/A
Signals	Inspect signal display brightness level on northbound approach to Silver Creek Road	Implemented (Jan 2008)	Silver Creek Road signal	Nominal
	Remove pedestrian signals at Silver Creek Road, Laughlin Ranch Boulevard, and Montano Place	Still evaluating	N/A	N/A
	If pedestrian activity increases, provide ADA-compliant pedestrian signals and accommodations where needed	No increase in pedestrians	N/A	N/A
	Remove middle signals from the mast arms for the approaches from Adobe Road and replace with far left signal heads	Signal heads moved (Feb 2009)	Adobe Road signal	Nominal
	For the northbound approach at Adobe Road, install a longer mast arm and adjust the signal head locations for proper lane alignment	Purchased arm but still need to install	N/A	N/A
Other Observations	Measure superelevation in the field and if found insufficient, address in future paving projects	Will do part of future paving	N/A	N/A
	Replace temporary stop sign at Montano Place with a higher sign (5- to 7 ft high)	Implemented (Jan 2008)	Montano Ridge signal	Nominal
	Initiate discussion with Laughlin casinos/area employers to address fatigued driver problem	Implemented (Mar 2007 and Oct 2008)	N/A	None, as no action taken

The following photos illustrate safety issues observed during the RSA ("before" on left) and the subsequent improvements resulting from the RSA suggestions ("after" on right).

Nontraversable median drains.

Raised traversable median drains.

Out-of-date end terminals.

Current standard end terminals.

T-intersection signing.

Enhanced T-intersection signing.


Short right-turn lane. **Extended right-turn lane.**

The cost, to date, of the suggestions implemented based on the findings totaled $839,478 (plus several nominal fee projects). These measures were paid for largely through Bullhead City's Capital Improvement Program. To cover the cost of programmed projects directly related to the RSA, the City completed local government Highway Safety Improvement Program (HSIP) grant applications and submitted to ADOT in the amount of $403,000. An additional $382,000 was also applied for to complete projects along the Parkway that were outside of the RSA suggestions. This amount included $200,000 for signal design and construction at the intersection with N. Oatman Road; $170,000 for the construction of a southbound right-turn lane at the intersection with Silver Creek Road; and $12,000 for the construction of ADA-compliant ramps at the corners of the intersection with Adobe Road.

In general, ADOT and Bullhead City viewed the RSA as a great success. For its efforts in garnering funds and implementing improvements, Bullhead City was presented with an "RSA Champion" award by ADOT and FHWA during the inaugural Arizona Traffic Safety Summit in 2009. ADOT district personnel have seen the value in RSAs, as the representative team member for this RSA has participated in several others since. The City has also accepted the RSA process and its benefits; two additional RSAs have been conducted in Bullhead City since the completion of the one along Bullhead Parkway. The City has also received some educational benefit from this RSA in terms of roadway and roadside hazard safety. For example, the City had previously installed trees along a low-speed facility as landscaping. A similar application was suggested by the City for use along the median of Bullhead Parkway; however, the use of large-diameter trees (i.e., greater than four inches wide) along the roadside of a high-speed facility is not conducive to safety, as the landscaping presents fixed object hazards.

RSA OUTCOMES

Geometric, traffic volume, and crash data were collected for both treatment and comparison sites in Arizona. The treatment site consisted of two consecutive segments that were divided at the point where the traffic volume changed. Data were provided by direction for the comparison site because certain roadway characteristics differed between the two directions. Similar to the treatment site, the comparison site was split into two segments at the point where the traffic volume changed. Table 9 provides a summary of the treatment and comparison site data.

Table 9. Summary of Arizona Data.

Variable		**Treatment Site**	**Comparison Site SB**	**Comparison Site NB**
Number of segments		2	2	2
Months before		60	60	60
Months after[1]		23	23	23
Total crashes/mile-year before		4.76	0.58	0.66
Total crashes/mile-year after[1]		2.25	0.99	0.61
Injury crashes/mile-year before		2.35	0.28	0.29
Injury crashes/mile-year after[1]		1.13	0.40	0.29
Intersection-related crashes/mile-year before		1.75	0.04	0.06
Intersection-related crashes/mile-year after[1]		1.64	0.05	0.08
AADT Before	Average	13,092	3,767	3,767
	Minimum	12,874	3,050	3,050
	Maximum	13,310	4,456	4,456
AADT After	Average	11,615	3,908	3,908
	Minimum	11,490	3,609	3,609
	Maximum	11,740	4,511	4,511
Area type		Rural	Rural	Rural
Number of Lanes		4	2	2
Median Type		Unpaved	Unpaved	Unpaved
Median Width (ft)		16	80	80
Shoulder Type		Unpaved	Unpaved	Paved
Shoulder Width (ft)		8	8	10
Posted Speed (mph)		50	65	65

[1]*Includes 2008 and 11 months in 2009*

In Arizona, the countermeasures implemented as a result of the RSA were mostly implemented in 2008; however, some countermeasures were implemented in 2009 and after. Thus, the after period conditions were continuously changing for the treated segments. Recognizing the changing conditions and the limited after period, the analysis was run for two after periods. The first after period was based on data from 2008 and the first 11 months of 2009. The second after period only considered the first 11 months of 2009.

The analysis did not account for regression-to-the-mean because the empirical Bayes (EB) approach could not be applied. However, it was possible to investigate the potential for regression-to-the-mean. Specifically, the yearly crash counts for both total and injury crashes were plotted over time for the treatment site, as shown in Figure 3. The period from 2003 to 2007 is relevant to the potential for regression-to-the-mean. If present, one would expect to see a spike in crash counts prior to the RSA being conducted in 2007. The plot indicates the potential for regression-to-the-mean for both total and injury crashes. Notably, the annual crash counts appear to spike for the three-year period from 2004 to 2006 and then decrease in 2007, prior to the implementation of any countermeasures from the RSA.

In this case, the potential regression-to-the-mean bias could result in an overestimation of the expected safety effects of the treatments. As such, the analyses were run with and without the three years of suspect data (2004 to 2006) to investigate the magnitude of the regression-to-the-mean bias.

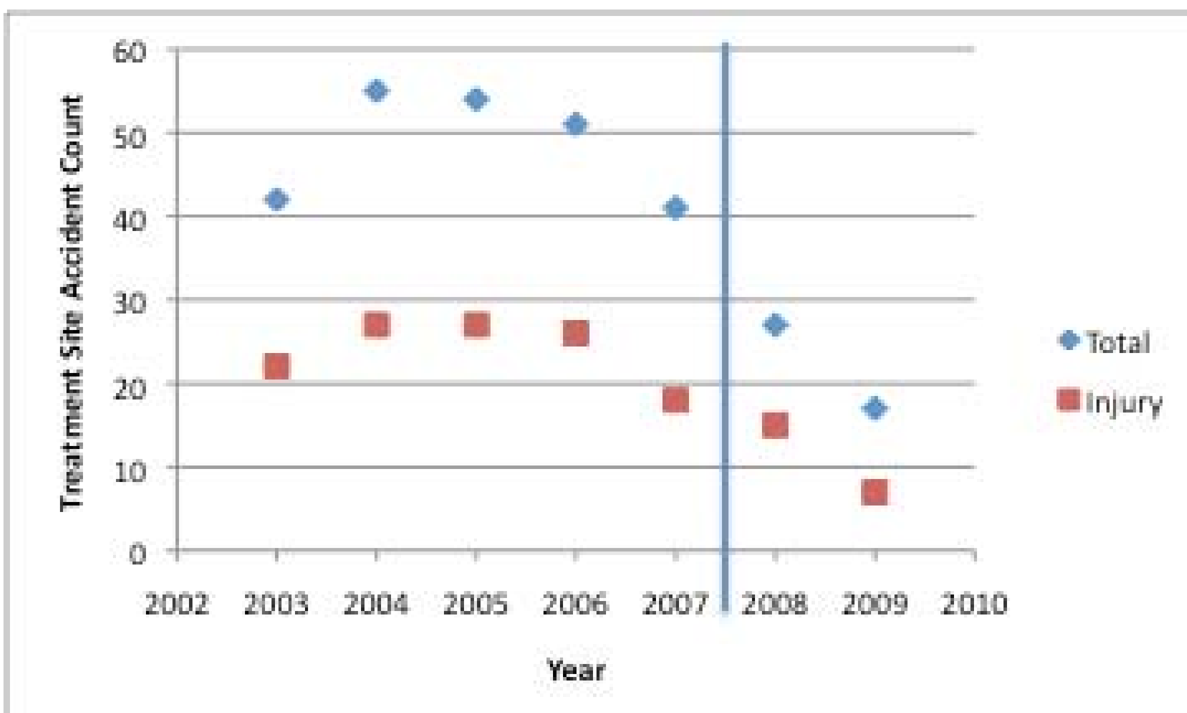


Figure 3. Treatment Site Crash Totals Over Time.

The following points should also be noted with respect to the analysis:

- For the comparison group method, total crashes in the before and after period at the comparison sites were used to account for general temporal trends in total and intersection-related crashes. Note that total crashes at the comparison sites were used to adjust the intersection-related crashes at the treatment sites due to limited intersection-related crashes at the comparison sites. Injury crashes at the comparison sites were used to adjust for injury crashes at the treatment site.
- When accounting for changes in traffic volume, a linear relationship was assumed between crashes and traffic volume. With a limited variation in traffic volumes it was not possible to develop an SPF or evaluate the suitability of existing SPFs to model the true relationship. Given the inherent uncertainty in other aspects of the analysis, and the relatively small changes in annual average daily traffic (AADT), this assumption was not deemed crucial.
- The suitability of the comparison group could not be rejected using the methods described by Hauer (1997). As such, the comparison site is deemed reliable for use in the comparison group method.

The results of the Arizona analyses are presented in Tables 10 – 13. Note that separate results are provided for each of the following:

1. Comparison-group method, including entire before period.
2. Comparison-group method, excluding years 2004 to 2006 from the before period.
3. Naïve method, including entire before period.
4. Naïve method, excluding years 2004 to 2006 from the before period.

Note that each table includes two sets of results, one considering 2008 in the after period and another excluding 2008 from the after period. Results that are statistically significant at the five percent level are noted in bold.

Table 10. Comparison Group Results from Arizona Including Total Before-Period.

	C-G Method Including 2008			**C-G Method Without 2008**		
Crash Type	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
Total	44	116.29	**0.339 (0.113)**	17	54.96	**0.277 (0.104)**
Injury	22	52.05	**0.361 (0.143)**	7	26.90	**0.221 (0.106)**
Intersection-Related	32	39.21	**0.683 (0.272)**	15	21.24	**0.572 (0.254)**

Table 11. Comparison Group Results from Arizona, Excluding 2004 to 2006.

Crash Type	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
Total	44	84.53	**0.462 (0.159)**	17	38.98	**0.386 (0.149)**
Injury	22	36.72	**0.501 (0.206)**	7	18.48	**0.315 (0.154)**
Intersection-Related	32	36.56	**0.698 (0.297)**	15	19.26	**0.604 (0.280)**

Table 12. Naïve Results from Arizona, Including all Before-Period Years.

Crash Type	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
Total	44	83.12	0.527 (0.086)	17	39.75	0.426 (0.106)
Injury	22	41.02	**0.532 (0.122)**	7	19.62	**0.354 (0.136)**
Intersection-Related	32	30.16	**1.049 (0.214)**	15	14.42	**1.028 (0.284)**

Table 13. Naïve Results from Arizona, Excluding 2004 to 2006.

Crash Type	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
Total	44	71.09	**0.612 (0.113)**	17	34.00	**0.494 (0.130)**
Injury	22	102.54	**0.213 (0.049)**	7	49.04	**0.142 (0.055)**
Intersection-Related	32	75.40	**0.420 (0.086)**	15	36.06	**0.411 (0.114)**

The results indicate a general safety benefit of conducting the RSA and implementing the treatments suggested in the RSA report. For total and injury crashes, the estimated crash modification factor (CMF) is consistently less than 1.0 for all variations of the analysis, indicating a reduction in expected crashes. Further, the reductions in total and injury crashes are substantial and highly significant. With respect to intersection-related crashes, the results generally indicate a safety benefit with two exceptions, which are not statistically significant.

While there are several variations of the analysis, the results from the comparison group method are preferred over the naïve before-after results. The estimated crash reductions are generally larger for the comparison group method than for the naïve method. This is due to the observed increase in crashes at the comparison site in accounting for time trends. However, the naïve method does appear to corroborate the results of the comparison group method. The remainder of the discussion is focused on the results of the comparison group method but generally applies to the naïve results, as well.

The estimated crash reductions are generally smaller when the 2004 to 2006 data are not included in the before period. This confirms the suspicion that regression-to-the-mean may be present. Therefore, the results from Table 11 (Comparison Group Results Excluding 2004 to 2006) provide a more conservative estimate of the safety effects than Table 10. Within each table, the estimated crash reductions are larger when 2008 is excluded from the after period. This is not surprising, as countermeasures were implemented throughout 2008 and 2009. As such, the analyses that include 2008 in the after period provide conservative estimates of the safety effect.

Table 14 presents a summary of the safety benefits estimated from the treatment site in Arizona. The conservative estimates are based on the comparison group method, excluding 2004 to 2006 from the before period and including 2008 in the after period. The range of results from both methods and all variations is also presented. The results indicate a 54 percent reduction in total crashes, a 50 percent reduction in injury crashes, and a 30 percent reduction in intersection-related crashes.

Table 14. Summary of Results from Arizona.

	Conservative Estimate (S.E.)	Range of Estimates
Total	0.462 (0.159)	0.277 to 0.612
Injury	0.501 (0.206)	0.142 to 0.532
Intersection-related	0.698 (0.297)	0.411 to 1.049

The annualized costs and benefits were then compared. Based on the comparison group method, there was an annual reduction of 21.1 total crashes, 7.7 injury crashes, and 2.4 intersection-related crashes. Using the FHWA crash costs document, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* (Publication Number FHWA-HRT-05-051), the annual benefits are $1,973,395, $1,582,195, and $222,025 for total, injury, and intersection-related crashes, respectively. Assuming a total cost of $869,478 ($30,000 for the RSA and $839,478 for the improvements), a discount rate of 2.2 percent, and a service life of 10 years, the annualized cost is $97,812. Therefore, the B/C ratio of the improvements made as a result of the RSA is 20:1, 16:1, and 2:1 for total, injury, and intersection-related crashes, respectively.

Program Review

The Arizona DOT (ADOT) uses its RSA program to build collaborative partnerships that proactively improve safety. RSAs have brought together State, county, and tribal transportation practitioners to solve complex safety issues. This has led to long-standing partnerships between ADOT, counties, and the tribes where each agency has a better understanding of each agencies concerns, limitations, and abilities. This collaborative approach applied through RSAs has also been helpful in educating local agencies about the risks associated with various crash types and bringing attention to safety issues at locations that may be lacking crash data. For example, a pedestrian crash may be a rare occurrence, but when one occurs, there is often a high probability of severe injury or death. ADOT staff brings perspectives to local agencies to help provide context on the types of operational and geometric characteristics that can adversely impact pedestrian safety. In an example of safety issues at locations lacking crash data, most non-fatal crashes occurring on tribal reservations are not entered into the state DOT crash database. This skews the crash frequencies and rates on reservation roads, many of which are state-owned and maintained, making it appear that these roads do not have a crash problem. The proactive nature of the RSA provides an opportunity to identify safety issues without the benefit of crash data and develop appropriate countermeasures to improve road safety.

Over time, the RSA program has successfully communicated to design engineers that merely following standards does not necessarily produce a safe design. The collaborative and independent approach of the RSA teams to improving safety is changing how design engineers initially viewed RSAs—from a strict adherence to design standards to a more open discussion about the safety implications of various designs. The findings from the RSA program have been used to update the DOT's policies and standards. The ADOT experience has shown a need for better upfront coordination with the road owner as a key element to obtain better data and reports and to determine who should be invited to the RSA meetings. ADOT also recommends a nighttime site review, even if the crash data does not indicate any issues, and to obtain the law enforcement perspective in each RSA.

STATE ROUTE 101 (PEAVINE ROAD): CUMBERLAND COUNTY, TENNESSEE

Road: Existing 3.84-mile section of paved, two-lane, rural roadway

RSA Sites:	• 2 unsignalized intersections • AADT: 12,860 vehicles per day (2007) • 45 mph posted speed limit
Environment:	☐ urban/urbanized ☐ suburban ☐ **rural**
Owners:	Tennessee DOT (TDOT); Cumberland County

Road Safety Audit

Date of RSA:	1 November 2005
RSA Stage(s):	☐ planning/design stage ☐ **RSA of existing roads**
RSA Team:	9 members representing FHWA and TDOT
RSA Cost:	$12,000
Implementation Cost:	$23,000
Crash Reduction:	13.7% total; 31.3% injury
Benefit / Cost Ratio:	51:1 total; 116:1 injury

BACKGROUND

An RSA was conducted along a 3.84-mile section of State Route 101 (Peavine Road) in Cumberland County, Tennessee (Figure 4). Throughout this section, State Route 101 is a two-lane, rural roadway with a posted speed limit of 45 mph. The AADT was reported as 12,860 vpd in 2007.

The area of concern was brought to attention by local citizens who perceived the section of roadway to be dangerous. Consequently, Tennessee DOT (TDOT) Planning staff were asked to evaluate this section of State Route 101 to determine the need for appropriate safety measures. Upon reviewing the crash data, the number of reported crashes supported the public's concern.

The RSA was conducted along State Route 101 in November 2005 from Peavine Firetower Road (L.M. 18.31) to Tuttle Lane (L.M. 22.15). The RSA team was comprised of nine members representing the FHWA, TDOT Headquarters, TDOT Traffic Engineering, and TDOT Planning. The efforts of the team were led by the TDOT Regional Engineer.

Figure 4. Aerial Map of State Route 101.

Information used by the RSA team to conduct the review included roadway data (i.e., geometrics, functional class, route features, etc.), traffic data, and crash data. A comprehensive list of the available information is as follows:

- Crash data and ambulance call records.
- General statements from citizens.
- Cumberland County general highway map.
- Tennessee Roadway Information Management System (TRIMS) Route Feature Description Listing.
- TRIMS Photolog.
- TRIMS Crash Data (2001 – 2003, and any available from 2004 and 2005).
- TRIMS Crash Rate Summary Report (01/01/2001 – partial 2005).
- TRIMS Crash Summary Report (01/01/2001 – partial 2005).
- Maps pinpointing crash locations (01/01/2001 – partial 2005).

While no cost information (i.e., consultant fees, time for public officials, etc.) was recorded with regard to completing the RSA on State Route 101, a typical RSA of this extent costs in the range of $10,000 to $12,000. For RSAs on the scale of five miles or more, the cost to complete the entire RSA process increases.

KEY FINDINGS AND SUGGESTIONS

The key findings and suggestions of the RSA are summarized in Table 15. TDOT responded that all of the suggested measures in the RSA report were installed in May 2006, six months after the RSA was completed and documented. There were no additional improvements made beyond those suggested in the RSA report. The cost of the measures implemented based on the findings of the RSA totaled $23,000. There were no locations along the study corridor that were eligible for funding by the Hazard Elimination Safety (HES) Program. However, the segment from L.M. 18.50 to L.M. 18.70 and the location at L.M. 20.81 were eligible for funding by the High Risk Rural Roads (HRRR) Program, as fatal and/or injury crash rates were in excess of statewide averages.

Table 15. Summary of Safety Issues and Suggestions: RSA of State Route 101.

Location	Safety Issues	Suggestions
L.M. 18.50 to L.M. 18.70	Horizontal curvature and vertical alignment	• Add chevron signs and advance curve warning signs • Provide extra wide (8-inch) thermoplastic edgelines • Restripe 0.2 mi of project limits with new thermoplastic
L.M. 20.81	Limited sight distance	• Move stop bar to increase sight distance • Remove trees from right-of-way • Relocate "Beach & Marina →" sign

Horizontal curvature looking south at L.M. 18.50 to L.M. 18.70.

Vertical alignment looking north at L.M. 18.50 to L.M. 18.70.

Limited sight distance looking south at L.M. 20.81.

Limited sight distance looking north at L.M. 20.81.

In general, the suggestions emerging from the RSA were well-received by TDOT, local transportation personnel, and the public. While the RSA was well-received, TDOT indicated that they did not observe a noticeable reduction in crashes after the measures were implemented. The cursory review did not, however, account for other potential changes over time. TDOT also stated that the effect of the implementation measures may be altered since the time of the study (i.e., signs are no longer in their suggested locations, vegetation has grown back, etc.). It was clear that a more formal analysis would be necessary to determine the safety impacts of the RSA and implemented strategies.

RSA OUTCOMES

Geometric, traffic volume, and crash data were collected for both treatment and reference sites in Tennessee. The treatment site consisted of a 3.84 mile corridor, and the specific treatments included the following:

- Segment treatments: add chevron signs, advance curve warning signs, extra-wide (8-inch) thermoplastic edge lines, and new thermoplastic for a portion of the project.
- Intersection treatments: move stop bar to increase sight distance, remove trees from the right-of-way, and relocate sign ("Beach & Marina →").

The reference sites included 21.46 miles of similar corridors that were selected to match the treatment site by number of lanes, speed limit, illumination, and shoulder width. Table 16 provides a summary of the treatment and reference site data.

The initial before period included the years 2000 to 2005 and a relatively large multi-jurisdictional reference group. Based on an initial examination of the data, it was determined that some of the years in both the treatment and reference group exhibited an unusual change in crashes. There was also a wide variation in the annual crash trends among the jurisdictions from which the reference group was selected. The DOT confirmed this finding and noted that in 2001 they changed the structure of their crash database, which resulted in a loss of data due to trouble reconciling the two systems. In addition, they developed a new paper report and implemented it during the period from 2001 to 2002. As a result, it was determined that years 2004 to 2005 would be more suitable for the before period as there were no changes during this timeframe and the previous changes had taken effect. Due to inconsistencies among the jurisdictions, it was also determined that the reference group would only include sites from Cumberland County, the same jurisdiction as the treatment site.

There was some concern regarding the integrity of the data in the after period. In the period from 2006 to 2007, TDOT switched to an electronic crash reporting system, and some of the location information was lost in the report processing (i.e., transferring the data entered by the police officers to the central database). There are some crash data missing for 2006 and approximately 10 percent of crashes missing statewide for 2007. Additional crash data were obtained for 2008 to 2009, and these data are more complete than those from 2006 to 2007.

Table 16. Summary of Tennessee Treatment and Reference Site Data.

Variable	Treatment Group (2004-2005 before period)	Cumberland County Reference Group
Total mileage	3.84	21.46
Mile-Years Before	7.68	171.68
Mile-Years After	3.84	171.68
Crashes/Million Vehicle Miles Before	2.77	4.00
Crashes/Million Vehicle Miles After	2.56	3.34
Injury Crashes/Million Vehicle Miles Before	1.00	1.31
Injury Crashes/Million Vehicle Miles After	0.72	4.00
Access Points/Mile (Driveways + Intersections)	4.69	Average 4.67 Min. 0.00 Max. 25.00
AADT Before (vpd)	11,738	Average 2,899 Min. 648 Max. 10,366
AADT After (vpd)	12,860	Average 2,899 Min. 648 Max. 10,366

The analysis considered the entire corridor. The reference group of similar corridors was used to develop SPFs for use in the EB process. Generalized linear modeling was used to estimate model coefficients, assuming a negative binomial error distribution, which is consistent with the state of research. Separate SPFs were calibrated for total and injury crashes.

The general model form for all models is given by Equation 1. Note that annual multipliers were estimated and added to each model for the appropriate year. The coefficients for each SPF are presented in Table 17.

$$Crashes/mile/year = exp^{ln(a)}(AADT)^{b}\ exp^{c(dd)} \quad (1)$$

Where:

AADT = annual average daily traffic (vehicles per day).

dd = driveway density (total number of driveways and intersections divided by the segment length in miles).

a, *b*, and *c* = coefficients estimated from the model.

Table 17. Estimated SPFs for Tennessee.

	Crash Type	
Variable	**Total**	**Injury**
a (s.e.)	-6.1428 (0.6891)	-6.7849 (0.6674)
b (s.e.)	0.8602 (0.0961)	0.8089 (0.0899)
c (s.e.)	0.0706 (0.0128)	0.0639 (0.0115)
k (s.e.)	0.4083 (0.0889)	0.2362 (0.0820)
Year	**Yearly Multipliers**	
2000	1.16	0.93
2001	1.60	1.97
2002	1.33	1.70
2003	1.76	1.82
2004	1.75	1.55
2005	1.49	1.63
2006	1.56	1.68
2007	1.39	1.54
2008	1.03	0.90
2009	1.22	1.10

The results of the Tennessee analyses are presented in Table 18 for total and injury crashes.

Table 18. EB Corridor Results for Tennessee.

Crash Type	Observed Crashes After	Expected Crashes After	CMF (S.E.)
Total	128	146.69	0.863 (0.116)
Injury	36	50.92	0.687 (0.159)

The results indicate a general safety benefit of conducting the RSA and implementing the treatments suggested in the RSA report. The estimated CMF is consistently less than 1.0 for both total and injury crashes, indicating a reduction in expected crashes. The reduction in injury crashes is statistically significant at the 95 percent confidence level, but the reduction in total crashes is statistically insignificant. Due to the limited crash counts for other crash types, it was not possible to conduct separate EB analyses for additional target crash types. Instead, a cursory analysis of the proportion of crash types was undertaken to see if any insights could be gleaned. Recall that the treatments included both segment- and intersection-related improvements.

Given the nature of the treatments, the intersection improvements may target rear-end and angle crashes, and the segment improvements may target run-off-road crashes. The crash data do not identify run-off-road crashes specifically but do indicate single- vehicle crashes that were analyzed as a substitute. Table 19 presents the analysis of crash proportions. There are no apparent insights in terms of changes in proportions of the various target crash types. Although there are reductions in the proportion of rear-end and angle crashes, the apparent effects are based on numbers that are much too small from which to draw definitive conclusions.

Table 19. Analysis of Proportion of Crash Types in Tennessee.

	Treated Site Crash Count		**Treated Site Proportion**		**Treated Site**	**Entire Reference Group**	
Crash Type	**Before**	**After**	**Before**	**After**	**Difference**	**Count**	**Proportion**
Total	203	128	1.00	1.00	N/A	1741	1.00
Rear-end	72	43	0.35	0.34	-0.01	359	0.21
Angle	40	15	0.20	0.12	-0.08	251	0.14
Single-vehicle	52	57	0.26	0.45	0.19	670	0.38

The annualized costs and benefits were then compared. Based on the EB methodology for observational before-after studies, this study indicated a 13.7 percent reduction in total crashes and a 31.3 percent reduction in injury crashes over a three-year "after" period. Using the FHWA crash costs document, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* (Publication Number FHWA-HRT-05-051), the annual reduction of 6.23 crashes results in an annual benefit of $200,830. Assuming a total cost of $35,000 ($12,000 for the RSA and $23,000 for the improvements), a discount rate of 2.2 percent, and a service life of 10 years, the estimated annual cost is $3,937. Therefore, the B/C of the improvements made as a result of the RSA is 51:1 based on the estimated change in total crashes.

The annual reduction in injury crashes is 4.97 crashes per year. This results in a range of annual benefits, from $199,301 per injury crash (assuming all Type C injuries) to $968,432 per injury crash (assuming all Type A injuries). The estimated cost of a generic injury crash is $367,668. Based on the same annual cost from above, the injury B/C ranges from 51:1 (Type C) to 246:1 (Type A). The B/C is estimated as 116:1 for generic injury crashes. These results indicate a positive effect on safety as a result of the RSA performed on State Route 101.

PROGRAM REVIEW

Selection Process

Each year, TDOT's safety section generates a list of candidate projects. On average, approximately 60 projects are selected statewide annually. These projects qualify as either a Hazard Elimination Safety Project (HESP) or an HRRR project. Three conditions must be met to qualify as a HESP: 1) locations must have experienced fatal and/or incapacitating injury crashes; 2) a total of seven crashes must have occurred in a three-year period; and 3) the actual crash rate must be at least four times the critical rate. (NOTE: crash rates are typically calculated on a per-million- vehicle- miles- traveled basis.) Instances that may remove projects from the HESP list include an unsupportive crash history due to a miscoding of incidents or other projects already programmed for the location in which a review has been or will be conducted.

HRRR projects consist of intersection, spot, or short segment locations. Like HESPs, these locations must have experienced fatal and/or incapacitating injury crashes, three total crashes must have occurred in a three-year period, and the severe crash rate must exceed the statewide average severe crash rate for similar locations.

In addition to the approximate 60 projects each year, additional localized projects are request-based. Requests are typically submitted via the comments section on TDOT's website, through locally-elected officials, or by public contact with TDOT regional offices. To be considered for review, crash data must indicate that the location has experienced a fatal and/or incapacitating injury crash, a total of three crashes must have occurred during a three-year period, the total crash rate must exceed the statewide average crash rate, and the severe crash rate must exceed the statewide average severe crash rate for similar sections. Although the statistics are calculated for a three-year period, it is recommended that data be studied for at least a six-year period to get a more thorough understanding of the severe crash history. The qualifying statistics can be developed based on any consecutive three years of the six-year period. On average, approximately 10 request-based projects are selected each year. Those locations that do not meet the requirements or are not selected are passed on to the regional engineer for a maintenance review or to be included in the "Spot Safety" program.

RSA Process

TDOT conducts spot or section RSAs – called Road Safety Audit Reviews (RSARs) by TDOT – on Interstates, State roads, and local functionally-classified roadways. For non-classified roadways, TDOT depends on the county or city to provide the appropriate data. RSAs on these facilities are generally request-based. The total number of RSAs conducted throughout the State typically varies from year to year.

Since the RSA on State Route 101 in 2005, the TDOT safety team has become more defined; thus, RSAs are conducted in a more efficient and cost effective manner. In-house RSAs are typically led and written by the project planning team. When consultants are involved, the team manages consultant activities. TDOT conceptual and National Environmental Policy Act (NEPA) planning personnel handle the RSA improvement cost estimates and development of layout sheets (design plans scaled down for field review purposes).

The size of an RSA team is typically 10 to 12 people. The team members represent TDOT Traffic Engineering, Planning, Design, Maintenance, Right-of-way, and Construction. Other agencies represented include regional metropolitan planning organizations (MPOs), rural planning organizations (RPOs), and law enforcement. The TDOT Bike and Pedestrian Coordinator is also generally contacted for input. Generally, the RSA team is led by the TDOT Regional Engineer.

Information typically requested for purposes of conducting RSAs includes crash data, traffic data, and design plans. In terms of crashes, data from the most recent five years are used for HRRR projects, and the most recent three years of crash data are used for HESP projects. The most recent year of traffic data is used. When applicable, turning movement counts are analyzed or may be conducted. Lastly, design plans are used to generate layout sheets to show problematic areas/issues and locations for potential improvements (e.g., sign placement, geometric/alignment changes, etc.).

In general, TDOT indicates that the time from when crash data reports are first pulled to the time when the RSA report is officially signed is typically between 2 and 2-1/2 months. The following is a list of the order of events and the associated time requirements:

1. Candidate projects are ranked in order of their severity index (from the most severe to the least severe), as calculated from the HSIP list.
2. A packet of crash reports and crash rate summary sheets are received. Crash rate sheets are supplied for in-house RSAs only; consultants generate their own. Information is distributed to the RSA team prior to the pre-brief meeting.
3. The pre-brief/background meeting is scheduled and the RSA time and location are set. Usually the RSA is conducted within one week of the pre-brief meeting.
4. For an RSA of one location, the draft report is developed within two weeks of the site visit. For an RSA conducted at multiple locations or along a corridor, the draft report is developed within three to four weeks of the site visit.
5. The draft report is reviewed over a one- to two-week period.

6. The draft report is edited within a two-week period.
7. The project manager (typically the TDOT Regional Engineer) verifies that changes have been made and then submits the RSA report to the director for review. At this point, the director ***may*** accept and sign the report; however, it is typical that the director will have comments to be addressed.
8. The report is typically finalized within one week of the Director's review.
9. The report is distributed to all RSA team members, both electronically and by hard copy.
10. The report is submitted to the TDOT environmental section, which typically takes one to two weeks to issue a "programmatic categorical exclusion (CE)."
11. The report is submitted to the TDOT funding section, where a project number is received. The project is then submitted for implementation.

Figure 5 illustrates TDOT's RSA process through the development phase.

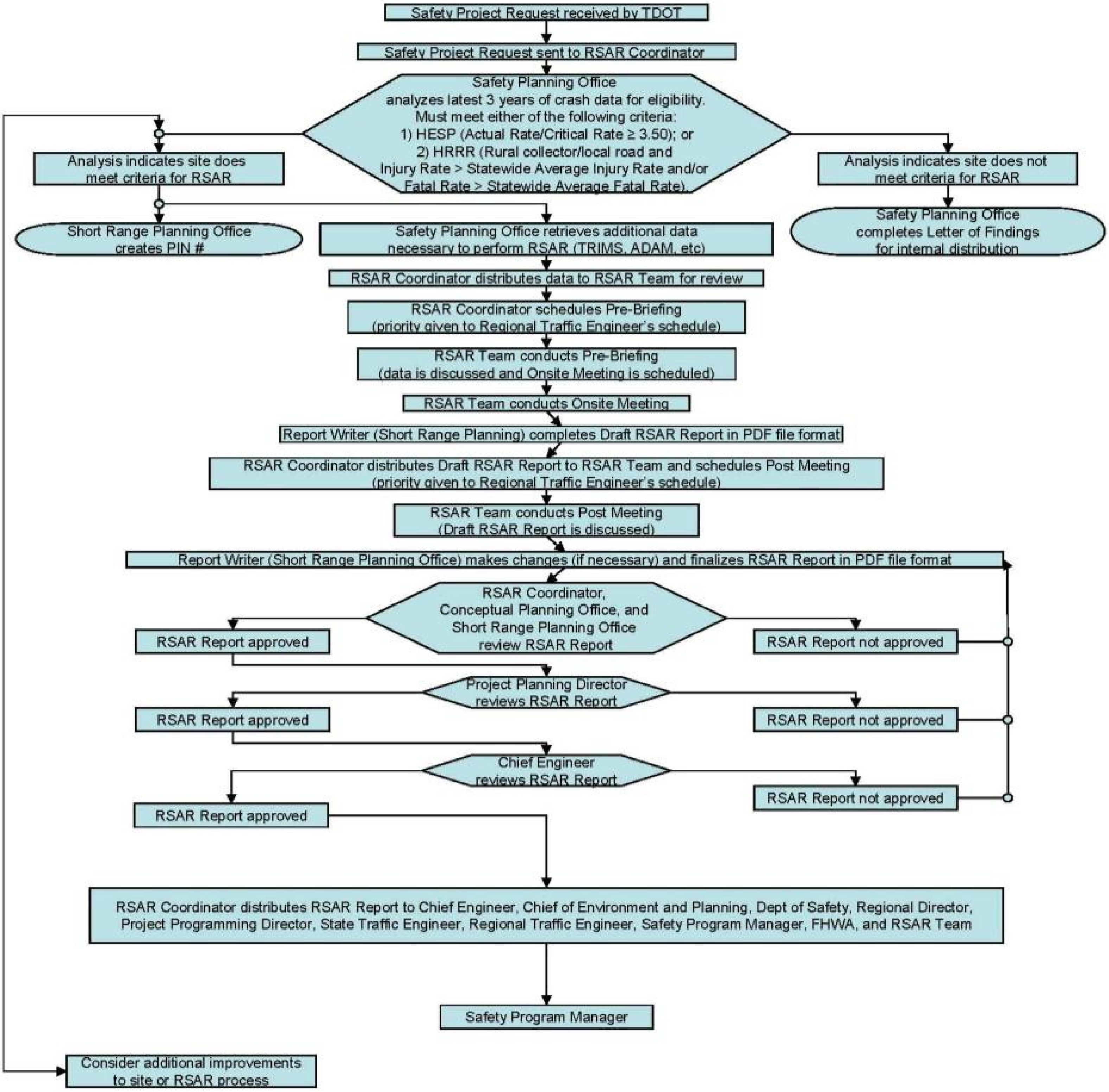


Figure 5. RSAR Review Flow Chart: Development Phase.

Implementation

On average, implementation occurs approximately 18 months from the start of the RSA process. TDOT indicates that this time period is highly variable, as "political motivation" occasionally drives implementation scheduling. Figure 6 illustrates TDOT's RSA process through the implementation phase.

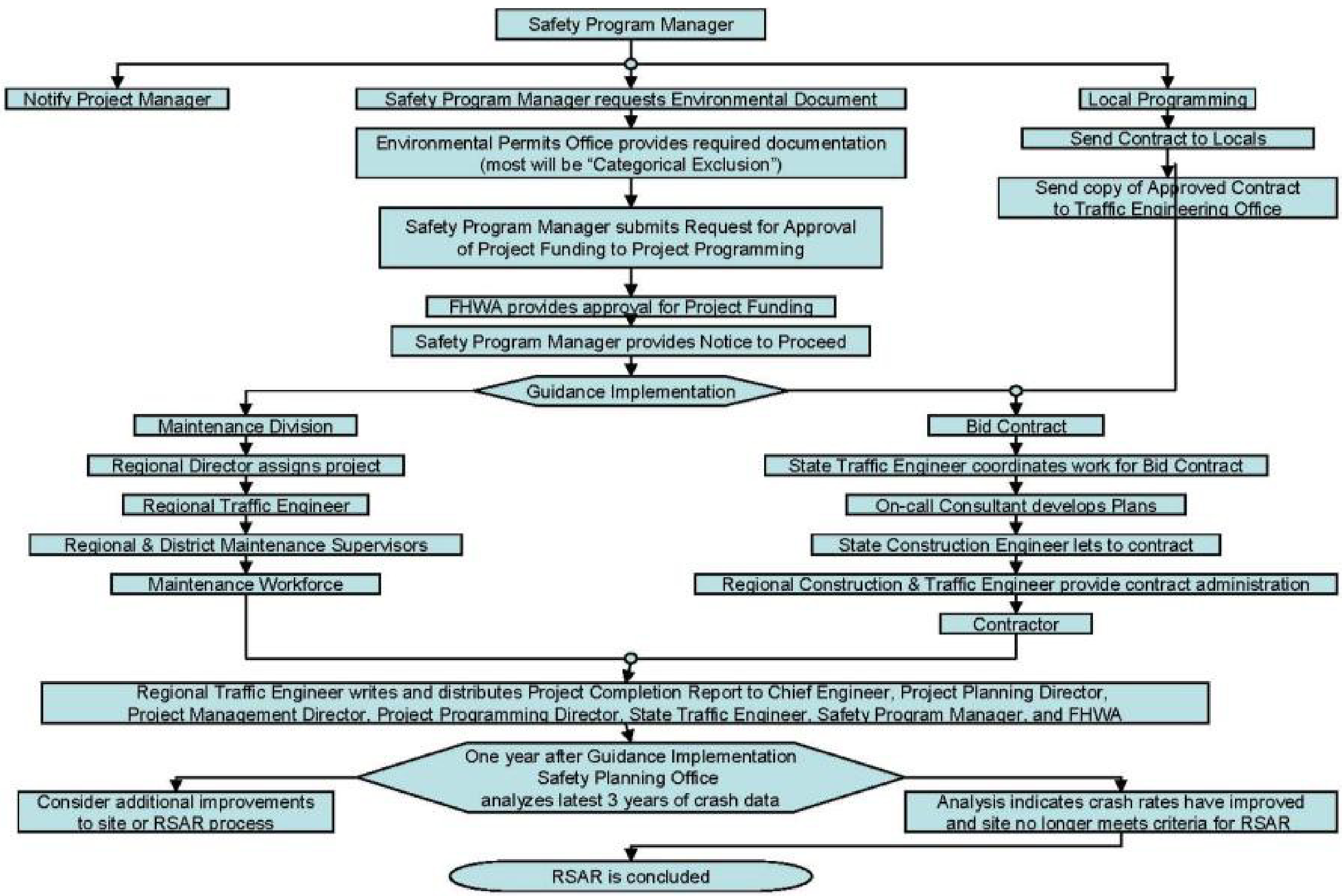


Figure 6. RSAR Review Flow Chart: Implementation Phase.

Funding for implementing RSA improvement measures may come from HRRR funds or HESP funds. For HRRR projects, TDOT has a self-imposed "soft cap" of $50,000 per project. For HESP projects, TDOT has a self-imposed "soft cap" of $1,000,000 per project. This self-imposed cap is intended to limit the project extents and the type of improvement measures to be considered. Funding in excess of the cap will be approved when necessary, but these occurrences are very rare. Local officials generally exhibit an interest in RSAs due to funding obligations. For projects not on TDOT's 100 percent funding list, locals have to match 10 percent of the total project cost.

At the time of the State Route 101 RSA, the implementation was somewhat rapid, being only six months from approval. This quick turnaround time was likely due to TDOT Maintenance involvement. However, since that time, all projects (including signing and marking) are let out to contract. Projects with a lower dollar amount are bundled together, adding time to implementation because of the need to wait for multiple projects to accumulate. Projects with a higher dollar amount may be implemented in a shorter timeframe, unless right-of-way acquisition is involved. In either case, contracting the work rather than using State forces has added significantly to implementation time. TDOT Maintenance divisions—which are responsible for implementation—are trying to reestablish the means to use on-call contractors rather than let out every project to contract.

TDOT is not aware of any problems with implementing RSA suggestions. Typical questions of "concern" include, "Why aren't we spending more (in terms of improvements)?" and "Why can't we (TDOT Maintenance) pay to do the work now and get reimbursed later?" In general, suggestions and improvements at all RSAs are well received. All stakeholders (i.e., TDOT, local agencies, and the public) seem pleased to see that strides are being made to improve roadway safety.

TDOT monitors each RSA location for a three-year period from the notice of completion. If there is a recurring problem within the three-year period, TDOT reevaluates the improvement measures and makes adjustments, as necessary. Each year, the locations from the HRRR and HSIP lists are reentered into TDOT's database to see if they come up again as repeat critical locations.

Since the time of this project in 2005, the RSA process has become more formalized and uniform. TDOT has developed a manual to guide the RSA process, to explain project and data needs, and to establish a "boilerplate" report format. TDOT has described the RSA as a "living process"; TDOT is consistently finding ways to improve the RSA process, making it better along the way.

COLLIER BOULEVARD AT GOLDEN GATE PARKWAY: COLLIER COUNTY, FLORIDA

Road: Existing intersections along paved, four-lane, divided roadway

RSA Sites:

- Three-legged, signalized intersection
- Adjacent unsignalized intersection at Collier Boulevard / 25th Avenue
- AADT: 18,000 – 24,000 vehicles per day (2005)
- 45 mph posted speed limit

Environment: ☐ urban/urbanized **☐ suburban** ☐ rural

Owners: Florida Department of Transportation (FDOT); Collier County

Road Safety Audit

Date of RSA: 12 July 2005

RSA Stage(s): ☐ planning/design stage **☐ RSA of existing roads**

RSA Team: 2 teams of 4 – 5 members representing the consultant, County engineers, non-engineers (i.e., technician), and law enforcement (County Sherriff Department)

RSA Cost: $15,000

Implementation Cost: $250,000

Crash Reduction: 11% total; -10% injury (note the "-" sign denotes an increase)

Benefit / Cost Ratio: 5:1 total; -3:1 injury

BACKGROUND

An RSA was conducted at the intersection of Collier Boulevard and Golden Gate Parkway in Collier County, Florida (Figure 7). The intersection was chosen based on a definitive crash issue. Consequently, Collier County decided to evaluate this intersection to determine the need for appropriate safety measures. Additionally, upgrades desired at this particular location were wrapped into the RSA process. Due to its close proximity, the RSA team also evaluated the adjacent unsignalized intersection at Collier Boulevard/25th Avenue. The County used the RSA for an in-house design of median closures and directional turns.

Figure 7. Aerial Map of Collier Boulevard/Golden Gate Parkway.

The RSA was conducted by two teams, with each having four to five members. The teams were comprised of consulting staff, County engineers, nonengineers (technicians), and law enforcement (County sheriff's department). The efforts of the teams were led by the consultant with direct oversight by County personnel.

Information used by the RSA teams to conduct the review included the following:

- Crash data (2002 – 2004, potentially partial 2005).
- Traffic data (2002 – 2004, potentially partial 2005).
- Aerial imagery.

Overhead maps were provided for use by the consultant to indicate problem areas and issues and to draw potential improvements (e.g., sign placement, geometric/alignment changes, etc.). If design plans were used, County personnel indicate that they were probably very old and out of date.

For this RSA, three hours (total) were required to hold the opening and closing meetings. The two RSA teams spent two days in the field reviewing the study locations. Both teams reviewed the same locations: one team started on Collier Boulevard, while the other started on Golden

Gate Parkway. A night review was also conducted by members of each team, although not all members from each participated. Each team completed RSA reports immediately following the site visits. The consultant compiled the reports written by the RSA teams. If one team felt more strongly about a particular issue or observation than the other team, the team's remarks were identified as "Team A" or "Team B" in the report. The draft report was submitted by the consultant to the County within one week after completion of the field reviews. In addition to meeting and field review time, the consultant traveled four hours each way to perform the RSA. Total cost to complete the RSA (including consultant fees) was $15,000.

Key Findings and Suggestions

The key findings and suggestions of the RSA are summarized in Table 20. County personnel responded that all of the suggested improvement measures in the RSA report were installed between January and March 2006, approximately six months after the RSA was completed and documented. There were no additional improvements made beyond those suggested in the RSA report. The costs of the measures implemented based on the findings of the RSA totaled $250,000. This amount covered design through construction activities. These improvements were funded by gas tax revenues. County personnel indicated that the tax source may be County and State, as well as Federal.

Table 20. Summary of Safety Issues and Suggestions:
RSA of Collier Boulevard & Golden Gate Parkway.

	Safety Issues	**Suggestions**
Signing and Marking	• Object markers obscured by signal poles on EB Golden Gate Pkwy • End of Golden Gate Pkwy not clearly defined. Need to enhance signing • NB approach not well marked • Route markers on all approaches poorly placed and obscured • Street name signs poorly placed. NB visibility is particularly poor	• Relocate obscured object markers • Install overhead signing • Add supplemental plaque for 25th Ave. SW to cross street sign on NB approach • Review and revise placement of route marker and destination signing • Improve placement of street name signs
Intersection Geometry	• EB left-turn lane confusing: (1) opportunity to make two left- turn movements out of a single lane (41st St. SW, alley to east); (2) possible misinterpretation of lane use • U-turns observed to cross over island at plaza just east of 41st St. SW • Provision for SB left turns to 25th Ave. SW impacts queue space on Collier Blvd • WB to SB left turn can be blocked by 2-stage left-turn movements	• Cut median nose back to facilitate U-turns just east of 41st St. SW. • Modify median opening providing access to 25th Ave. SW. • Consider median closure
Visibility, Sight Distance	• SB sight distance issues from inside lane with NB through. Problem compounded when left-turning vehicle from 25th Ave. SW to SB. • Median hedges impact visibility for NB and SB left- turn and U-turn movements	• Trim vegetation in median
Pedestrian Accommodations	• No sidewalk on south side	• Review sidewalk needs • Confirm pedestrian phasing will be installed

The following photos illustrate safety issues observed during the RSA ("before" on left) and the subsequent improvements resulting from the RSA suggestions ("after" on right).

SB left-turn lane to 25th Ave. SW (before).

SB left-turn lane to 25th Ave. SW (after). SB left only; no WB left.

EB median nose at plaza just east of 41st St. SW (before).

EB median nose at plaza just east of 41st St. SW (after). Nose cut back.

In general, the suggestions resulting from the RSA were well-received by County personnel, law enforcement, and the public. Residents near the study intersection were satisfied with the changes, as access into the residential area across the canal at 25th Street was improved. Overall, a qualitative improvement in safety has been observed. County personnel also indicate that, in the long term, the measures implemented have eased traffic flow through the intersection. Drivers are now more expectant of the maneuvers to be made, enhancing the traffic flow and overall intersection safety.

Those involved with this RSA were also satisfied with the process. In the end, the County decided that they probably didn't need two teams to complete this RSA. County personnel indicated that one team could complete the same amount of work required and still come up with the same conclusions.

RSA OUTCOMES

Geometric, traffic volume, and crash data were collected for both treatment and reference sites in Florida. The treatment sites consisted of one signalized intersection (Collier Boulevard/Golden Gate Parkway) and the nearby unsignalized intersection (Collier Boulevard25th Avenue Southwest). The RSA considered both locations because the improvements at 25th Avenue Southwest included the prohibition of left-turns from one direction, which now requires that those vehicles first turn right and make a U-turn at the intersection with Golden Gate Parkway. The reference sites consisted of 22 untreated signalized intersections that were otherwise similar to the treated signalized intersection. A specific reference group was not available for the unsignalized treatment site, but the signalized reference group was utilized to adjust for specific trends. (This is discussed further in analysis section.) Table 21 provides a summary of the treatment and reference site data.

Table 21. Summary of Florida (Collier Boulevard) Data.

Variable	**Signalized Intersection**	**Unsignalized Intersection**	**Signalized Reference Group (22 Sites)**
Years before	1	1	4.58 years/site
Years after	2.75	2.75	4.58 years/site
Total Crashes/year before	43.0	22.0	Average 21.8/site/yr
Total Crashes/year after	35.3	7.3	Average 21.8/site/yr
Injury Crashes/year before	4.0	3.0	Average 1.8/site/yr
Injury Crashes/year after	4.0	1.5	Average 1.8/site/yr
Left-Turn Crashes/year before	6.0	4.0	Average 1.4/site/yr
Left-Turn Crashes/year after	3.6	0.7	Average 1.4/site/yr
Rear-End Crashes/year before	18.0	3.0	Average 9.3/site/yr
Rear-End Crashes/year after	10.9	2.2	Average 9.3/site/yr
Sideswipe Crashes/year before	5.0	3.0	Average 2.4/site/yr
Sideswipe Crashes/year after	4.4	0.7	Average 2.4/site/yr
Major AADT before	29,160	30,552	Average 32,564
Major AADT after	26,130	27,173	Average 32,564
Minor AADT before	n/a	20,501	Average 18,452
Minor AADT after	n/a	18,455	Average 18,452

The signalized reference group was used to develop SPFs for use in the EB process. Generalized linear modeling was used to estimate model coefficients, assuming a negative binomial error distribution, which is consistent with the state of research. Separate SPFs were calibrated for each target crash type. Since minor road AADTs were only available for some of the reference sites, only the major road AADT was considered as an exposure variable in the models.

The general model form for all models is given by Equation 2. Note that annual multipliers were estimated and added to each model for the appropriate year. The coefficients for each SPF are presented in Table 22.

$$Crashes/year = exp^{(a)}(MajAADT)^{b} \tag{2}$$

Where:

MajAADT = major road AADT

a and *b* = coefficients estimated from the model

Table 22. Estimated SPFs for Florida.

Crash Type	A (s.e)	B (s.e.)	K (s.e.)	Yearly Multipliers
Total	-5.4177 (3.6207)	0.8194 (0.3501)	0.2903 (0.0868)	2005=1.24 2006=1.19 2007=1.11 2008=0.81
Injury	-3.33078 (4.0671)	0.3766 (0.3929)	0.2277 (0.1063)	
Left-Turn	-10.0017 (4.3556)	0.9919 (0.4191)	0.2509 (0.1213)	
Rear-End	-4.1189 (3.5534)	0.6126 (0.3435)	0.2599 (0.0825)	
Sideswipe	-14.7367 (5.9866)	1.4985 (0.5774)	0.6233 (0.2119)	

The EB method could not be applied to estimate the number of crashes without treatment at the unsignalized intersection because a suitable reference group was not provided. For this location, the expected number of crashes without treatment was estimated by the before period crash counts and several factors. The first factor was used to adjust for the different lengths of the before and after periods and was computed as the ratio of the duration of the after period to the before period. The second factor was used to adjust for the change in traffic volume between the before and after period and was computed as the ratio of AADT in the after period to before period. (Note that this adjustment assumes a linear relationship between traffic volume and crashes, which may not be valid for large changes from the before to the after period). The final factor was used to adjust for general temporal trends and was computed as the ratio of SPF estimates in the after period to the before period.

The results of the Florida analyses for Collier Boulevard are presented in Table 23. Note that specific results are provided for total, injury, left-turn, rear-end, and sideswipe crashes. Results are presented separately for the unsignalized treatment site, the signalized treatment site, and the two sites combined.

The results indicate a general safety benefit of implementing the treatments at the unsignalized intersection. As expected, the elimination of westbound left-turns resulted in a substantial and significant reduction in several crash types, including total, injury, left-turn, and sideswipe crashes. There was also a reduction in rear-end crashes, but the result was not statistically significant.

As might be expected, there was an increase in several crash types at the signalized intersection, potentially due to the increase in turning movements after the westbound left-turns were eliminated at the adjacent unsignalized intersection. Specifically, there was an increase in total, injury, left-turn, and sideswipe crashes at the signalized intersection; however, these increases are highly insignificant. There does appear to be a reduction in rear-end crashes at the signalized intersection, but, again, the result is highly insignificant.

Table 23. EB Results from Florida.

Crash Type	25th Avenue Southwest			Golden Gate Parkway			Both Locations Combined		
	Observed Crashes After	Expected Crashes	CMF (S.E.)	Observed Crashes After	Expected Crashes	CMF (S.E.)	Observed Crashes After	Expected Crashes	CMF (S.E.)
Total	20	45.19	0.423 (0.125)	97	84.06	1.130 (0.197)	117	129.25	0.892 (0.134)
Injury	4	6.16	0.487 (0.279)	11	6.08	1.616 (0.662)	15	12.25	1.100 (0.419)
Left-Turn	2	8.22	0.195 (0.135)	10	5.70	1.594 (0.648)	12	13.92	0.781 (0.306)
Rear-End	6	6.16	0.735 (0.387)	30	34.19	0.839 (0.226)	36	40.36	0.857 (0.215)
Sideswipe	2	6.16	0.243 (0.167)	12	7.76	1.342 (0.565)	14	13.93	0.904 (0.348)

Overall, there appears to be a reduction in several crash types based on the results for both sites combined. The reduction in crashes at the unsignalized intersection is partly offset by an increase in crashes at the signalized intersection, but the results still show an overall reduction in total crashes. Specifically, the net effect is an 11 percent reduction in total crashes over the two intersections, which is significant at the 58 percent confidence level. The combined results also indicate a reduction in left-turn, rear-end, and sideswipe crashes. These results are highly insignificant, as is the increase in injury crashes.

The annualized costs and benefits were then compared based on the results of the two intersections combined and focusing on total crashes. Based on the analysis, this study indicated an 11 percent reduction in total crashes over a 2.75-year after period. Using the FHWA crash costs document, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* (Publication Number FHWA-HRT-05-051), the annual reduction of 4.45 total crashes results in an annual benefit of approximately $143,597. The analysis was conducted based on a total cost of $265,000 ($15,000 for the RSA and $250,000 for the improvements), a discount rate of 2.2 percent, and a service life of 10 years, resulting in an annual cost of $29,811. Therefore, the collective B/C of the improvements made as a result of the RSA is 5:1, indicating an overall positive effect on safety in terms of total crashes.

Program Review

The Board of Collier County Commissioners in the State of Florida adopted an RSA Policy that included RSAs for 30 percent and 60 percent design plans for their capital improvement projects, as well as a predetermined number of existing high-crash locations or roadways. RSAs are also required for new site development permits. The County utilizes an annual professional services contract to deliver the RSA program. The consultant serves as the team leader with agency staff and other experts serving as the RSA team. The contract is negotiated for each specific RSA project with typical consultant costs between $6,000 and $15,000. The County has found that the life-cycle savings far outweigh the RSA cost. The services contract is an effective method to train county staff on how to perform an RSA. The contract has also institutionalized the RSA process, which has adapted to meet local needs and focuses on what is implementable.

The County has also trained locally-based groups of highway safety advocates to form Community Traffic Safety Teams (CTSTs) to complete RSAs. An example of CTST involvement was a predesign RSA on a greenway. Members of the CTST were avid cyclists who provide a safety perspective from a cyclist’s standpoint. The CTST is not always called upon to assist in intersection or corridor reviews. The County has also had members of RSA teams in wheelchairs. Again, this adds another perspective to RSA reviews, as such a team member can enhance the RSA team’s understanding of issues that affect people with mobility restrictions.

IMMOKALEE ROAD: COLLIER COUNTY, FLORIDA

Road: Planned widening of 3.25-mile section from four-lane to six-lane arterial road

RSA Site:

- 3.25-mile section
- Paved, four-lane divided roadway (existing)
- Paved, six-lane divided roadway (planned)
- 6 signalized intersections
- AADT: 45,488 vehicles per day (2005)
- 45 mph posted speed limit

Environment: ☐ urban/urbanized ☑ **suburban** ☐ rural

Owners: Collier County, Florida

Road Safety Audit

Date of RSA: 15-19 November 2004

RSA Stage(s): ☑ **planning/design stage** ☐ RSA of existing roads

RSA Team: Members representing the consultant, Collier County, and Federal Highway Administration Resource Center

Crash Reduction: 10.8% total

BACKGROUND

An RSA was conducted along Immokalee Road from Interstate (I-) 75 to Collier Boulevard in Collier County, Florida (Figure 8). To accommodate current and forecasted future demand, the County was considering widening the road. The proposed upgrade entailed widening the road from a four-lane to a six-lane divided urban arterial. At the time of the RSA, the widening project was at a conceptual stage. Design documentation consisted of State design practices and the County's typical section for a six-lane divided urban arterial.

The RSA was conducted by a team of experts representing staff from the consultant, Collier County, and the FHWA Resource Center. The efforts of the teams were led by the consultant, with direct oversight by County personnel.

Signalized intersections shown.

Figure 8. Aerial Map of Immokalee Road RSA Location.

Conceptual design plans (less than 30 percent complete), the State's design standards, and aerial photos were used to conduct this RSA.

Three hours (total) were required to hold the opening and closing meetings. The RSA team spent two days in the field reviewing the study locations. A night review was also conducted, although not all members participated.

KEY FINDINGS AND SUGGESTIONS

The RSA findings were divided into the following two parts:

1. Issues arising from the proposed upgrade: These issues reflected concerns arising from the proposed upgrading from a four-lane mixed urban/rural arterial to a six-lane urban arterial cross section and dealt with properties or specific conditions of the Immokalee Road widening project that could influence design details or require the modification of design standards.
2. Further opportunities for improvement: Additional opportunities for improvements that could be incorporated during the upgrade were also identified. Although these improvements were not specifically related to the proposed widening, they responded to issues observed along the corridor by the RSA team. These improvements could be "piggybacked" onto the upgrade project at relatively limited effort and expense.

The key findings and suggestions as a result of the RSA are summarized in Table 24. County personnel indicated that most of the suggested improvement measures in the RSA report were installed between March 2006 and March 2009.

Table 24. Summary of Safety Issues and Suggestions: RSA of Immokalee Road.

Safety Issue		**Suggestions**
Issues arising from the proposed upgrade		
Access Along Arterial Road	Movements at driveways and local road intersections interfere with traffic on Immokalee Road, an arterial road.	• Consult County's access management manual. • Consider closure of some median breaks. • Introduce right-turn acceleration lanes. • Introduce devices and designs to prevent wrong-way movements.
School-Related Pedestrian and Vehicle Traffic	Increased volumes, lanes, and width may increase the collision risk for vehicle and pedestrian traffic associated with adjacent schools.	• Revise flashing signal operation at adjacent intersections. • Consider median treatment to obstruct midblock crossings. • Implement a continuous pedestrian network. • Reduce curb return radii at adjacent intersections.
Pedestrian Facilities	Pedestrians need to be safely accommodated on the upgraded roadway.	• Provide a continuous and convenient pedestrian network. • Provide pedestrian countdown signal heads. • Reduce return radii at intersections and driveways.
Cycling Facilities	Cyclists need to be safely accommodated on the upgraded roadway.	• Replace 4-ft bike lanes with wider paved shoulder. • Provide sufficient bike lane width at intersections.
Barriers with Curb	The design of roadside barriers must accommodate the proposed barrier curb.	• Consider anticipated speeds when designing barrier system.
Stakeholder Consultation	Widening Immokalee Road may affect the North Naples fire station and may generate an increased need for speed enforcement.	• Consult fire station to determine the need for a fire signal. • Consult with police to identify their enforcement requirements.
Median Treatments	The impact of median treatments on road safety should be considered in this urbanized transition area.	• Avoid fixed-object safety issues in the median. • Avoid sight-line obstructions in the median. • Consider median treatments that obstruct midblock crossings. • Minimize median maintenance requirements. • Consider angled left turn lanes in wide medians.
Road Shoulders	Shoulders may be desirable for emergency use, especially where fire-station traffic is expected.	• Confirm whether shoulders are desirable for fire department and other emergency use.
Signal Display	Signal displays should be visible and conspicuous at all times.	• Mount overhead signals on mast arms. • Consider redundant signal displays and/or double red display for left-turn signals. • Consider one signal head for each lane. • Use a backplate with reflective border.
Accommodation of Older and Unfamiliar Drivers	Older and unfamiliar drivers require enhanced signing, pavement marking, and signal displays.	• Follow recommended practices of the Florida DOT Elder Road User program.

The following photos illustrate safety issues observed during the RSA.

Immokalee Road near Valewood Drive.

Immokalee Road in front of schools.

In general, the suggestions resulting from the RSA were well-received. In design-stage RSAs, a wider scope for safety enhancements exists. This opportunity is even more pronounced for designs that are early in the planning process (e.g., a conceptual design).

This RSA was conducted very early in the planning stage, when the only design documentation was the County's typical section for a six-lane divided urban roadway. As a result, the RSA was able to not only consider issues related specifically to the proposed widening from four to six lanes but could also suggest additional opportunities to enhance road safety that were not necessarily related to the specified widening. Of particular significance was the opportunity to include several measures to accommodate older drivers, which will help the County to implement elements of the Florida DOT's "Elder Road User Program" on County roads.

RSA Outcomes

Geometric, traffic volume, and crash data were collected for both treatment and comparison sites in Florida. The treatment site consisted of 3.25-mile corridor that included six signalized and several unsignalized intersections and driveways. The comparison sites consisted of six untreated corridors that were otherwise similar to the treated site. The comparison group was utilized to adjust for specific trends. (This is discussed further in analysis section.) Table 25 provides a summary of the treatment and reference site data.

Table 25. Summary of Florida (Immokalee Road) Data.

Variable	Treatment Color	Comparison
Years Before	1	1.0 Year/Site
Years After	1.6	1.0 Year/Site
Total Crashes/Year Before	68.0	Average 268.3/Site/Yr.
Total Crashes/Year After	72.1	Average 281.7/Site/Yr.
AADT Before	45,488	34,564
AADT After	43,389	34,564

The analysis considered the corridor in its entirety, including the signalized and unsignalized intersections. A naïve before-after analysis was conducted but included adjustments from a comparison group and also employed an EB technique to assess the potential for regression-to-the-mean bias. It was only possible to analyze total crashes because data were not provided for other crash categories.
The EB method was used to assess the potential for regression-to-the-mean bias. Based on a relatively limited reference group, an SPF was developed for total crashes. Generalized linear modeling was used to estimate model coefficients, assuming a negative binomial error distribution, which is consistent with the state of research. The general model form for the SPF is given by Equation 3 and the model coefficients are presented in Table 26.

$$Crashes/year = Length * exp^{(a+b*lanes)}(AADT)^{c} \tag{3}$$

Where:

AADT = total two-way traffic volume (vehicles per day)
Lanes = indicator variable for the number of lanes (1 if 4-lanes; 0 if 6-lanes)
Length = segment length (miles)
a, *b*, and *c* = coefficients estimated from the model

Table 26. Estimated SPFs for Florida.

Crash Type	a	b	c
Total	0.2365	-0.0436	0.2857

While the coefficients from the SPF were not statistically significant, it was possible to investigate the potential for regression-to-the-mean. The EB-adjusted expected crash count in the before period was 70.74 as opposed to 68 observed crashes indicating that regression-to-the-mean is not a significant consideration. Based on the lack of evidence to suggest the potential for regression-to-the-mean and the fact that the SPF and Collier County reference data are suspect for some locations, it was decided to use the naïve before-after method with observed crash counts in the analysis.

The naive before-after method was used to estimate the overall change in safety at the treatment site. However, there were other improvements made to the treatment site in addition to the suggestions from the RSA. Specifically, the corridor was widened from a four-lane to a six-lane cross section. As such, it was necessary to adjust for the lane conversion to isolate the effects associated with the RSA. An adjustment factor was derived from the most relevant CMF information in the Highway Safety Manual (HSM).[3] The HSM provides separate CMFs for four- to five-lane conversions and five- to six-lane conversions as follows:

CMF for 4-lane to 5-lane conversion = 1.10 (standard error =0.07)

CMF for 5-lane to 6-lane conversion = 1.04 (standard error = 0.11)

The estimated effect of converting from four to six lanes is obtained by multiplying the two CMFs (CMF = 1.10*1.04 = 1.14).

A final factor was used to adjust for general temporal trends and was computed as the ratio of number of crashes in the after period to number of crashes occurring in the before period for the comparison group. The time trend factor is 1.05 and represents the change from 2004 to 2009. It was assumed that this calculated time trend was applicable to the treatment site for which the before period is 2005 and the after period is January 2010 to July 2011.

The results of the Florida analyses for Immokalee Road are presented in Table 27 for the corridor. Note that Table 27 contains three sets of results, including 1) the naïve before-after analysis without adjustment, 2) adjustment for the lane conversion, and 3) adjustment for the lane conversion and time trend.

Table 27. Corridor Results for Florida (Immokalee Road).

Method	Observed Crashes After	Expected Crashes After	CMF (S.E.)
Naïve (without adjustment)	117	107.67	1.071 (0.161)
Naïve (with adjustment for lane conversion)	117	123.17	0.936 (0.141)
Naïve (with adjustment for lane conversion and time trends)	117	129.33	0.892 (0.134)

[3] American Association of State Highway Safety Officials. (2010). *The Highway Safety Manual*. Washington, D.C.: American Association of State Highway Safety Officials.

The results indicate a general safety benefit of implementing the treatments suggested in the RSA report.

While the unadjusted naïve analysis indicates an insignificant increase in total crashes, the results show an expected reduction in crashes once adjustments are made to account for the effects of the four- to six-lane conversion and time trends. Specifically, the analysis indicates an expected 10.8 percent reduction in total crashes as a result of the RSA and associated improvements after adjusting for time trends and the lane conversion. Note that this result is statistically insignificant at the 95 percent confidence level. Using the FHWA crash costs document, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* (Publication Number FHWA-HRT-05-051), the annual reduction of 12.33 total crashes results in an annual benefit of approximately $397,470. It was not possible to compute the B/C ratio for the improvements made as a result of the RSA because cost data were not provided, but there appears to be an overall positive effect on safety in terms of total crashes. As long as the annual costs are less than approximately $400,000, there will also be a positive return on investment.

PROGRAM REVIEW

See information in the previous section for Collier Boulevard.

NINTH STREET: OCEAN CITY, NEW JERSEY

Road: Existing 0.47-mile section of paved, four-lane arterial roadway

RSA Sites:	• 5 signalized, 1 unsignalized “major” intersections • 6 unsignalized other intersections and alleyways • AADT: 13,870 vehicles per day (2007) • 25 mph posted speed limit
Environment:	☐ **urban/urbanized** ☐ suburban ☐ rural
Owners:	Ocean City, New Jersey

Road Safety Audit

Date of RSA:	28 May 2004
RSA Stage(s):	☐ planning/design stage ☐ **RSA of existing roads**
RSA Team:	14 members representing Cape May County, FHWA, NJ Division of Highway Traffic Safety, New Jersey Department of Transportation (NJDOT), Ocean City, South Jersey Transportation Planning Organization (SJTPO), and Orth-Rodgers & Associates, Inc.
RSA Cost:	$21,000
Implementation Cost:	$900,000
Crash Reduction:	25.6% total
Benefit / Cost Ratio:	1.2:1 total

BACKGROUND

An RSA was conducted along a 0.47-mile section of Ninth Street in Ocean City, New Jersey from Bay Avenue to Atlantic Avenue (Figure 9). Throughout this section, Ninth Street is a four-lane arterial roadway with a posted speed limit of 25 mph. Five signalized intersections and one “major” unsignalized intersection are present within the study area; six other unsignalized intersections/alleyways are also present. The AADT along Ninth Street was reported as 13,870 vehicles per day in 2007. Ninth Street is owned and maintained by Ocean City.

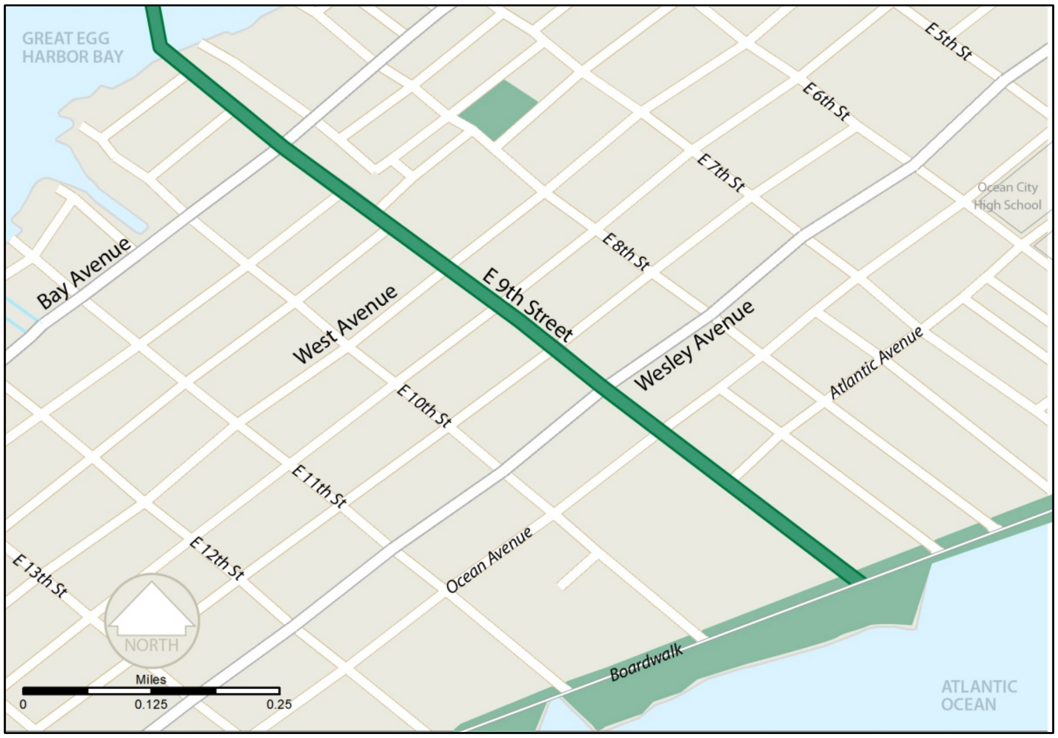


Figure 9. Aerial Map of Ninth Street.

In November 2003, a preliminary list of six candidate locations for RSAs was submitted by the Cape May County Engineer and forwarded to the NJDOT Bureau of Data Development for further analysis. At this time, the Local Safety Program provided only $0.5 million to each NJ metropolitan planning organization annually. Due to time constraints for using the available metropolitan planning (PL) funding, all RSA work needed to be completed by June 30, 2004. Data-driven approaches to the RSA process had not yet been well developed; therefore, the SJTPO used outreach, local knowledge, and limited data analysis to identify Ninth Street as a high-crash corridor. As a result, Ninth Street was one of two locations selected for an initial pilot project by the SJTPO for a formal RSA to determine safety deficiencies and appropriate countermeasures. SJTPO proceeded with the expectation that the RSA was likely to yield low-cost, quick-turnaround improvements, as opposed to high-cost, construction-intensive projects requiring extensive NEPA processing.

A kickoff meeting was held in March 2004 and attended by 24 individuals. RSAs were relatively new to New Jersey, and there was a strong desire to see the process expanded to other parts of South Jersey. In May 2004, the RSA was conducted by a team of 14 individuals from various agencies, including representatives from Ocean City, Cape May County, SJTPO, NJDOT, the New Jersey Division of Transportation Safety, and FHWA.

The team was comprised of consulting staff, engineers, planners, and law enforcement. The efforts of the team were led by the consultant with direct oversight by County personnel.

Information used by the RSA team to conduct the review included the following:

- Aerial imagery and maps.
- Traffic volume data (2000).
- Bicycle and pedestrian counts.
- Level of Service (LOS) analysis.
- Crash data (2001-2004).
- Traffic signal plans.
- Video logs.

Aerial maps (including an 11-inch by 14-inch sheet scaled at 1 inch =500 ft and additional maps at 1 inch =60 ft) were provided for use by the County to indicate problem areas and issues and to draw potential improvements (e.g., sign placement, traffic signal improvements, etc.). Traffic volumes indicated a large presence of nonmotorized traffic, with peak demand occurring during the midday period. A capacity analysis demonstrated that all intersections were operating at acceptable levels of service, except for the Bay Avenue intersection. Approximately 200 crashes were submitted for review; 128 were identified as having occurred within the study area (which included an influence area around the intersections as determined by the consultant).

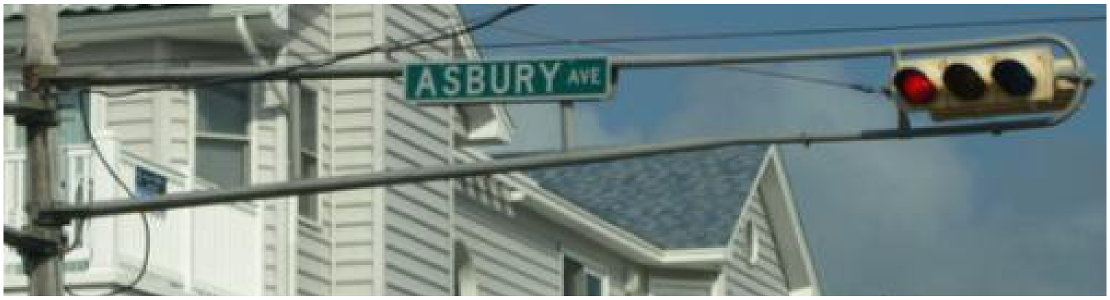
In the morning, after a brief introduction, a three-hour brainstorming session allowed participants to review the existing data and discuss several operational and congestion-related issues. In the afternoon, the team conducted the field review. It was estimated that five hours were utilized to complete the field review. The total cost to complete the RSA (including consultant fees) was approximately $21,000.

Key Findings and Suggestions

The consultant prepared a draft report to document the RSA, the key findings, and suggestions. In total, 42 issues were identified with 53 safety measures suggested. The measures cover a wide range of actions, from maintenance-level tasks to capital-intensive projects. Each measure was ranked in priority high to low based upon the level of effort required and the potential safety benefit. Of the 53 suggestions, 33 (62 percent) were projected to have a high safety benefit, and 13 (25 percent) were projected to have a medium safety benefit. Fifteen of the proposed suggestions could be implemented within one year, whereas the remaining 38 suggestions were intended to be incorporated into longer-range design plans. Those suggestions that were implemented are summarized in Table 28.

Table 28. Summary of Safety Issues and Suggestions: RSA of Ninth Street.

Safety Issues	Suggestions	Implementation		Location	Cost
		(Y/N)	Date		
Pedestrian behavior is not consistent	Install Walk/Don't Walk signals at all signalized intersections	Y	2006: Ninth & West; 2008: other intersections		Portion of $170K (West); $659K (others)
With the exception of Bay Ave., traffic signals along the Ninth St. corridor do not provide clear indication for pedestrians	Redesign each of the six signals within the corridor to provide man/hand signals. Pedestrian countdown signals should be considered	Y			
Pavement surface along entire Ninth St. corridor is in general state of disrepair. Much of the aggregate has been exposed and polished, indicating a lower level of skid resistance	Resurface the roadway to improve skid resistance and improve travel surface for all modes of transportation	Partial		Asbury to Boardwalk	Portion of $170K (West)
The traffic signal at Ninth St. and West Ave. is not pedestrian-friendly. Some crossings have no signals readily visible to pedestrians	Modify the traffic signal installation to better serve pedestrians. (This item is already being done by ORA at the direction of the County Engineer.)	Y	2006	Ninth & West	
There is no advance notice regarding the lane configuration on the Asbury Ave. approaches to Ninth St.	Place advance lane use control signs (R3-8) on the approaches	Y	One is partially obscured by tree		
A crosswalk at the corner of Wesley Ave. leads to a full-face curb without depression for users with mobility restrictions	Install a curb depression for users with mobility restrictions	Y			
There is no northbound pedestrian signal on the northeast corner at the intersection of Ocean Ave. and Ninth St.	Upgrade the traffic signals to better serve the pedestrians	Y			
The crosswalk at Atlantic Ave. leads to a full-face curb without depression for users with mobility restrictions	Install a curb depression for users with mobility restrictions	Y-3, N-1			



Traffic signal mast arms and signal display alignments prior to improvements.

One of the major changes suggested as a result of the RSA was to implement a roadway diet, converting Ninth Street from a four-lane section to a three-lane section with a two-way left-turn lane and bicycle lanes. Another suggestion resulting from the RSA was to install a traffic signal at the intersection of Ninth Street and West Avenue. The improvements included an uninterruptible power supply, all new signal hardware, 12-inch LED lenses, accessible countdown pedestrian signals with ramps, sidewalk improvements, and signing and pavement marking enhancements. A preliminary before-after study indicated a 50 percent reduction in crashes and injuries at the intersection. This study provides the results of a more rigorous evaluation. The cost of this improvement was $172,000 and was completed on June 15, 2005.

New traffic signal mast arms and signal display alignments resulting from the RSA.

Further traffic signal improvement work was implemented based on the RSA suggestions. The existing traffic signals were outdated and did not provide pedestrian accommodations. The work consisted of installing countdown pedestrian traffic signals at the intersections of Asbury, Central, Wesley, and Ocean Avenues. The work also interconnected signal controller communications with all five traffic signals between West Avenue and Ocean Avenue. This was a joint project between Cape May County and Ocean City and was funded by the HSIP program. The Ninth Street Signals Improvement Project was completed in May 2007 at a cost of $728,000.

In addition to the traffic signal upgrades, several other safety measures will be implemented with the Route 52 Causeway construction project to the immediate west of the study corridor. The Route 52 project will replace two drawbridges and tie into the Ninth Street corridor at West Avenue. Included within this project is the raising of portions of Ninth Street where flooding causes periodic closures, new raised medians, and new pedestrian sidewalk along the south side of the roadway (Figure 10). Construction began in August 2006 and is scheduled for completion in December 2012 at a cost of $400 million. Ocean City was aware that the Route 52 construction would affect the western portion of the corridor, particularly in terms of significantly altering traffic patterns. Additional improvements will be made beyond those suggested in the RSA report, as the causeway is a significant gateway to Ocean City.

Figure 10. Route 52 Construction Changes to Ninth Street.

In general, the suggestions resulting from the RSA were well-received by County personnel, law enforcement, and the public. Those involved with this RSA were pleased with the process and sought to expand this pilot into a full RSA program. Additionally, residents near the study area were happy with the outcomes. According to local officials, the public was especially receptive of the traffic signal improvements.

RSA Outcomes

Geometric, traffic volume, and crash data were collected for both treatment and comparison sites in New Jersey. The treatment site consisted of a 0.47-mile corridor that was divided into two consecutive segments based on geometric changes. Data were obtained for each segment of the corridor and the signalized intersections within the corridor. Several comparison sites were identified for the corridor and signalized intersection analyses. A total of 4.32 miles of corridor were identified for the comparison group. Tables 29 and 30 provide a summary of the treatment and comparison site data for the corridors and signalized intersections, respectively. Note that two before periods were analyzed separately: 2003 to 2004 and 2003 to 2007. This approach was based on the implementation period in which most changes were implemented in 2008, but the intersection of Ninth Street/West Street was also modified in 2005. It is preferable to include more than two years of data in the before period; hence, the analysis considers a before period of 2003 to 2007. The additional years in the before period provide a more stable estimate of the safety performance prior to the treatment's installation. The period from 2003 to 2004 was used to account for changes due to the improvements made in 2005.

Table 29. Summary of New Jersey Corridor Data.

Variable		Treatment Site	Comparison Site
Number of segments		2	5
Before Period[1]		2003-2004 2003-2007	2003-2004 2003-2007
After Period		2009	2009
Length (miles)	Average	0.24	0.86
	Minimum	0.06	0.10
	Maximum	0.41	2.70
Total Crashes/ mile-year before (2003-2004)	Average	80.3	21.8
	Minimum	43.9	5.0
	Maximum	116.7	35.0
Total Crashes/mile-year before (2003-2007)	Average	66.8	20.1
	Minimum	46.8	12.0
	Maximum	86.7	31.0
Total Crashes/mile-year after	Average	44.5	8.5
	Minimum	39.0	0.0
	Maximum	50.0	15.6
AADT Before[2]	Average	9,251; 11,231	
	Minimum	9,251; 11,231	7,631
	Maximum	9,251; 11,231	6,078
AADT After[2]	Average	16,513	8,666
	Minimum	16,513	
	Maximum	16,513	
Area Type		Urban	Urban
Number of Lanes		4	2 (0.82 miles) 4 (3.50 miles)
Median Type		None (0.41 miles) TWLTL (0.06 miles)	None
Median Width (ft)		0 (0.41 miles) 15 (0.06 miles)	0
Shoulder Type		None	None
Shoulder Width (ft)		0	0
Posted Speeds (mph)		25	25 (1.42 miles) 30 (0.20 miles) 35 (2.70 miles)

[1]Two before periods were used. One of the signalized intersections was treated in 2005 while the rest were treated in 2008.

[2]Only one count was available for the comparison site; treated site had counts available in 2004 and 2007, other years were estimated assuming a linear trend over time

Table 30. Summary of New Jersey Signalized Intersection Data.

Variable		**Treatment Sites**	**Comparison Sites**
Number of Sites		6	41
Years Before	Average	4.7	Appropriate years for all sites used for each comparison site
	Minimum	3.0	
	Maximum	5.0	
Years After	Average	1.3	Appropriate years for all sites used for each comparison site
	Minimum	1.0	
	Maximum	3.0	
Total Crashes/Year Before	Average	2.8	
	Minimum	1.7	1.0
	Maximum	3.8	0.0
Total Crashes/Year After[1]	Average	2.4	2.6
	Minimum	0.0	
	Maximum	4.7	
Major Road AADT Before[1]	Average	11,011	
	Minimum	9,911	7,899
	Maximum	11,231	6,078
Major Road AADT After	Average	16,293	8,666
	Minimum	15,192	
	Maximum	16,513	
Area Type		Urban	Urban
Number of Approaches		4	4

[1]Treated sites had major road counts available in 2004 and 2007, other years were estimated assuming a linear trend over time. Minor road AADTs were not available.

In New Jersey, the countermeasures implemented as a result of the RSA were mostly implemented in 2008; however, one intersection was modified in 2005. Thus, the after period conditions changed at two different times for the treated segments. Recognizing the changing conditions, the analysis was run for two after periods. The first after period was based on data from 2003 to 2007 (i.e., the period before most of the major changes occurred). The second after period only considered the period from 2003 to 2004 (i.e., the period before any changes occurred).

The analysis considered the corridor in its entirety, including the signalized intersections, and separately considered the signalized intersections within the corridor. Comparison group and naïve before-after analyses were conducted for both scenarios. It was only possible to analyze total crashes for each scenario because there were too few crashes in the other categories.

The analysis did not account for regression-to-the-mean because the EB approach could not be applied. However, it was possible to investigate the potential for regression-to-the-mean. Specifically, total crashes were plotted over time for the corridor and signalized intersections, as shown in Figures 11 and 12. If regression-to-the- mean is present, one would expect to see a spike in crashes just prior to 2005 and/or 2008 (recall that the majority of changes occurred in 2008, with modifications to a signalized intersection in 2005). Figures 11 and 12 do not indicate such a spike in crashes but rather reflect a consistent oscillation around some mean value. Thus, for the purposes of the analysis, it is concluded that regression-to-the-mean is not likely to introduce significant bias.

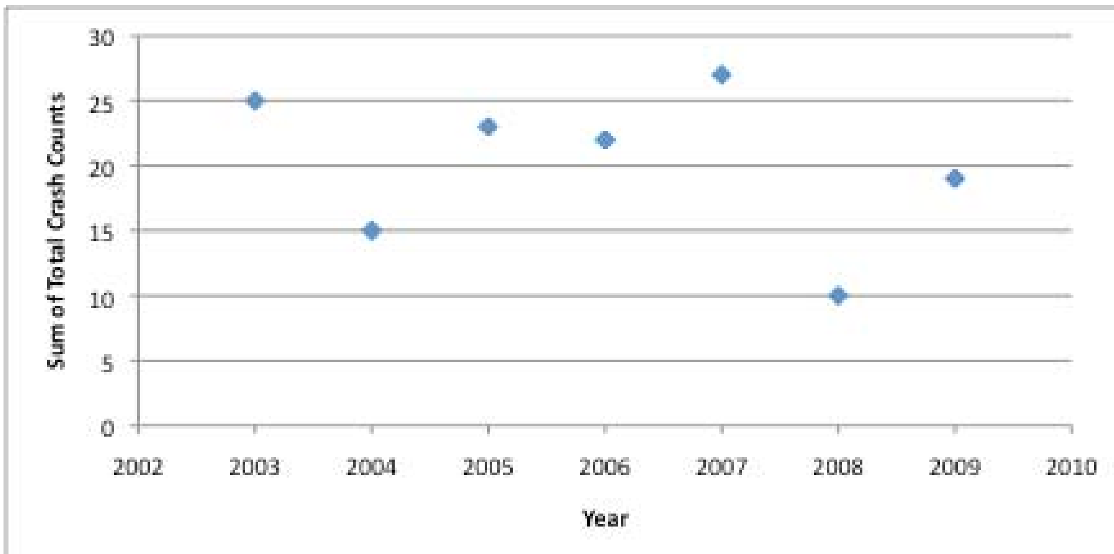


Figure 11. Corridor-Level Crash Totals Over Time.

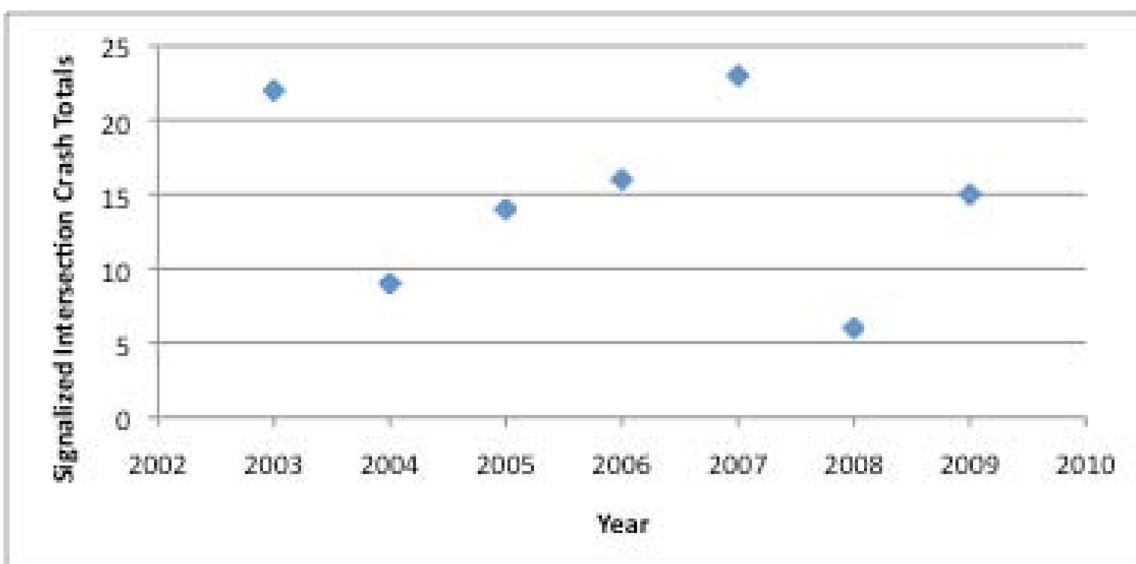


Figure 12. Signalized Intersection Crash Totals Over Time.

The following points should also be noted with respect to the analysis.

- A linear relationship was assumed between crashes and traffic volume when accounting for changes in traffic volume. With a limited variation in traffic volumes, it was not possible to develop an SPF or evaluate the suitability of existing SPFs to model the true relationship. Given the inherent uncertainty in other aspects of the analysis and the relatively small changes in AADT, this assumption was not deemed crucial.
- The suitability of the comparison group could not be rejected using the methods described by Hauer (1997). As such, the comparison site is deemed reliable for use in the comparison group method.

The results of the New Jersey analyses are presented in Table 31 and Table 32 for the corridor and signalized intersections, respectively. Results that are statistically significant at the five percent level are noted in bold. Note that Table 31 contains results for the comparison group and naïve before-after analyses; separate results are provided for each of the following:

1. Comparison group and naïve before-after methods, including entire before period.
2. Comparison group and naïve before-after methods, excluding years 2005 to 2007 from the before period.

Table 32 contains results for the comparison group and naïve before-after analyses, and separate results are provided for each of the following:

1. Comparison group and naïve before-after methods, including the signalized intersection of Ninth Street and West Avenue.
2. Comparison group and naïve before-after methods, excluding the signalized intersection of Ninth Street and West Avenue.

Table 31. Corridor Results for New Jersey.

	C-G Method			**Naïve Method**		
Before Period	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
2003 to 2004	19	26.3	**0.643 (0.240)**	19	44.6	**0.417 (0.110)**
2003 to 2007	19	22.8	**0.744 (0.277)**	19	35.9	**0.525 (0.129)**

Table 32. Signalized Intersection Results for New Jersey.

	C-G Method			Naïve Method		
Before Period	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**	**Observed Crashes After**	**Expected Crashes After**	**CMF (Standard Error)**
Including Ninth and West	24	24.3	**0.895 (0.308)**	24	29.7	**0.791 (0.194)**
Excluding Ninth and West	10	17.7	**0.510 (0.209)**	10	22.1	**0.447 (0.149)**

The results indicate a general safety benefit of conducting the RSA and implementing the treatments suggested in the RSA report. The estimated CMF is consistently less than 1.0 for all variations of the analysis, indicating a reduction in expected crashes. While the estimated reductions in total crashes for the corridor are substantial, they are insignificant for the comparison group method. With respect to the treated signalized intersections, the results indicate a safety benefit, although not statistically significant when the intersection of Ninth Street and West Avenue is included.

While there are several variations of the analysis, the results from the comparison group method are preferred over the naïve before-after results. The estimated crash reductions are consistently smaller for the comparison-group method than for the naïve method and could be considered conservative. However, the naïve method does appear to corroborate the results of the comparison group method.

While the EB methodology could not be applied in this evaluation, the results are consistent among the various approaches, even when considering the potential for regression-to-the-mean. The estimated crash reductions are also large enough to justify confidence in the RSA process, especially considering that the evaluation was based on only one project and on relatively low crash counts. The confidence level in the RSA process will be increased as the results of other projects developed from RSAs are amalgamated with the results in this report.

The annualized costs and benefits were then compared based on the results of the comparison group before-after study. For the corridor as a whole, the analysis indicated a 25.6 percent reduction in total crashes over a one-year "after" period. Using the FHWA crash costs document, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries* (Publication Number FHWA-HRT-05-051), the annual reduction of 3.8 total crashes results in an annual benefit of $122,497. Assuming a total cost of $921,000 ($21,000 for the RSA and $900,000 for the improvements), a discount rate of 2.2 percent, and a service life of 10 years, the annualized cost is $103,608. Therefore, the B/C ratio of the improvements made as a result of the RSA is 1.2:1 for the corridor, indicating an overall positive effect on safety in terms of total crashes.

Program Review

Transportation safety is one of the SJTPO's top priorities. Since completing its first RSA on Ninth Street in 2004 without the benefit of rigorous corridor-selection criteria, the SJTPO created a comprehensive process for the evaluation of future candidate RSA locations. In its fiscal year 2005 Planning Work Program, SJTPO began to gear the RSA program towards identifying locations where quick, low-cost safety improvements could be implemented. A process was established to program approximately $1 million in HSIP funding towards efforts that would have the highest reduction on severe crashes.

In 2005, two procedures were adopted as a means to select sites for RSAs.

<u>Nomination Selection Process</u>

The nomination selection process uses a "bottom up" approach. County engineers and officials qualitatively nominate sites based on their knowledge of high-crash locations. Geographic considerations, local control and cooperation, and available funding sources are several factors used to determine suitable locations. The following questions also help to identify locations that would likely have a high return on the investment of conducting an RSA and quickly implementing safety improvements:

- Are there few State road intersections in the corridor?
- Are there few municipalities involved, and are they responsive to safety projects?
- Is the corridor length compact enough to make for a good concentrated RSA?
- Are planning funds available for this project?

<u>Crash Data Selection Process</u>

The crash data selection process uses a "top down" approach. The process began with the SJTPO reviewing two years of crash data for every road in the region and identifying high crash-density locations as suitable sites. Crash data were reviewed based on crash density per mile, prior high-crash locations, and high-crash segments versus intersections. Of the three, crash density was given the most weight.

In 2006, the selection process became more refined. Fiscal year 2006 RSA corridors were selected using a balance of qualitative and quantitative elements. The SJTPO engaged local experts to nominate locations that could be improved quickly with inexpensive countermeasures. The South Jersey Traffic Safety Alliance and the SJTPO's Technical Advisory Committee solicited nominations from engineers, planners, and traffic officers who possessed first-hand knowledge of the local roadways, driving habits, and crash documentation. Once nominations were received, four factors were used as a filter:

- Geographic compactness of the corridor.
- High degree of local control.
- Good local cooperation.
- Potential for safety improvements.

The sites that met the above criteria were considered as top candidates and continued to SJTPO's quantitative analysis. A high-crash corridor was considered to experience at least 15 crashes per mile per year and a minimum of 100 total crashes. Injuries and fatalities were also considered. The top candidates from this step of the process were compared to all routes in the region on the basis of crash density. A sliding window technique was utilized to find the crash clusters. An overview flowchart of the process is illustrated in Figure 13.

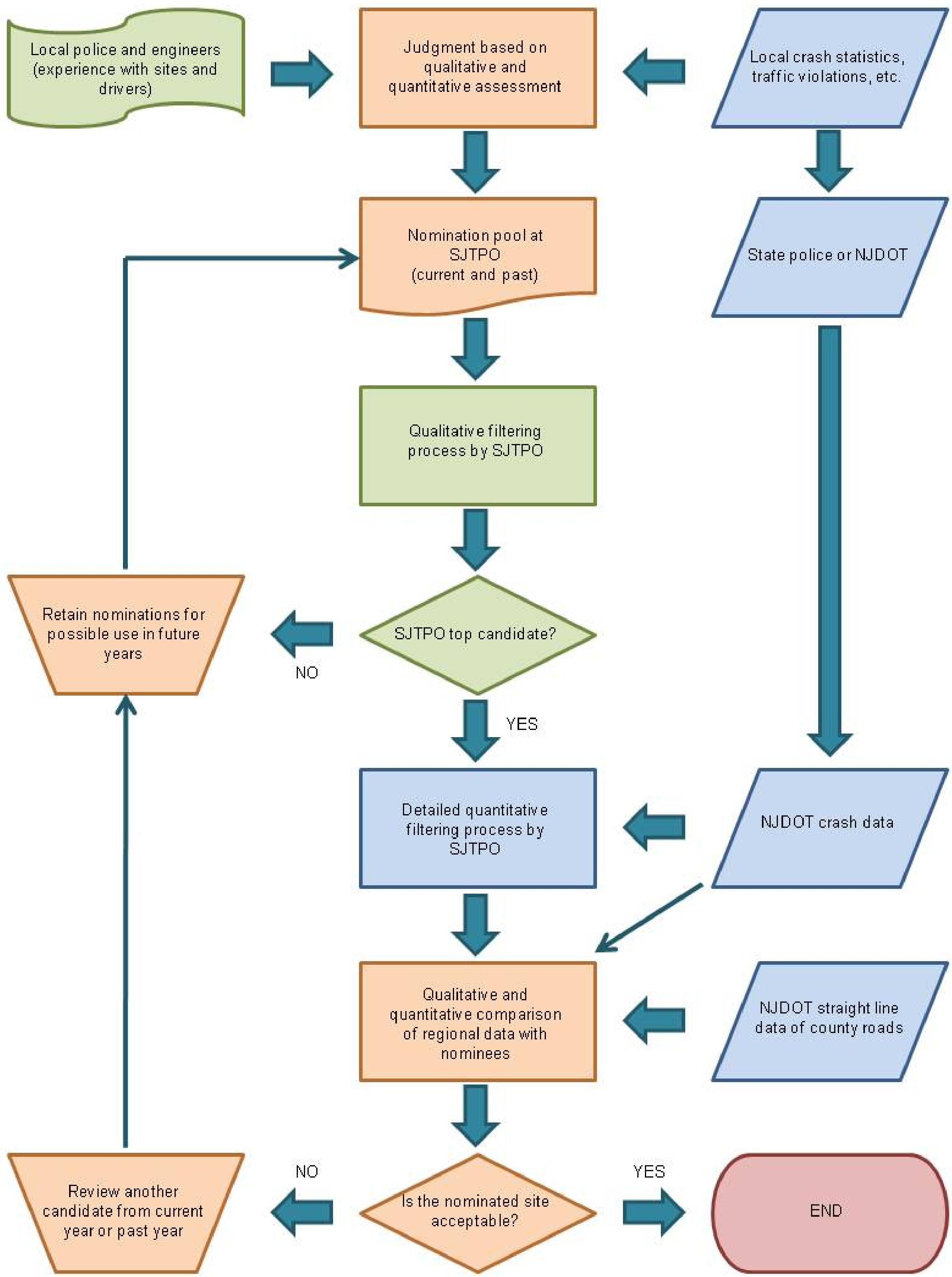


Figure 13. Overview of the South Jersey Transportation Planning Organization's RSA Site Selection Process.

NJDOT is very supportive of the SJTPO RSA program, working to enable the authorization of HSIP funds and assisting with unobligated HSIP funding issues. The NJ Division of Transportation Safety has also devoted a considerable amount of time to partnering with the SJTPO to conduct RSAs. Over the past several years, this RSA program has been highlighted by FHWA. In 2005, the program received an Honorable Mention in the National Roadway Safety Awards:

> "It is one of the first local programs of its kind, utilizing Federal planning funds to systemically identify local road segments of concern, organizing a team of independent specialists under the auspices of a metropolitan planning organization, engaging a consultant team for the audits and securing Federal funding for the resulting recommended improvement packages."

Additionally, in 2007, the SJTPO Director received the Dave Powell Excellence Award. This award is given to recognize partnerships with the FHWA New Jersey Division Office.

Transportation Safety Planning Results

In 2005, the results yielded four corridors from the nomination selection process and one corridor from the crash data selection process. The corridors ranged from 1.2 miles to 5.3 miles in length. In 2006, the results yielded five corridors from the qualitative and quantitative selection process. These corridors ranged from 1.9 miles to 4.3 miles in length.

In recent years, the SJTPO has shifted from using consultant support for the actual RSA to more project development tasks. The RSAs are now conducted by the localities as the SJTPO flexes regional Surface Transportation Program (STP) funds to metropolitan planning funds to conduct the RSA. In the near future, to ensure independent teams are being used, localities will begin a pilot effort to conduct peer expert exchanges in neighboring counties. For example, an established RSA team based in one county would conduct an independent safety assessment in a neighboring county in return for in-kind services.

Roadway Safety Scans

Since 2007, the SJTPO has also been using a "Road Safety Scan" (RSS) process. An RSS is a scaled-down version of an RSA and is more comparable to a traditional safety review. The scans allow experienced highway safety engineers to cover significantly more road mileage than a formal RSA. Local participation is also encouraged.

For an RSS, each section of study roadway is first driven at normal operating speeds and then at slower speeds to stop as necessary to take pictures and measurements. Particular items the engineers are looking for include traffic control device deficiencies, clear zone issues, sight distance issues, pavement drop-offs, guardrail end treatment deficiencies, etc. Voice-over video-recording devices are also used extensively for documentation and further office review.

There are three parts to the scan:

- **Data collection** – crash data printouts are reviewed by engineers to identify potential safety issues.
- **Field review** – conducted by the traffic engineer with local participation; each location is documented as accurately as possible.
- **Preparation of the report and findings** – documentation of findings and any recommended actions.

In 2007, a scan was completed for 31 sections (totaling 122 miles) in Cumberland, NJ and 13 sections (totaling 46 miles) in Atlantic, NJ. Each section had several safety issues identified, proposed remedial actions, an estimate of the level of effort required to implement the measures, and the potential safety benefit. A map with additional photographs and the reviewed crash data were also included to complete the scan.