ROAD SAFETY AUDITS:

CASE STUDIES

U.S. Department of Transportation
Federal Highway Administration

Making Your Roads Safer

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public under-standing. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Technical Report Documentation Page

1. Report No. FHWA-SA-06-17	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle *Road Safety Audits: Case Studies*		5. Report Date December 2006 6. Performing Organization Code
7. Authors Margaret Gibbs; Sany R. Zein; Dan Nabors; Hugh McGee; Kim Eccles		8. Performing Organization Report No.
9. Performing Organization Name and Address		10. Work Unit No.
Opus Hamilton Consultants Ltd 900 – 1199 West Hastings Street Vancouver, B.C., Canada V6E 3T5	Vanasse Hangen Brustlin Inc 700 – 8300 Boone Boulevard Vienna, VA 22182-2626	11. Contract or Grant No. DTFH61-03-D-00105
12. Sponsoring Agency Name and Address Office of Safety Federal Highway Administration U.S. Department of Transportation 400 Seventh Street SW, HSA-20 Washington, D.C. 20590		13. Type of Report and Period Covered Final Report Dec 2004 – April 2006 14. Sponsoring Agency Code
15. Supplementary Notes: The Federal Highway Administration (Office of Safety) sponsored the RSAs reported in this document. The FHWA Office of Safety Contract Task Order Manager was Louisa Ward.		

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 a series of ten RSAs. The aim of these case studies was to demonstrate the usefulness and effectiveness of RSAs for a variety of projects and project stages, and in a variety of agencies throughout the United States.

The results of the RSAs have been compiled in this case studies document. Each case study includes photographs, a project description, a summary of key findings, and the lessons learned. The aim of this document is to provide state and local agencies and Tribal governments with examples and advice that can assist them in implementing RSAs in their own jurisdictions.

17. Key Words Safety, Road Safety Audit	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages: 64	22. Price

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

PREFACE

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. Additional information on RSAs is available on the web at *http://safety.fhwa.dot.gov/rsa* and *www.roadwaysafetyaudits.org*.

Information for the case studies reported in this document was gathered during a series of ten RSAs conducted throughout the United States during 2004-2006, involving transportation agencies at the city, county, state, federal, and tribal levels, and examining roadway projects at all stages of design and operation. FHWA and the authors greatly appreciate the cooperation of the following agencies for their willing and enthusiastic participation in the FHWA-sponsored RSA series: Illinois DOT, Oklahoma DOT, Oregon DOT, Wisconsin DOT, the Standing Rock Sioux Tribe, the City of Cincinnati, the City of Tucson, Clark County (WA), Collier County (FL), and the National Park Service.

TABLE OF CONTENTS

INTRODUCTION 1
Background 1
What is an RSA? 1
The FHWA RSA Case Study Program 3

THE RSA PROCESS 5
Eight Steps of an RSA 5
Prioritization of Issues for Design-Stage RSAs 8

RSAs: COSTS AND BENEFITS 10
RSA Costs 10
RSA Benefits 11

THE FHWA RSA CASE STUDY PROJECT: PROMOTING THE ACCEPTANCE OF RSAs 14
Key Factors for Success 14
Lessons Learned 19

CONCLUSION 22

APPENDIX A: CASE STUDY RSAs A-1

RSA 1 Illinois DOT A-2
RSA 2 Oklahoma DOT A-5
RSA 3 Oregon DOT A-8
RSA 4 Wisconsin DOT A-12
RSA 5 Clark County A-17
RSA 5 Collier County A-21
RSA 7 City of Cincinnati A-25
RSA 8 City of Tucson A-29
RSA 9 Standing Rock Sioux Tribe A-32
RSA 10 Yellowstone National Park A-36

LIST OF FIGURES

FIGURE 1 RSA PROCESS 5
FIGURE 2 START-UP MEETING 6
FIGURE 3 FIELD REVIEW 6
FIGURE 4 RSA ANALYSIS SESSION 7
FIGURE 5 PRELIMINARY FINDINGS MEETING 7
FIGURE 6 EXAMPLE DISCUSSION OF AN RSA SAFETY ISSUE 18

LIST OF TABLES

TABLE 1	CASE STUDY RSAs	3
TABLE 2	FREQUENCY RATING	9
TABLE 3	SEVERITY RATING	9
TABLE 4	CRASH RISK ASSESSMENT	9

INTRODUCTION

Background

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, in December 2003 the Federal Highway Administration (FHWA) Office of Safety sponsored a RSA of the Marquette Interchange in Milwaukee, WI. The RSA team reviewed the detailed design for an $800 million interchange reconstruction project. Subsequently, in the summer of 2004, the FHWA Office of Safety commissioned a series of nine additional RSAs. The aim of these case studies was to demonstrate the usefulness and effectiveness of RSAs for a variety of projects and project stages, and in a variety of agencies throughout the United States.

The results of the RSAs have been compiled in this case studies document. Each case study includes photographs, a project description, a summary of key findings, and the lessons learned. The aim of this document is to provide state and local agencies and Tribal governments with examples and advice that can assist them in implementing RSAs in their own jurisdictions.

What is an RSA?

A road safety audit (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team.

Compromises and constraints among the competing interests that typically drive a road project (such as cost, right of way, environment, topographic and geotechnical conditions, socioeconomic issues, and capacity/efficiency) are a normal part of the planning and design process. The design team has the responsibility of integrating these competing interests to arrive at a design that accommodates these interests in as balanced and effective a manner as possible. RSAs, conducted by a team that is independent of the design, enhance safety by

explicitly and exclusively identifying the safety implications of project decisions. By focusing on safety, RSAs make sure that safety does not “fall through the cracks”.

The RSAs followed 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 discussed later in this case study document.

The multidisciplinary RSA team is typically composed of at least three members having a background in road safety, traffic operations, and/or road design, and members from other areas such as maintenance, human factors, enforcement, and first responders. Members of the RSA team are independent of the operations of the road or the design of the project being audited. The RSA team’s independence assures two things: that there is no potential conflict of interest or defensiveness, and the project is reviewed with “fresh eyes”.

RSAs 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, 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 pre-construction RSA is conducted, the more potential it has to efficiently remedy possible safety concerns.

- *Construction RSAs (work zone, changes in design during construction, and pre-opening)* 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.

The FHWA RSA Case Study Program

The ten RSAs conducted in this case study program are summarized in Table 1.

TABLE 1 CASE STUDY RSAs

FACILITY OWNER	PROJECT	RSA STAGE
State Departments of Transportation		
Illinois DOT	improvement to four-lane arterial road	preliminary design stage and existing roads
Oklahoma DOT	widening and resurfacing of two-lane rural highway	detailed design stage
Oregon DOT	improvements to two-lane rural highway	conceptual design stage
Wisconsin DOT	replacement of major interstate interchange	detailed design stage
Counties		
Clark County, WA	road alignment and intersection improvements to two-lane rural road	detailed design stage
Collier County, FL	widening of four-lane arterial road	planning stage
Cities		
Cincinnati, OH	improvements to commuter arterial, including bridge widening and intersection improvements	planning stage and existing roads
Tucson, AZ	six pedestrian crossings with HAWK signals	detailed design stage
Tribal		
Standing Rock Sioux Tribe, ND/SD	existing two-lane rural tribal roads	existing roads
Federal Lands		
Yellowstone National Park, WY	replacement of existing interchange with new access	planning stage and existing roads

All participating transportation agencies volunteered to be involved in this RSA program. Involvement in the case study program required the agency to nominate the project for the RSA; provide the RSA team with the materials (such as design drawings) on which the RSA would be based, or that provided useful background information, such as justification reports, traffic counts, collision data, or the results of public hearings; participate at a senior level in the RSA start-up and closing meetings; and contribute at least one engineer from their staff, not previously involved in the project, to participate on the RSA team. The RSA teams were led by two experienced and independent consultants.

Information on each of these RSAs, including background, a summary of RSA issues, and a list of suggested improvements, is included in the Appendix.

THE RSA PROCESS

Eight Steps of an RSA

The eight steps of an RSA are shown in Figure 1, and are discussed below with reference to the case studies.

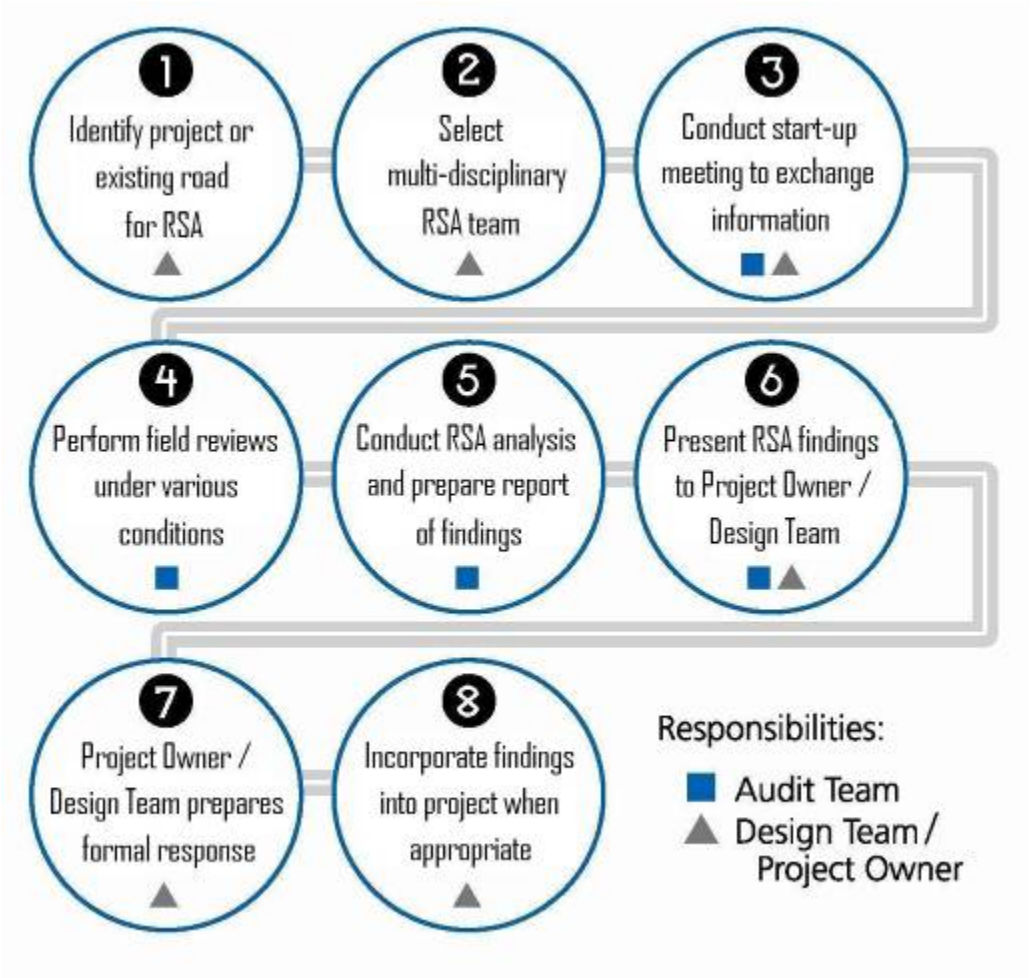


FIGURE 1 RSA PROCESS

RSA projects and the **RSA team** (Steps 1 and 2) were pre-selected in this FHWA case studies project. All meetings and site visits for the RSAs in the case studies project were conducted over two to four days, depending on the size and complexity of the project. The RSAs typically began with a **start-up meeting** (Step 3) attended by the Project Owner (hereafter referred to as the Owner), the Design Team, and the RSA team:

- The Owner described the objectives of the road project, including why it was being pursued and the improvements it was expected to accomplish. The Owner also explained why this project had been chosen for an RSA.

- The Design Team then described the road design (if the RSA was being conducted on a design), including a description of its individual elements; the current design stage and anticipated design/construction schedule; and the constraints and challenges involved in the design.

- The multidisciplinary RSA team then described the RSA process. This included an overview of the RSA process with examples of safety issues that are typically encountered and mitigation measures to address them.

Illinois DOT

FIGURE 2
START-UP MEETING

Standing Rock Sioux Reservation

FIGURE 3
FIELD REVIEW

Following the start-up meeting and a preliminary review of the design or site documentation provided by the Owner and Design Team, the RSA team conducted a **field review** (Step 4). The purpose of the field review was to observe the ambient conditions in which the proposed design would operate (for design-stage RSAs), or to observe geometric and operating conditions (for RSAs of existing roads). The RSA team observed road user characteristics (such as typical speeds and traffic mix), surrounding land uses (including traffic and pedestrian generators), and link points to the adjacent transportation network. Field reviews were conducted by the RSA team under a variety of environmental conditions (such as daytime and night-time) and operational conditions (such as peak and non-peak times).

The team conducted the **RSA analysis** (Step 5) in a setting in which all team members reviewed available background information (such as design criteria, project/justification reports, traffic volumes, and any relevant collision data) and drawings. The RSA analysis methodology involved a systematic review of design drawings, examining features such as road geometry, sight distances, clear zones, drainage, signing, lighting, and barriers. Human factors issues were also considered by the RSA team, including road and intersection "readability", sign location and sequencing, older-driver limitations, and driver perception of geometric features constructed to minimum standards. On the basis of this review of drawings, reports, and information obtained during the field review, the RSA team identified and prioritized safety issues, project features that could contribute to a higher frequency and/or severity of crashes. For each safety issue, the RSA team generated a list of possible ways to mitigate the crash potential.

At the end of the analysis session, the Owner, Design Team, and RSA team reconvened for a **preliminary findings meeting** (Step 6). Presenting the preliminary findings verbally in a meeting gave the Owner and Design Team the opportunity to ask questions and seek clarification on the RSA findings, and also provided a useful forum for the Owner and Design Team to suggest additional or alternative mitigation measures in conjunction with the RSA team. The discussion provided practical information that was subsequently used to write the RSA report.

Marquette Interchange RSA (Milwaukee, WI)

FIGURE 4
RSA ANALYSIS SESSION

Collier County, FL

FIGURE 5
PRELIMINARY FINDINGS MEETING

In the weeks following the on-site portion of the RSA, the RSA team wrote and issued the **RSA report** (also part of Step 6) to the Owner and Design Team documenting the results of the RSA. The main contents of the RSA report were a prioritized listing and description of the safety issues identified (illustrated using photographs taken during the site visit), with suggestions for improvements.

The Owner and Design Team were then encouraged to write a brief **response letter** (Step 7) containing a point-by-point response to each of the safety issues identified in the RSA report. The response letter identifies the action(s) to be taken, or explains why no action would be taken. The formal response letter is an important "closure" document for the RSA. As a final step, the Owner and Design Team use the RSA findings to identify and implement safety improvements as and when policy, manpower, and funding permit (Step 8).

Prioritization of Issues for Design-Stage RSAs

For design-stage RSAs, a prioritization framework was applied in both the RSA analysis and presentation of findings. The likely *frequency* and *severity* of crashes associated with each safety issue were qualitatively estimated, based on team members' experience and expectations. Expected crash *frequency* (Table 2) was qualitatively estimated on the basis of expected exposure (how many road users would likely be exposed to the identified safety issue?) and probability (how likely was it that a collision would result from the identified issue?). Expected crash *severity* (Table 3) was qualitatively estimated on the basis of factors such as anticipated speeds, expected collision types, and the likelihood that vulnerable road users would be exposed. These two risk elements (frequency and severity) were then combined to obtain a qualitative risk assessment on the basis of the matrix shown in Table 4. Consequently, each safety issue was prioritized on the basis of a ranking between A (lowest risk and lowest priority) and F (highest risk and highest priority). It should be stressed that this prioritization method was qualitative, based on the expectations and judgment of the RSA team members, and was employed to help the Owner and Design Team prioritize the multiple issues identified in the RSA.

For each safety issue identified, possible mitigation measures were suggested. The suggestions focused on measures that could be cost-effectively implemented at the current design stage.

TABLE 2 FREQUENCY RATING

ESTIMATED		EXPECTED CRASH FREQUENCY (per RSA item)	FREQUENCY RATING
EXPOSURE	PROBABILITY		
high	high	10 or more crashes per year	*Frequent*
medium	high		
high	medium	1 to 9 crashes per year	*Occasional*
medium	medium		
low	high		
high	low	less than 1 crash per year, but more than 1 crash every 5 years	*Infrequent*
low	medium		
medium	low	less than 1 crash every 5 years	*Rare*
low	low		

TABLE 3 SEVERITY RATING

TYPICAL CRASHES EXPECTED (per RSA item)	EXPECTED CRASH SEVERITY	SEVERITY RATING
crashes involving high speeds or heavy vehicles, pedestrians, or bicycles	probable fatality or incapacitating injury	*Extreme*
crashes involving medium to high speed; head-on, crossing, or off-road crashes	moderate to severe injury	*High*
crashes involving medium to low speeds; left-turn and right-turn crashes	minor to moderate injury	*Moderate*
crashes involving low to medium speeds; rear-end or sideswipe crashes	property damage only or minor injury	*Low*

TABLE 4 CRASH RISK ASSESSMENT

FREQUENCY RATING	SEVERITY RATING			
	Low	*Moderate*	*High*	*Extreme*
Frequent	**C**	**D**	**E**	**F**
Occasional	**B**	**C**	**D**	**E**
Infrequent	**A**	**B**	**C**	**D**
Rare	**A**	**A**	**B**	**C**

Crash Risk Ratings: *A: lowest risk level* *B: low risk level* *C: moderate-low risk level* *D: moderate-high risk level* *E: high risk level* *F: highest risk level*

RSAs: COSTS AND BENEFITS

RSA Costs

Three main factors contribute to the cost of an RSA:

- RSA team costs,
- design team and owner costs,
- costs of design changes or enhancements.

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. For the RSAs in this case studies project, the following cost components are noted:

- RSA teams were composed of between four and ten persons in this case studies project, but these teams were large since the RSAs served as training exercises for local engineering staff. Without the need for training, the RSA teams would more typically have been composed of three or four persons.

- Opening and closing meetings, site visits, and RSA analysis sessions were conducted in a three-day period for each RSA.

- Prior to and following the on-site portion of the RSA, the time required for analysis (such as analysis of collision records, and research on applicable design standards or mitigation measures) and writing the RSA report ranged between 20 and 55 man-hours, with 30 to 40 man-hours being typical. The wide range primarily reflected the number and complexity of the issues identified during the RSA.

For this case studies project, additional RSA team costs were incurred in travel for experienced RSA team leaders. However, typical RSAs would employ local team members, and consequently entail only minor travel costs.

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 design drawings and other project or site materials for the RSA team.
The final cost component is that resulting from *design changes or enhancements,* which reflect the number and complexity of the issues identified during the RSA. Suggested design changes and enhancements, listed in the Appendix (Tables A.1 through A.12) for each of the RSAs conducted for this case studies project, have focused on low-cost improvements or countermeasures where possible.

- Suggested improvements for the four RSAs of existing roads focused mainly on improved signing, signal enhancements, parking and access management.
- Suggested improvements for the four detailed-design RSAs focused on improved signing and pavement markings, minor or moderate geometric changes (such as added auxiliary lanes at intersections), and barrier improvements. It should be noted, however, that one project owner initiated a fundamental reconsideration of its entire project on the basis of the RSA findings, which identified fundamental concerns regarding the net safety benefits of the improvement project.
- Suggestions for the preliminary and planning stage RSAs ranged from minor improvements such as signing, through moderate geometric improvements such as median and gateway treatments, to suggestions related to fundamental issues such as design vehicles, design volumes, and access restrictions.

RSA Benefits

The primary benefits of RSAs are to be found in reduced crash costs as road safety is improved. The costs of automotive crashes are estimated by the US Department of Transportation[1] as:

- $3,000,000 for a traffic fatality,
- $2,290,000 for a critical injury,
- $565,000 for a severe injury,
- $175,000 for a serious injury,
- $45,000 for a moderate injury,
- $6,000 for a minor injury.

[1] *Intersection Safety Issue Brief No. 15 ("Road Safety Audits: An Emerging and Effective Tool for Improved Safety"), issued April 2004 by Federal Highway Administration and Institute of Transportation Engineers.*

Other benefits of RSAs include reduced life-cycle project costs as crashes and the need for retrofitted safety improvements are reduced, and the development of good safety engineering and design practices, including integration of multimodal safety concerns and consideration of human factors in the design.

As mentioned in the recent FHWA/ITE Intersection Safety Issue Brief on RSAs, it is difficult to quantify the benefits of design-stage RSAs, since they aim to prevent crashes from occurring on new or improved facilities that have no crash record. However, when compared with the high cost of motor-vehicle injuries discussed above, the moderate cost of a design-stage RSA suggests that changes implemented from an RSA only need to prevent a few moderate- or high-severity crashes for an RSA to be cost effective.

The benefits of RSAs on existing roads can be more easily quantified, since pre- and post-improvement collision histories are available. As an example, the Road Improvement Demonstration Project conducted by AAA Michigan in Detroit and Grand Rapids (MI), which is based on RSAs of existing high-crash urban intersections and implementation of low-cost safety measures at them, has demonstrated a benefit-cost ratio of 16:1.

Another example of U.S. data on the quantitative safety benefit of RSAs conducted on existing roads comes from the New York DOT, which reports a 20 to 40 percent reduction in crashes at more than 300 high-crash locations that had received surface improvements and had been treated with other low-cost safety improvements suggested by RSAs.

The South Carolina DOT RSA program has had a positive impact on safety. Early results from four separate RSAs, following one year of results, are promising. One site, implementing four of eight suggested improvements, saw total crashes decrease 12.5 percent, resulting in an economic savings of $40,000. A second site had a 15.8 percent increase in crashes after only two of the thirteen suggestions for improvements were incorporated. A third site, implementing all nine suggested improvements, saw a reduction of 60 percent in fatalities, resulting in an economic savings of $3,660,000. Finally, a fourth location, implementing 25 of the 37 suggested safety improvements, had a 23.4 percent reduction in crashes, resulting in an economic savings of $147,000.

The most objective and most often-cited study of the benefits of RSAs, conducted in Surrey County, United Kingdom, compared fatal and injury crash reductions at 19 audited highway projects to those at 19 highway projects for which RSAs were not conducted. It found that, while the average yearly fatal and injury crash frequency at the RSA sites had dropped by 1.25 crashes per year (an average reduction from 2.08 to 0.83 crashes per year), the average yearly fatal and injury crash frequency at the sites that were not audited had dropped by only 0.26 crashes per hear (an average reduction from 2.6 to 2.34 crashes per year). This suggests that RSAs of highway projects make them almost five times more effective in reducing fatal and injury crashes.

Other major studies from the United Kingdom, Denmark, New Zealand, and Jordan quantify the benefits of RSAs in different ways. However, all report that RSAs are relatively inexpensive to conduct and are highly cost effective in identifying safety enhancements.

THE FHWA CASE STUDIES: PROMOTING THE ACCEPTANCE OF RSAs

The RSAs in this case studies project have been well received by all participating agencies. Characteristics of the FHWA RSAs that have promoted their acceptance by the participating agencies are generally those that are aimed at making the RSA as useful and "user-friendly" as possible:

Key Factors for Success

1. The RSA suggestions have been consistent with the project's design stage.

When a safety issue is identified by the RSA team, one or more possible mitigation measures are suggested for consideration by the Design Team and Owner. Suggested mitigation measures must be consistent with the design stage at which the RSA is being conducted.

For example, an RSA was conducted on the detailed design of improvements to US 60 in Oklahoma within 12 weeks of the date on which the final design was due for submission. In the course of the RSA, the team identified a vertical crest curve that limited sight distance to an intersection and driveways. Both the RSA team and Design Team agreed that redesign of the road profile would improve sight distance, but was infeasible financially and at such an advanced project stage, when the land acquisition process had already been completed and utility relocation was underway. The Design Team had already incorporated geometric features to address the limited sight distance in the design, and the RSA team put forward further mitigation measures that could feasibly be implemented at the advanced design stage, such as signing and driveway relocation. Conversely, for the RSA conducted at an early (planning) stage for widening an arterial roadway in Collier County, FL, the RSA team could consider a wider range of safety improvements that could feasibly be included in subsequent design stages. Suggested measures included improved pedestrian and cycling facilities (since the arterial was adjacent to newly constructed schools) and a comprehensive access management program.

2. Preliminary RSA results (findings and suggestions) have been presented to the Owner twice, verbally and in a draft written form, to provide the Owner and Design Team with the opportunity for input and review before the results are documented in the final report.

Since RSA reports may become public documents, transportation agencies may be sensitive to their contents and the way in which the RSA results are presented. To address an agency's concerns and provide it with an opportunity for input, the RSA team first discusses the RSA results in the preliminary findings meeting. In this discussion, the design team and the Owner have the opportunity to identify potentially sensitive safety issues or alternative suggestions to those that have been identified by the RSA team. In practice, the safety issues identified by the RSA team in this case studies project have been consistently accepted as valid, and no agency has attempted to discourage their inclusion in the RSA report. In contrast, the RSA team's suggestions for improvements were discussed at some length.

After discussion in the preliminary findings meeting, a final set of suggestions can be identified and incorporated in the RSA report. A draft version of the RSA report is provided to the Owner for review. The Owner or Design Team can suggest clarifications or provide additional information that can be incorporated in the final RSA report. In practice, of the ten RSA reports completed to date in this case studies project, changes to the draft have been requested in only three reports. These changes were minor in nature, dealing with details such as terminology and clarification of some transportation agency policies.

By discussing RSA findings in the preliminary findings meeting and issuing a draft version of the report, the RSA team, Design Team, and Owner can work together to ensure that potentially sensitive issues are appropriately presented. It remains the responsibility of the RSA team to ensure that, while the Owner's concerns are adequately addressed, the final RSA report is an objective and accurate reflection of its findings, and that the integrity and independence of the RSA process are maintained.

3. For RSAs at an early design stage, the RSA team has provided guidance on possible low-cost improvements that could be implemented as interim measures to decrease interim crash risks.

Two of the RSAs in this pilot series were conducted in the planning or preliminary design stage, when construction was expected to start two or more years in the future. In the interim, while waiting for the public consultation, design and funding processes to proceed, the RSA team and Owner agreed that the safety issues that had partly motivated the projects should be addressed. Accordingly, during field reviews, the RSA team conducted an RSA of the existing facilities aimed at identifying safety issues and low-cost countermeasures that could be implemented as stopgap measures to improve safety as much as possible while waiting for the redesign to be implemented. Representative stopgap improvements included improved signing, improved pedestrian facilities (crosswalks and signal heads), and a suggestion to review signal operations to determine if left-turn phasing should be changed.

4. The RSA process has been applied to enhance the implementation of innovative road safety measures, with the aim of promoting their success.

Transportation agencies may develop or adopt technologies or measures that are innovative (locally or nationally) with the aim of promoting road safety. A common example of such a measure is the modern roundabout. Since these measures may be new to both the transportation agency and the wider community of road users, they may involve unforeseen consequences that ultimately compromise, rather than promote, safety. An RSA can be beneficial as a means of reviewing the innovative improvement in its intended environment, identifying possible factors that may compromise its successful implementation, and suggesting measures to address them.

For example, the City of Tucson has developed an innovative pedestrian crossing device, the HAWK signal (**H**igh Intensity **A**ctivated Cross**W**al**K**, a type of flashing beacon), and is implementing it at intersections where pedestrian safety is a concern. The City of Tucson received approval from FHWA to experiment with this device; it is not yet adopted in the *Manual of Uniform Traffic Control Devices*. One of the outcomes of the RSA conducted for six implementation sites in Tucson was a set of suggestions to enhance the HAWK system with a view to its wider (statewide or nationwide) application. Another outcome was a set of suggestions

for site-specific low-cost improvements that could be “piggybacked” onto the signal implementation works to further enhance pedestrian and traffic safety.

5. The safety benefits of a project have been identified as part of the RSA process and report.

In this RSA case studies project, all of the road improvement projects on which RSAs were conducted during the planning or design stages were initially motivated, wholly or in part, by a desire to address safety issues. Part of the RSA process developed in this case studies project has been to identify safety issues that were observed on-site or through collision data, and to clearly state how the elements of the Design Team’s proposed improvements or design can be expected to positively address these issues. Acknowledging the safety benefits of the original design puts the RSA findings in an appropriate context.

6. RSA teams have been composed of a multidisciplinary group of experienced professionals.

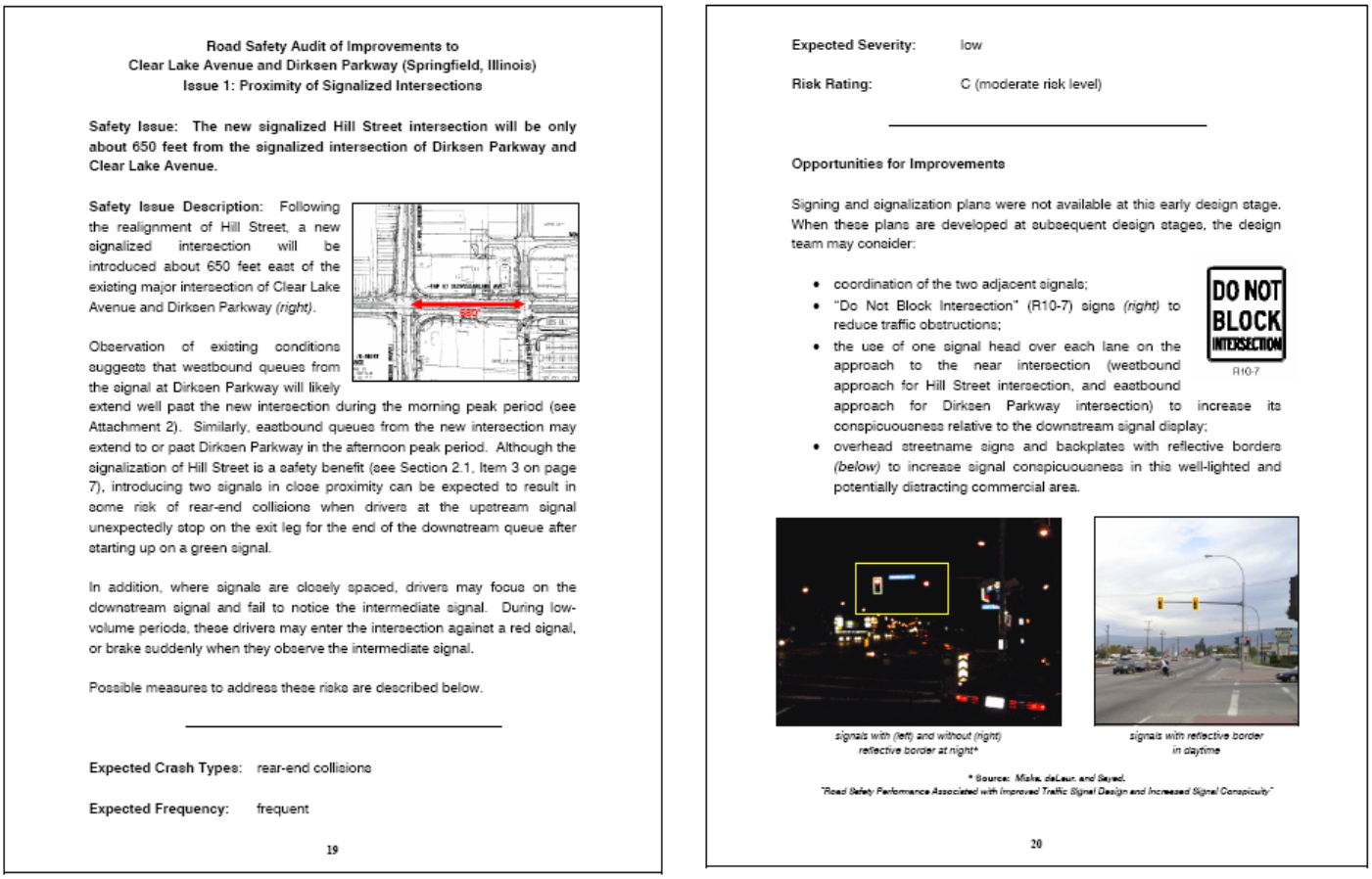
The core disciplines on an RSA team are traffic operations, geometric design, and road safety. Beyond these core requirements, all of the RSA teams in this case studies project have included members who have brought a range of backgrounds and specialties to the RSA. For example, the RSA of a preliminary design for arterial road upgrades for the Illinois DOT involved a team of professionals with individual specialties in construction, maintenance, access management, and enforcement. In addition, the RSA team included members from outside the state as well as locally based members from Illinois DOT and FHWA Field Safety staff. Those team members with local experience provided first-hand knowledge of local policies, practices, and conditions (including important information on commuter routes and local land use), while those from outside the state contributed ideas gained from experience with other agencies and in other jurisdictions.

7. RSA reports have been brief.

The RSA report is concise, and focuses on describing safety issues and suggested mitigation. Graphics and photographs were used as extensively as possible. The reports included:

- *background:* a brief summary of the road or project being audited;

- *RSA team and process:* a listing of the RSA team members, the design or as-built drawings used, site visit dates, and a description of the prioritization method used;
- *site observations* made during site visits, including photographs;
- *safety benefits of the proposed improvements,* describing elements of the project that are expected to effectively address existing safety issues or otherwise enhance road safety;
- *RSA findings:* a listing of safety issues and suggested mitigation, usually one or two pages each. A two-page example is shown in FIGURE 6. A safety issue has been identified in a single sentence at the top of the page. A description of the safety issue follows, describing the nature of the safety concern and how it may contribute to collisions. A figure has been used to illustrate the safety issue. Prioritization of the safety issue follows, using the prioritization matrix described earlier, and ways to address the safety issue are suggested.



Road Safety Audit of Improvements to
Clear Lake Avenue and Dirksen Parkway (Springfield, Illinois)
Issue 1: Proximity of Signalized Intersections

Safety Issue: The new signalized Hill Street intersection will be only about 650 feet from the signalized intersection of Dirksen Parkway and Clear Lake Avenue.

Safety Issue Description: Following the realignment of Hill Street, a new signalized intersection will be introduced about 650 feet east of the existing major intersection of Clear Lake Avenue and Dirksen Parkway *(right)*.

Observation of existing conditions suggests that westbound queues from the signal at Dirksen Parkway will likely extend well past the new intersection during the morning peak period (see Attachment 2). Similarly, eastbound queues from the new intersection may extend to or past Dirksen Parkway in the afternoon peak period. Although the signalization of Hill Street is a safety benefit (see Section 2.1, Item 3 on page 7), introducing two signals in close proximity can be expected to result in some risk of rear-end collisions when drivers at the upstream signal unexpectedly stop on the exit leg for the end of the downstream queue after starting up on a green signal.

In addition, where signals are closely spaced, drivers may focus on the downstream signal and fail to notice the intermediate signal. During low-volume periods, these drivers may enter the intersection against a red signal, or brake suddenly when they observe the intermediate signal.

Possible measures to address these risks are described below.

Expected Crash Types: rear-end collisions

Expected Frequency: frequent

19

Expected Severity: low

Risk Rating: C (moderate risk level)

Opportunities for Improvements

Signing and signalization plans were not available at this early design stage. When these plans are developed at subsequent design stages, the design team may consider:

- coordination of the two adjacent signals;
- "Do Not Block Intersection" (R10-7) signs *(right)* to reduce traffic obstructions;
- the use of one signal head over each lane on the approach to the near intersection (westbound approach for Hill Street intersection, and eastbound approach for Dirksen Parkway intersection) to increase its conspicuousness relative to the downstream signal display;
- overhead streetname signs and backplates with reflective borders *(below)* to increase signal conspicuousness in this well-lighted and potentially distracting commercial area.

DO NOT BLOCK INTERSECTION
R10-7

*signals with (left) and without (right) reflective border at night**

signals with reflective border in daytime

* Source: Misle, deLeur, and Sayed, "Road Safety Performance Associated with Improved Traffic Signal Design and Increased Signal Conspicuity"

20

FIGURE 6 EXAMPLE DISCUSSION OF AN RSA SAFETY ISSUE

Lessons Learned

Over the course of the RSA case studies project, the RSA teams have identified several key elements that help to make an RSA successful.

1. The RSA team must acquire a clear understanding of the project background and constraints.

At the RSA start-up meeting, a frank discussion of the constraints and challenges encountered in the design of the project, or operation of existing road, is critical to the success of the RSA. It is crucial that the RSA team understand the trade-offs and compromises that were a part of the design process. Knowledge of these constraints helps the RSA team to identify mitigation measures that are practical and reasonable.

2. The RSA team and Design Team need to work in a cooperative fashion to achieve a successful RSA result. It is important to maintain an atmosphere of cooperation among all participants in the RSA process – the Design Team, RSA team, and the Owner.

The RSA team should be consistently positive and constructive when dealing with the Design Team. Many problems can be avoided if the RSA team maintains effective communication with the Design Team during the RSA (including the opportunities presented in the start-up and preliminary findings meetings) to understand why roadway elements were designed as they were, and whether mitigation measures identified by the RSA team are feasible and practical. This consultation also gives the Design Team a “heads-up” regarding the issues identified during the RSA, as well as some input into possible solutions, both of which can reduce apprehension (and therefore defensiveness) concerning the RSA findings.

The cooperation of the Design Team is vital to the success of the RSA. An RSA is not a critical review of the design team's work, but rather a supportive review of the design with a focus on how safety can be further incorporated into it. Cooperation between the RSA team and Design Team usually results in a productive RSA, since the RSA team will fully understand the design issues and challenges (as explained by the Design Team), and suggested mitigation measures (as discussed in advance with the Design Team) will be practical and reasonable.

Support from the Owner is vital to the success of individual RSAs and the RSA program as a whole. It is essential that the Owner commit the necessary time within the project schedule for conducting the RSA and incorporating any improvements resulting from it, as well as the staff to represent the Owner in the RSA process (primarily the start-up and preliminary findings meetings).

3. A "local champion" can greatly help to facilitate the establishment of RSAs.

Wilson and Lipinski[2] noted in their recent synthesis of RSA practices in the United States *(1)* that the introduction of RSAs or an RSA program can face opposition based on liability concerns, the anticipated costs of the RSA or of implementing suggested changes, and commitment of staff resources. To help overcome this resistance, a "local champion" who understands the purposes and procedures of an RSA, and who is willing and able to promote RSAs on at least a trial basis, is desirable. Thus, measures to introduce RSAs to a core of senior transportation professionals can help to promote their wider acceptance. "Local champions" have been found within state DOTs, FHWA field offices, or city, county, or Tribal transportation agencies.

4. The RSA field review should be scheduled to coincide with important site conditions.

The RSA team should visit the project site when traffic conditions are typical or representative. For example, the RSA in Yellowstone National Park was conducted at the start of the Park's summer season when visitor volumes were

[2] Eugene Wilson and Martin Lipinski. *NCHRP Synthesis 336: Road Safety Audits, A Synthesis of Highway Practice* (National Cooperative Highway Research Program, TRB, 2004)

increasing. Consequently, the RSA team observed parking and circulation issues that were characteristic of the Park's high-volume summer season. In contrast, the RSA in Cincinnati was conducted in late December, after classes at a nearby university had ended. The RSA team was consequently unable to observe the impact of university traffic at the site. Although this did not significantly affect the RSA findings, scheduling the field review to observe typical or usual traffic conditions is preferable, since it allows the RSA team to see how regularly-recurring traffic conditions and road user behavior may affect safety.

CONCLUSION

The RSA case studies project sponsored by the FHWA Office of Safety has been well received by the participating transportation agencies. The case studies project has exposed State and local agencies and Tribal governments to the concepts and practices of an RSA, and provided the opportunity for agency staff members to participate on the RSA team as part of the process. Within a year of the first case study RSA, at least two of the participating agencies have implemented regular RSA programs for their new and upgrade transportation projects.

This case study document has summarized the results of each RSA, with the intent of providing State and local agencies and Tribal governments with examples and advice to assist them in implementing RSAs in their own jurisdictions. In the future, an evaluation of these RSAs, as well as other RSAs conducted in the United States, will be conducted and published to provide further guidance to agencies contemplating an RSA program in their jurisdictions.

APPENDIX A

RSA CASE STUDIES

RSA NUMBER 1

ILLINOIS DEPARTMENT OF TRANSPORTATION: RSA OF IMPROVEMENTS TO CLEAR LAKE AVENUE AND DIRKSEN PARKWAY

Project: improvements to roadways and intersections in a commercial area adjacent to an interchange

Planned Improvements:
- access consolidation and construction of two new service roads
- dual left turn lanes at existing intersection
- realignment of local road
- new signalized intersection

Project Environment:	☐ urban	☑ **suburban**	☐ rural
Project Design Stage:	☐ conceptual (0 to 30%)	☑ **preliminary (40 to 80%)**	☐ advanced (over 80%)
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Illinois Department of Transportation		

Road Safety Audit

Date of RSA:	8-10 February 2005	
RSA Stage(s):	☑ **design stage**	☑ **RSA of existing roads**
RSA team:	staff from Federal Highway Administration Resource Center, Federal Highway Administration Illinois Field Office, Illinois DOT, and Opus Hamilton	

PROJECT BACKGROUND:

Clear Lake Avenue connects the I-72/I-55 interchange east of Springfield, Illinois, with downtown Springfield. Dirksen Parkway intersects Clear Lake Avenue just west of the interchange. Views of Clear Lake Avenue and Dirksen Parkway are shown in FIGURE A.1. In addition to functioning as major arterials, both roadways provide access to adjacent commercial properties.

The intersection of Clear Lake Avenue and Dirksen Parkway was designated a high accident location for six consecutive years (1998 through 2003), and the intersection of Hill Street and Clear Lake Avenue was designated a high accident location in 2003. In response, the Illinois Department of Transportation (IDOT) developed plans to upgrade Clear Lake Avenue between Dirksen Parkway and the I-72/I-55 interchange. The scope of the planned improvements, shown in FIGURE A.2, included:

- access consolidation and construction of two new service roads intersecting Clear Lake Avenue at a new signalized intersection east of Dirksen Parkway;
- realignment of Hill Street (a local road) to intersect Clear Lake Avenue at new signalized intersection;
- dual left turn lanes on all legs of the intersection of Clear Lake Avenue and Dirksen Parkway, and dual right turn lanes on the southeast corner of the intersection.

Clear Lake Avenue (looking west toward intersection with Dirksen Parkway)

Dirksen Parkway (looking south toward intersection with Clear Lake Avenue)

FIGURE A.1 VIEWS OF RSA SITE (ILLINOIS DOT RSA)

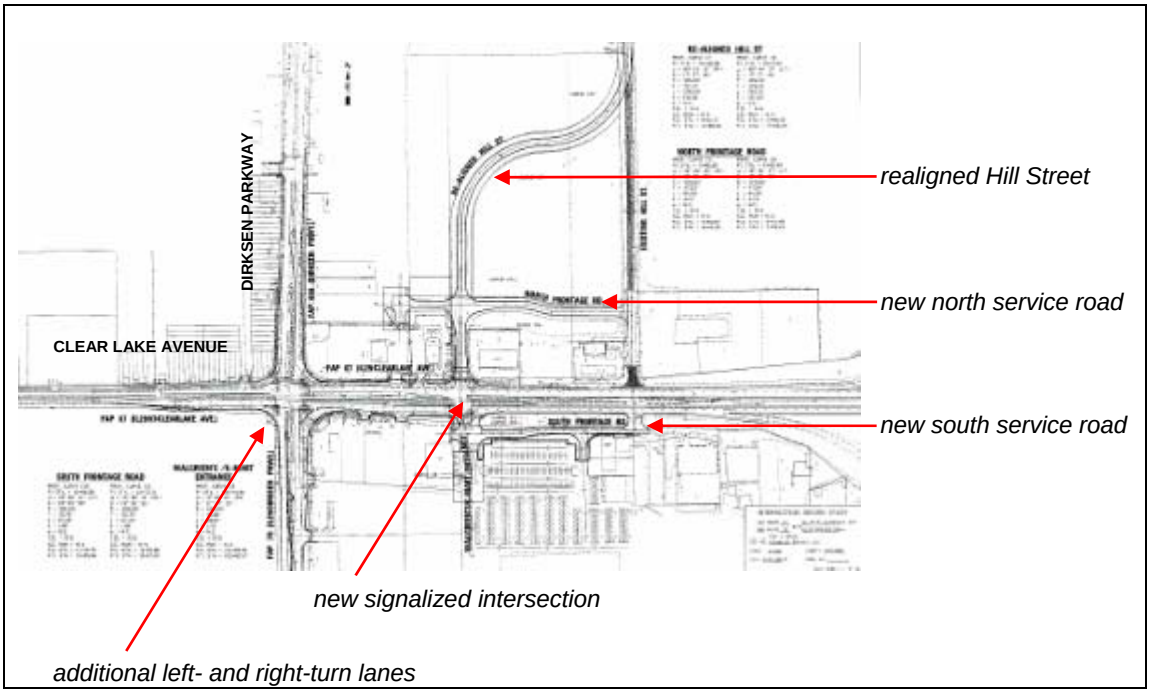


FIGURE A.2 RSA PROJECT (ILLINOIS DOT RSA)

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.1.

TABLE A.1 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS ILLINOIS DOT RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	The new signalized Hill Street intersection will be about 650 feet from the signalized intersection of Dirksen Parkway and Clear Lake Avenue.	C	• coordination of adjacent signals • "Do Not Block Intersection" signs • signing and signal displays to enhance intersection conspicuousness
2	The realigned Hill Street can be expected to accommodate commercial driveways, which may be located on back-to-back horizontal curves.	C	• raised medians to prohibit left turns • inclusion of service roads along Hill Street • measures to regulate driveway design and location
3	Queued, turning, and parking vehicles around the closely-spaced intersections at Clear Lake Ave. and the south service road may interfere with each other.	D	• restricted turning movements • relocation of service road intersection • relocation of specified parking stalls in parking lot • confirmation of pavement strength
4	Drivers exiting the interchange onto Clear Lake Avenue encounter a new urban driving environment with slower speeds and greater potential for conflicts with stopping and turning vehicles.	--	"Gateway" treatment: • curb and gutter drainage • landscaping treatments • more conspicuous signing • visitor pull-out (if space permits)
5	Opportunities for interim improvements	--	• clearer signing for eastbound traffic • improved signing at raised medians • accommodation of high demand at Hill Street intersection • review of permitted left turns • improved pedestrian facilities • interim access management • improved signal visibility (eastbound)

KEY LESSONS LEARNED:

The benefit of a design-stage RSA can be increased by including a review of existing roads, based on the RSA team's site visit, particularly where the design project will not be implemented for several years. Typically, roadway improvements are motivated at least in part by an effort to improve traffic safety. Consequently, traffic safety issues are frequently already a concern at the RSA site. The RSA site visit provides an opportunity for a group of traffic and road safety experts to examine the site with a view to identifying immediate, low-cost improvements that can be implemented on an interim basis before the start of construction.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

RSA NUMBER 2

OKLAHAMA DEPARTMENT OF TRANSPORTATION: RSA OF IMPROVEMENTS TO US HIGHWAY 60

Project: widening and resurfacing a two-lane rural highway

Planned Improvements:
- replacement of three bridges over two creeks
- shoulder widening to provide a continuous 8-foot paved shoulder
- intersection improvements (one intersection)
- resurfacing of improved section as well as an adjacent 1.2-mile section

Project Environment:	☐ urban	☐ suburban	☑ **rural**
Project Design Stage:	☐ conceptual (0 to 30%)	☐ preliminary (40 to 80%)	☑ **advanced (over 80%)**
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Oklahoma Department of Transportation		

Road Safety Audit

Date of RSA:	1-3 February 2005	
RSA Stage(s):	☑ **design stage**	☐ RSA of existing roads
RSA team:	staff from Federal Highway Administration Oklahoma Field Office, Oklahoma DOT, and Opus Hamilton	

PROJECT BACKGROUND:

US 60 is a US numbered highway (part of the National Highway System) extending for 350 miles across northern Oklahoma. The RSA team reviewed detailed (90 percent) design stage drawings of upgrades to a 2.9-mile stretch of US 60 in Osage County. Along the upgraded section, US 60 has a posted speed limit of 65 mph, and a reported AADT of 3,500 vehicles. The existing roadway, shown in FIGURE A.3, is a two-lane rural roadway having 12-foot driving lanes with narrow or absent paved shoulders. In addition to resurfacing, the upgrades included:

- replacing existing bridges over Buck Creek and Turkey Creek, including reconstructing the approach roadways as two 12-foot lanes with 8-foot paved shoulders;
- between the bridges, widening shoulders to provide a continuous 8-foot paved shoulder and adding one channelized right turn lane at the unsignalized intersection with Bowring Road, a section-line road;
- resurfacing a 1.2-mile “incidental section” west of Buck Creek (12-foot lanes with 2-foot paved shoulders) to connect with an adjacent segment of US 60 further west that had been recently overlaid.

The RSA team also reviewed proposed construction-stage detours.

Buck Creek bridge
(planned improvements include repaving, bridge improvements, and 8' paved shoulders)

adjacent "incidental" section
(planned improvements include repaving and 2' paved shoulders)

FIGURE A.3 VIEWS OF RSA SITE (OKLAHOMA DOT RSA)

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.2. The DOT responded that changes would be made as suggested except for changes that would involve re-negotiation with property owners or utility relocation (Issue 1), since these processes were already complete, or changes that would entail substantial delay or additional expense (redesign of cross-section elements on the incidental section, Issue 2D). The DOT also declined the suggestion to install rumble strips, since they are not typically used on Oklahoma highways.

KEY LESSONS LEARNED:

It is important to identify the safety benefits of the design as part of the RSA process. The improvements to US60 were motivated largely by safety, to provide a consistent and high-quality roadway where the existing roadway was characterized by poor pavement and roadside conditions. As part of the RSA process, the RSA team identified how the elements of the Design Team's proposed improvements were expected to positively address existing safety concerns. Examples cited in the RSA report included the following:

- Paved 8-foot shoulders and shallower fill slopes will reduce the risk and severity of off-road collisions.
- Resurfacing will improve the travel surface, and new pavement markings will improve driver guidance.
- Bridge reconstruction will increase the clearance distance to roadside safety issues, and provide the opportunity to improve barrier end treatments.

Acknowledging the safety benefits of the original design put the RSA findings in an appropriate context.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

TABLE A.2 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS OKLAHOMA DOT RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	Vertical crest curves limit drivers' advance view of the intersection of US60 with Bowring Road.	C	• "Intersection Ahead" warning signs • relocate private driveways to minor approach • provide acceleration lane
2	The safety impacts of improving the incidental section should be reviewed:		
2A	The overlay may reduce the effectiveness of an existing guardrail.	C	• Reinstall guardrail at an appropriate height.
2B	The shoulder width will drop from 8 feet to 2 feet for westbound traffic.		• Provide appropriate tapers at transition point. • Provide appropriate delineation.
2C	Westbound drivers may fail to follow the horizontal curve near the east end of the incidental section.		• Provide appropriate signs and delineation.
2D	The improved overlay surface may encourage higher prevailing speeds along the incidental section, which may be designed to an outdated standard.		• Confirm that existing design elements are consistent with likely speeds and current geometric standards. • Introduce edgeline and/or centerline rumble strips.
3	Potential roadside safety issues may be present during construction.	C	• Consider reduction in construction speed limit. • Flare or protect ends of temporary barrier. • Introduce temporary barrier near 2:1 slope.
4	A proposed guardrail ends at a private driveway.	B	• Wrap guardrail around driveway.

RSA NUMBER 3

OREGON DEPARTMENT OF TRANSPORTATION: RSA OF IMPROVEMENTS TO US 97 (MODOC POINT TO SHADY PINE ROAD)

Project: improvements to two-lane rural highway in a constrained area

Planned Improvements:

- cold plane removal and overlay of the existing surface
- widening of shoulders to 8 feet along some sections
- elimination or protection of clear zone safety issues
- new and upgraded barriers, guardrails, and end terminals
- minor realignment to improve sight distances and to move the highway away from some rock fall areas
- construction of retaining walls

Project Environment:	☐ urban	☐ suburban	☑ **rural**
Project Design Stage:	☑ **conceptual (0 to 30%)**	☐ preliminary (40 to 80%)	☐ advanced (over 80%)
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Oregon Department of Transportation		

Road Safety Audit

Date of RSA:	11-13 April 2006	
RSA Stage(s):	☑ **design stage**	☐ RSA of existing roads
RSA team:	staff from Federal Highway Administration (including Office of Safety, Resource Center, and Oregon Field Office), Oregon DOT, VHB, and Opus Hamilton Consultants	

PROJECT BACKGROUND:

The project, along US Highway 97 between Modoc Point and Algoma, was located in Klamath County in South Central Oregon. In this area, the US 97 alignment passes along the east side of Upper Klamath Lake and the Union Pacific Railroad (FIGURE A.4). The Oregon Department of Transportation (ODOT) identified several safety issues along this section of US 97, including a fatality rate of 5.3 per million vehicle miles, almost double the average rate for similar Oregon highways. The DOT noted the presence of narrow substandard shoulders widths, substandard cut and fill slopes, and unprotected safety issues within clear the zone, including barriers, guardrail, and guardrail end terminals that did not meet current standards.

FIGURE A.4 RSA SEGMENT OF US 97

To address these and other concerns, a two-phase road improvement program was adopted by ODOT. Phase One work, which began in early 2005 and was in progress at the time of the RSA, included replacement/repair of four bridges as well as rockfall work and widening on the east side of the highway. Phase Two work, which was to be let in September 2007 with a projected completion date of November 2009, was expected to take place on the west side of US 97, between the highway and the adjacent railroad tracks.

The improvement projects were subject to several conditions that imposed unique and substantial constraints on design and construction:

- Topography and slope stability were challenging constraints. Steep, unstable slopes were present on both sides of the highway (FIGURE A.4). The project limits included six rockfall sites, one of which would be affected by construction.
- To the west of the roadway, the Union Pacific Railroad imposed right-of-way constraints that affected road design. In addition, the railroad's rockfall warning system affected construction methods.
- Cultural sites associated with the area's Indian tribes affected slope stabilization efforts.
- The roadway, which was to remain open during construction, must accommodate mobility needs. ODOT required that the construction design maintain specified minimum lane widths and that average traffic delay not exceed six minutes. In addition, US 97 is a designated truck corridor, and was expected to accommodate additional truck traffic diverted from nearby construction works on Interstate Highway 5.

This RSA incorporated the use of the Interactive Highway Safety Design Model (IHSDM), a suite of software analysis tools[3] being developed by the FHWA to provide an explicit, quantitative evaluation of safety and operational effects of geometric design on two-lane rural highways. IHSDM was used to evaluate the elements of the existing and proposed design against design policy values, design consistency, and to predict the expected safety of the future road. IHSDM may be downloaded free of charge at *http://www.ihsdm.org.*

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.3.

[3] *IHSDM currently includes five evaluation modules: Crash Prediction Module (CPM), Design Consistency Module (DCM), Intersection Review Module (IRM), Policy Review Module (PRM), and Traffic Analysis Module (TAM).*

TABLE A.3 SUMMARY OF RSA SAFETY ISSUES AND SUGGESTIONS
OREGON DOT RSA

SAFETY ISSUE (Number and Description)		Risk Rating	Suggestions
1	*Roadside safety issues* included*:* • steep slopes and ditches within clear zone • unprotected utility poles • shoulder edge-drops.	D	▪ additional roadside barriers ▪ relocation or shielding of utility poles ▪ fillet to limit edge-drops
2	*Sight distance* was constrained by roadside topography, rockfall fences, and bridge superstructures at horizontal curves and at intersections.	C	▪ confirm stopping sight distance ▪ review of specified sight distance obstructions at intersections
3	*Limited night-time guidance* was provided on a curved alignment with hazardous side slopes. An enhanced level of delineation would be beneficial along this hazardous segment of roadway.	B	• enhanced post-mounted delineators • improved centerline and edgeline delineation
4	*Signing issues* included possible re-use of faded signs, missing intersection warning signs, and use of small lettering on street name signs.	B	▪ intersection warning signs ▪ advance street name signs and larger street name signs ▪ confirm retroreflectivity of reused signs
5	*Rockfall protection* formed an important part of the design requirements. The very challenging improvement site may be a candidate for the use of enhanced rockfall protection measures.	B	• enhanced rockfall protection measures if standard measures are ineffective or infeasible
6	*High speeds* contributed to increased collision risk and severity.	C	▪ use of IHSDM in speed enforcement ▪ variable speed limits
7	*Winter weather:* A high proportion of crashes occurred under winter road conditions.	C	▪ ice detection and warning system

KEY LESSONS LEARNED:

The Interactive Highway Safety Design Model (IHSDM) is a useful tool to quantify safety issues associated with the audited design.

This RSA used IHSDM to evaluate design consistency, compliance with selected design policy values, and to predict the expected safety of the future roadway. Specifically, the proposed alignment was analyzed using:

- *the IHSDM Policy Review Module (PRM)* to identify two locations where stopping sight distance did not appear to meet minimum sight distance requirements. It is important to note that an RSA is not simply a check that design standards have been met. Therefore, minimum policy checks using IHSDM were limited to sight distance policy checks. This enabled the RSA team to observe conditions in the field that IHSDM identified as having a sight distance issue.
- *the IHSDM Crash Prediction Module (CPM)* and five years of crash data (2000-2004) to identify the potential for a future increase in crash frequency at two intersections along the alignment;
- *the IHSDM Design Consistency Module (DCM)* to estimate free flow 85th percentile operating speeds between successive alignment elements, as a measure of design consistency. The results from the DCM suggested that, with the proposed improvements, the alignment of US 97 was reasonably consistent. The DCM found no locations requiring speed reductions greater than 6 mi/hr entering a curve, which was considered the upper limit for good consistency. There were however, two horizontal curves where the DCM module identified speed differentials approaching this limit, and the PRM module identified insufficient stopping sight distances. The RSA team flagged the locations where the combination of design-consistency and sight-distance issues was found for the Design Team's further consideration.

The ability to quantify values associated with design issues such as stopping sight distance, and to estimate future crash frequencies based on the road re-design, enhanced the value of the RSA by demonstrating the magnitude of the safety issues identified by the RSA team. Without IHSDM estimates, the RSA team could identify, but could not necessarily quantify, expected changes in safety parameters such as operating speeds or in expected crash frequencies. Quantifying these parameters and frequencies provided a higher level of confidence to all parties (the RSA team, Design Team, and Owner) concerning the magnitude and importance of the safety issues identified in the RSA.

See also the discussion of “Key Factors for Success” and “Lessons Learned” in the main text.

RSA NUMBER 4

WISCONSIN DEPARTMENT OF TRANSPORTATION: RSA OF IMPROVEMENTS TO MARQUETTE INTERCHANGE

Project: reconstruction of a major interstate interchange in Milwaukee, Wisconsin

Planned Improvements:
- replacement of three bridges over two creeks
- shoulder widening to provide a continuous 8-foot paved shoulder
- intersection improvements (one intersection)
- resurfacing of improved section as well as an adjacent 1.2-mile section

Project Environment:	☑ **urban**	☐ suburban	☐ rural
Project Design Stage:	☐ conceptual (0 to 30%)	☐ preliminary (40 to 80%)	☑ **advanced (over 80%)**
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Wisconsin Department of Transportation		

Road Safety Audit

Date of RSA:	1-3 February 2005	
RSA Stage(s):	☑ **design stage**	☐ RSA of existing roads
RSA team:	staff from Wisconsin DOT, Milwaukee County Sheriff's Office, Federal Highway Administration, and Opus Hamilton	

PROJECT BACKGROUND:

Highways I-94, I-794, and I-43 meet at the Marquette Interchange in Milwaukee. The interchange, considered the cornerstone of the southeastern Wisconsin freeway system, accommodates Milwaukee's commuter traffic, as well as interurban traffic traveling to and from Madison, Green Bay, and Chicago, and long-distance interstate traffic. Reconstruction of the existing interchange, which built in 1968, was required to address structural deterioration and operational concerns. At the time of the RSA in December 2003, planning and design for the reconstructed interchange had been ongoing for several years, and construction was to commence in about six months. The RSA examined both the proposed changes and construction-stage plans, since the interchange was required to remain operational throughout the four-year construction period. The existing and redesigned interchanges are shown in FIGURE A.5. The total cost of the interchange reconstruction was anticipated to be $800 million.

Existing Interchange

Improved Interchange (simulation)

FIGURE A.5 EXISTING INTERCHANGE AND PROPOSED IMPROVEMENTS

The planned reconstruction includes upgrades and improvements include:

- replacement of left-side ramps with conventional right-side ramps,
- lengthening or elimination of existing short weaving sections,
- increased curve radii on ramps,
- lane continuity and consistency for through traffic,
- increased capacity on system ramps,
- increased barrier height.

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.4. In their response, the design team accepted a number of suggestions that could be implemented at the late design stage for this RSA, but declined suggestions that would entail revisiting the public involvement, design, or environmental assessment processes. A number of suggestions were identified as already in the design plans (see discussion below on document control under “Lessons Learned”). Where signing could be retroactively deployed to correct a safety issue (Issue 2), the design team suggested monitoring operations after improvements were completed to confirm whether the safety issue would actually occur before implementing suggested signing changes.

TABLE A.4 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS WISCONSIN DOT RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	Plankinton Exit Ramp and Clybourn Street Entry Ramp: Mainline drivers may attempt an abrupt, unsafe lane change to access these ramps.	D	• Extend a proposed concrete barrier to block unsafe movements.
2	Westbound I-94: Traffic from two high-volume system ramps meets the east-west mainline approximately about 1,700 feet upstream of Exit 309B, resulting in a limited weave distance.	E	• Provide advanced signing for Exit 309B to reduce the need for sudden lane changes. • Block access to Exit 309B from westbound I-94.
3A	Wisconsin Avenue at 11th Street: Dual turning lanes leading to different destinations may cause driver confusion and erratic movements.	C	• Improve signing and pavement marking. • Consider geometric changes (possibly as a future retrofit).
3B	Highland Street: During peak periods, left-turn queues may extend into or past adjacent closely-spaced intersections on Highland Street.	D	• Conduct microsimulation modeling. • Signalize / coordinate ramp intersection. • Restrict some left-turn movements.
3C	Highland Street at 12th: Long crossing distances, diagonal curb ramps, and a partial crosswalk obstruction may increase the pedestrian collision risk.	D	• Review / improve accommodation of pedestrians.
4	Barrier Heights at Ramps: The proposed barrier height of 42 inches on system-to-system ramps may not be sufficient to prevent truck roll-over collisions.	C	• Consider higher barriers where needed and where feasible.
5	Signing: Some proposed signing may not provide sufficient guidance, especially to unfamiliar drivers.	B	• Clarify “Downtown” signing. • Clarify cardinal directions. • Add advance signing at noted locations. • Add ramp advisory speed limit signs.
6A	Distractions During Construction: Roadside construction activities may distract or startle drivers,	C	• Consider “gawk screens” to block drivers’ view of construction activities.
6B	Construction Phase Traffic Management: Construction-phase routing may entail some risk for drivers.	D	• Conduct microsimulation analysis, and consider specified road closures or turning restrictions to reduce traffic load on unsuitable local streets.

KEY LESSONS LEARNED:

RSAs conducted late in the design process require a selective focus to be effective. The Marquette Interchange RSA was conducted at an advanced stage in the interchange design, after the completion of the public involvement process, and was consequently limited in the range of items and suggested alternatives that could usefully and practically be identified and implemented. Fundamental design elements had to be taken as "given", since changes to them were impractical at the advanced stage that the RSA was conducted. Consequently, the RSA team focused on elements of the design that could be amended or mitigated at the detailed design stage.

Time constraints require that the RSA team direct its efforts and use its time efficiently. As is typical for design-stage RSAs, this RSA was on the critical path in the Interchange design schedule. The RSA team had less than five days to review a comprehensive interchange design that had been many years in the making. The RSA was therefore limited in its level of detail. Consequently, the RSA team split into two- or three-person teams to cover the interchange elements as comprehensively as possible. The RSA team presented its preliminary findings to the Owner and Design Team after the RSA analysis session, and followed up with the RSA report. The design team issued a timely response to the RSA, outlining what actions had or would be taken. The entire RSA process was completed within three months.

Document control is an important element of the RSA process to ensure that the RSA is based on the most recent design drawings. As with all very large design projects, the Marquette Interchange design generated a vast number of drawings and other documents. The RSA team based its review on drawings which, in some cases, had been superseded at the time of the RSA. The inadvertent inclusion of superseded drawings in the RSA materials reflected the large volume of design documentation on this very large project that was in its final design stages, and the resulting document control issues.

Specialists contribute valuable insight on the RSA team. Members of the eight-person RSA team had a general knowledge of road safety, geometric design, and traffic operations, but several members also had specialized knowledge in various areas. The RSA team included an officer from the Milwaukee County Sheriff's Office who had extensive experience as a patrol officer on the existing interchange. The insights offered by the officer regarding driver behavior helped the design team to realistically assess the risk associated with design elements and the effectiveness of suggested improvements.

The success of the RSA was promoted by early management of expectations, and by a cooperative approach on the part of all participants. At the start of the RSA, the RSA team explained to the Design Team and Owner what could feasibly be audited within the constraints of the time available and the advanced design stage. At the same time, the Design Team outlined its constraints in terms of the trade-offs that were a necessary part of the design process. This exchange promoted an understanding on the part of all participants concerning what could feasibly be achieved in the RSA. Prior to the start of the RSA, the Design Team responded to the RSA team's request to identify design issues that they felt the RSA team could assist with. The Design Team identified twelve issues, such as complex intersection channelization and the need to obstruct improper or prohibited vehicle movements (such as wrong-way movements onto exit ramps). The RSA was conducted in the Design Team office, and the Design Team made available a senior designer to answer the RSA team's questions and clarify issues. This continual liaison enabled the RSA to be completed in the limited time available.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

RSA NUMBER 5

CLARK COUNTY (WASHINGTON): RSA OF IMPROVEMENTS TO UPPER WARD ROAD

Project: road alignment and intersection improvements to two-lane rural road

Planned Improvements:	• realignment of horizontal curves • reconfiguration of four intersections, including traffic control changes		
Project Environment:	☐ urban	☑ **suburban**	☑ **rural**
Project Design Stage:	☐ conceptual (0 to 30%)	☐ preliminary (40 to 80%)	☑ **advanced (over 80%)**
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Clark County, Washington		

Road Safety Audit

Date of RSA:	10-12 May 2005	
RSA Stage(s):	☑ **design stage**	☐ RSA of existing roads
RSA team:	staff from Clark County and Opus Hamilton	

PROJECT BACKGROUND:

The improvements to Ward Road, a two-lane rural roadway, were initially motivated by safety concerns resulting from high-severity off-road collisions. Subsequently, the county's Growth Management Act (1995) resulted in anticipated changes to the road network and hierarchy in the vicinity of the planned improvements, which resulted in the introduction of additional elements to the upgrades. The road improvements were the subject of considerable public interest and input, which have also influenced their design.

The planned improvements affected three roads: Ward Road (also known as 182nd Avenue), 172nd Avenue, and 119th Street, shown in FIGURE A.6. In addition to functioning as major rural collectors, these roads provided access to adjacent properties (residential and farm) and a small farming town. Improvements, numbered and shown in FIGURE A.7, included:

1) realignment of Ward Road between 172nd Avenue and Davis Road (involving abandonment of an existing road section on structure), and introduction of a new four-way signalized intersection;

2 and 3) intersection improvements at the STOP-controlled intersections of 119th Street / 172nd Avenue and 119th Street / 182nd Avenue, including the introduction of a free right turn lane on one approach;

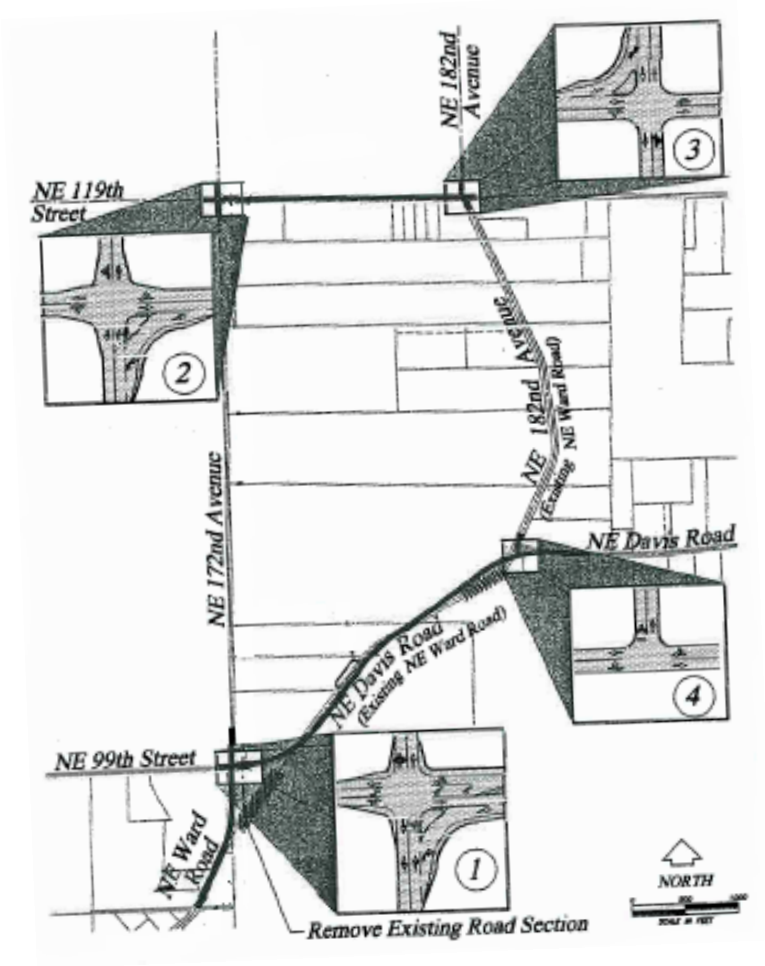
4) reconfiguration of the existing Ward Road / Davis Road intersection, and relocating the STOP sign from Davis Road to 182nd Street.

Ward Road near Davis Road

172nd Avenue near Ward Road

182nd Avenue at 119th Street

FIGURE A.6 VIEWS OF RSA SITE (CLARK COUNTY RSA)



SOURCE: Wallis Engineering

FIGURE A.7 RSA PROJECT (CLARK COUNTY RSA)

At the time of the RSA, the improvements were in the county's current Transportation Improvement Program, and were in the final design stage. Overall construction costs were estimated at about $9 million, including land acquisition costs.

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.5.

TABLE A.5 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS CLARK COUNTY RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*New Conflict Points:* Traffic on Ward Road will be directed through reconfigured intersections where new traffic control devices and required turn maneuvers will generate an increased potential for rear-end, turning, and merging conflicts.	C	• Provide turning lanes. • Revise turning radius at free right turns to better accommodate pedestrian safety. • Install YIELD control at free right turns. • Review safety of right-turn-on-red. • Provide delineation in merge areas. • Review pedestrian and bicycle requirements.
2	*Free Right Turn Lanes:* Driver workload may be high at free right turn lanes.	B	• Confirm that guardrail does not restrict sight distances. • Revise turning radius to better accommodate pedestrian safety. • Install YIELD control. • Review safety of right-on-red. • Provide delineation in merge area.
3	*Limited Clear Zones:* Limited clear zones increase the risk and potential severity of collisions when drivers leave the travel lanes.	C	• Remove fixed objects within the clear zone. • Provide barriers at marginally critical slopes if the slope steepness cannot be reduced.
4	*Limited Sight Distances:* Limited sight distance may increase the risk of collision when drivers fail to observe potentially hazardous conditions ahead.	C	• Review alignment where a crest vertical curve restricts drivers' view of conditions ahead. If alignment cannot be altered, provide warning signs and delineation. • Confirm that guardrail does not restrict sight distances at free right turn lanes.
5	*Signing and Pavement Markings:* Proposed signing and pavement markings may not be adequate.	--	Improve signing and pavement markings for: • dedicated turn lanes • unexpected conditions where horizontal and vertical curves limit sightlines • right turn channelizing island at 182nd Avenue and 119th Street.
6	*Future Conditions on 172nd Avenue:* Proposed new land use may increase vehicle, pedestrian, and bicycle traffic on the improved roads.	B	• Review pedestrian and bicycle requirements. • Prohibit street parking near proposed park.

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
7	Opportunities for Interim Improvements	--	• Introduce left turn lane at existing intersection of Ward Road/172nd Avenue. • Paint stop bar at existing intersection of Ward Rd/172nd Ave. • Remove vegetation to improve sight triangle if proposed change to 2-way STOP control at 119th St. and 182nd Ave is implemented.

KEY LESSONS LEARNED:

Even at a final design stage, the RSA team may need to identify significant safety issues associated with fundamental design elements. Discussions with County staff indicated that, although improvements to Ward Road were initially proposed primarily to address high-severity off-road collisions, additional issues arose during the lengthy public consultation process concerning the level of traffic considered by different community groups to be suitable on the improved roads. To reconcile the competing desires of these groups, and to provide a forum for the groups to contribute beyond the public consultation stage to the actual design, a Community Design Team (CDT) was established that included representatives of the adjacent communities. The design that was adopted to meet the requirements of the CDT appeared to have expanded beyond the initial safety-related aim of reducing collisions, to include two additional (and potentially competing) aims of controlling traffic speeds by increasing the number of controlled intersections through which traffic would pass, and achieving a redistribution of traffic that the CDT deemed equitable. Although the County's efforts to include the public in the design process were in many ways laudable, the resulting reconfiguration of intersections and introduction of new traffic control devices were expected to compromise traffic safety by introducing additional conflict points (see Issues 1 and 2 in TABLE A.5). The RSA team felt it necessary to point out that that net result of directing formerly free-flowing traffic through controlled intersections was expected to be decreased severity, but increased frequency, of collisions compared with existing conditions. As a result of the RSA, County engineering staff started a re-examination of major elements of the project, which they expected would lead to a safer project at considerably less expense.

RSAs can contribute to achieving pre-existing roadway safety goals. This FHWA-sponsored RSA contributed to the achievement of the Washington Traffic Safety Commission's *Target Zero: A Strategic Plan for Highway Safety 2000*, a statewide traffic safety plan supporting the achievement of a transportation system without deaths or disabling injuries. Specifically, one of the *Target Zero* emphasis areas was the road environment. Strategies in this area that the RSA supported included improving signing and delineation, and training county traffic engineers and planners to identify traffic safety problems and develop solutions. As a pilot implementation of a potential state-wide program of RSAs, it may also have helped to promote the *Target Zero* strategy to develop programs and partnerships to implement safety projects for local roadways.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

RSA NUMBER 6

COLLIER COUNTY (FLORIDA): RSA OF IMPROVEMENTS TO IMMOKALEE ROAD

Project: widening of four-lane arterial road

Planned Improvement:	widening of arterial roadway from four lanes to six lanes		
Project Environment:	☐ urban	☑ **suburban**	☐ rural
Project Design Stage:	☑ **conceptual (0 to 30%)**	☐ preliminary (40 to 80%)	☐ advanced (over 80%)
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	Collier County, Florida		

Road Safety Audit

Date of RSA:	15-19 November 2004	
RSA Stage(s):	☑ **design stage**	☐ RSA of existing roads
RSA team:	staff from Collier County, Federal Highway Administration Resource Center, VHB, and Opus Hamilton	

PROJECT BACKGROUND:

Immokalee Road, a County road, is a major east/west arterial connecting residential areas in western Collier County with I-75, US Highway 41, and the City of Naples. The RSA section of the roadway, shown in FIGURE A.8, was widened from two lanes to four lanes in 2002. The four-lane cross-section, shown in FIGURE A.9, was a divided arterial roadway with two through lanes in each direction, a grass median (up to about 40 feet wide), and turning lanes at signalized intersections. The corridor was adjacent to low-density residential, commercial, and institutional land uses, including the North Naples Fire Station No. 42, Gulf Coast High School, Laurel Oaks Elementary School, and several churches.

To accommodate current and forecast future demand, the County was considering additional widening to six lanes. The proposed upgrade would entail widening the road to a six-lane divided urban arterial standard. 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.

Signalized intersections shown.

FIGURE A.8 RSA SEGMENT (COLLIER COUNTY RSA)

Immokalee Road near Valewood Drive

Immokalee Road in front of schools

FIGURE A.9 VIEWS OF RSA SITE (COLLIER COUNTY RSA)

KEY RSA FINDINGS AND SUGGESTIONS:

The RSA findings were divided into two parts:

- *issues arising from the proposed upgrade (TABLE A.6):* 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.

- *further opportunities for improvement (TABLE A.7):* Additional opportunities for improvements that could be incorporated in the upgrading works 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.

TABLE A.6 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS COLLIER COUNTY RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*accesses off arterial road:* Movements at driveways and local road intersections interfere with traffic on Immokalee Road, an arterial road.	D	• 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.
2	*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.	C	• 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.
3	*pedestrian facilities:* Pedestrians need to be safely accommodated on the upgraded roadway.	C	• Provide a continuous and convenient pedestrian network. • Provide pedestrian countdown signal heads. • Reduce return radii at intersections and driveways.
4	*cycling facilities:* Cyclists need to be safely accommodated on the upgraded roadway.	C	• Replace 4-foot bike lanes with wider paved shoulder. • Provide sufficient bike lane width at intersections.
5	*barriers with curb:* The design of roadside barriers must accommodate the proposed barrier curb.	C	• Consider anticipated speeds when designing barrier system.
6	*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.

TABLE A.7 SUMMARY OF OPPORTUNITIES FOR IMPROVEMENT: COLLIER COUNTY RSA

SAFETY ISSUE (Number and Description)		SUGGESTIONS
1	*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.
2	*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.
3	*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.
4	*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.

KEY LESSONS LEARNED:

In very early-stage design RSAs, a wider scope for safety enhancements exists. 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 consider not only issues related specifically to the proposed widening from four to six lanes (TABLE A.6), but could also suggest additional opportunities, not necessarily related to the specified widening, to enhance road safety (TABLE A.7). Of particular significance was the opportunity to include in the roadway upgrades several measures to accommodate older drivers, which will help to County to implement elements of the Florida DOT's "Elder Road User Program" on County roads.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

RSA NUMBER 7

CITY OF CINCINNATI (OHIO): RSA OF IMPROVEMENTS TO THE SPRING GROVE AVENUE CORRIDOR

Project: improvements to commuter arterial, including bridge widening and intersection improvements

Planned Improvements:	• intersection improvements • road and bridge widening • traffic signal improvements		
Project Environment:	☑ **urban**	☐ suburban	☐ rural
Project Design Stage:	☑ **conceptual (0 to 30%)**	☐ preliminary (40 to 80%)	☐ advanced (over 80%)
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	City of Cincinnati		

Road Safety Audit

Date of RSA:	14-16 December 2004	
RSA Stage(s):	☑ **design stage**	☑ **RSA of existing roads**
RSA team:	staff from Federal Highway Administration, City of Cincinnati, VHB, and Opus Hamilton	

PROJECT BACKGROUND:

The City of Cincinnati was considering improvements along the Spring Grove Avenue corridor between Winton Road and Clifton Avenue (FIGURES A.10 and A.11). Spring Grove Avenue and Winton Road are major commuter arterials connecting areas to the north, east, and west to I-75. Clifton Avenue is a two-lane major/minor arterial street connecting Spring Grove Road to the Clifton area to the south, and providing access to commercial developments constructed in the past five years on Kenard Avenue, a collector road.

The corridor had recently experienced a high number of crashes, putting the intersection of Spring Grove Avenue and Winton Road at the top of the City's High Accident Location list, and resulting in an above-average collision rate at the intersection of Spring Grove Avenue and Clifton Avenue. In addition, traffic near the intersection of Clifton Avenue and Kenard Avenue had increased to a point where widening Clifton Avenue at the intersection (which would involve bridge widening south of the intersection) was being considered.

This planning-stage RSA reviewed several upgrades, including:

- Clifton Avenue bridge widening to accommodate four 10-foot lanes and a 10-foot painted median strip,
- traffic signal improvements at the intersection of Spring Grove Avenue and West Mitchell Avenue,

- other possible improvements to Spring Grove Avenue in connection with the planned upgrade.

FIGURE A.10 RSA SITE (CITY OF CINCINNATI)

Spring Grove Avenue

intersection of Winton Road and Spring Grove Avenue

FIGURE A.11 VIEWS OF RSA SITE (CINCINNATI RSA)

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.8.

TABLE A.8 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS CINCINNATI RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*traffic signal infrastructure:* Signal displays should be visible and conspicuous at all times.	D	• Align traffic signal heads with approach lanes. • Use redundant signal displays. • Upgrade all signal lenses to 12”. • Provide advance warning signs for signals that follow horizontal curves. • Use backplates with reflective border.
2	*turn-movement operations and geometry:* Conflicting turning movements and complex geometry increase the risk of collisions at intersections.	D	• Review the need for dual turns. • Review concurrent dual turns. • Review the practice of providing protected turn phasing in shared-use lanes. • Investigate opportunities for increasing turn radii.
3	*driveways and access management:* Movements at driveways interfere with traffic on arterial roads and intersections, creating potentially hazardous conflicts.	C	• Investigate opportunities to close and consolidate some driveways. • Consider eliminating left turns into and out of driveways. • Include driveway on the west leg of Clifton Avenue / Kenard Avenue in the intersection signalization.
4	*road cross section:* The cross section of Spring Grove Avenue includes apparent inconsistencies.	B	• Design the new cross-section with uniform lane widths.
5	*pedestrian facilities:* Pedestrian facilities need upgrading and maintenance.	C	• Provide consistent levels of lighting and upgrade lighting at crosswalks. • Review warrant for upgrading crosswalk makings near Station Avenue. • Improve sidewalk conditions.

KEY LESSONS LEARNED:

The RSA field review should be scheduled to coincide with important site conditions. This RSA was conducted in late December, after classes at a nearby university had ended. The RSA team was consequently unable to observe the impact of university traffic at the site. Although this did not significantly affect the RSA findings, scheduling the field review to observe typical or usual traffic conditions is preferable, since it allows the RSA team to see how regularly-recurring traffic conditions and road user behavior may affect safety.

See also the discussion of “Key Factors for Success” and “Lessons Learned” in the main text.

RSA NUMBER 8

CITY OF TUCSON (ARIZONA): RSA OF PEDESTRIAN CROSSING IMPROVEMENTS

Project: installation of six new HAWK signalized pedestrian crossings

Planned Improvement:	installation of HAWK signals at six existing pedestrian crosswalks		
Project Environment:	☑ **urban**	☑ **suburban**	☐ rural
Project Design Stage:	☐ conceptual (0 to 30%)	☐ preliminary (40 - 80%)	☑ **advanced (over 80%)**
Project Cost:	☑ **< $100,000 per crossing**	☐ $100,000 - $1,000,000	☐ >$1,000,000
Project Owner:	City of Tucson		

Road Safety Audit

Date of RSA:	26 - 28 October 2004	
RSA Stage(s):	☑ **design stage**	☐ **RSA of existing roads**
RSA team:	staff from Federal Highway Administration Resource Center, Arizona DOT, and Opus Hamilton	

PROJECT BACKGROUND:

HAWK (**H**igh-Intensity **A**ctivated Cross**W**al**K**) signals are a type of traffic control beacon for marked pedestrian crosswalks, developed by the City of Tucson and implemented in Tucson and elsewhere in Arizona. The City of Tucson received approval from FHWA to experiment with this device; it is not yet adopted in the *Manual of Uniform Traffic Control Devices.* The innovative HAWK signal, shown in FIGURE A.12, incorporates elements from fire station signals and school bus flashing displays, as well as from European pedestrian signal displays, to provide a familiar signal sequence for drivers and pedestrians. The HAWK signal is activated by a pedestrian

Source: *City of Tucson*

FIGURE A.12 HAWK PEDESTRIAN SIGNAL

pushbutton. The activated signal progresses from a dark display through flashing amber, solid amber, solid red, and flashing red, ending with a dark display. Drivers are required to stop during the solid red display, and may proceed with caution during the flashing red display. Pedestrians are controlled using traditional pedestrian signal displays and, at the sites audited under this contract, countdown timers.

At the time of the RSA, about 40 HAWK signals were operating in Tucson, and the City was expanding its HAWK installation program. In 2003, the City's Mayor and Council allocated increased funding to install HAWK signals at six additional locations throughout the City.[4] The six sites selected for HAWK implementation were chosen on the basis of pedestrian and bicycle collision frequency from 1999 through 2002. The six sites, listed in TABLE A.9, were the focus of this RSA.

TABLE A.9 TUCSON RSA SITES

MAJOR ROAD	MINOR ROAD	2004 MAJOR ROAD AADT*
Flowing Wells Road	Pastime Road	24,900
First Avenue	Graybill Drive	39,000
Broadway Boulevard	Cherry Avenue	26,700
Fort Lowell Road	Park Avenue	21,800
Speedway Boulevard	Rook Avenue	47,600
Grant Road	Palo Verde Boulevard	62,300

** Annual Average Daily Traffic volumes reported by the Pima Association of Governments*

At the time of the RSA, the contract for construction had been awarded, and the underground portion of construction was underway or had been completed at many of the sites. Final design drawings for the signal hardware were complete. This RSA of locations where an experimental pedestrian signal system was being implemented provided an opportunity to conduct an RSA with a focus on pedestrian needs.

KEY RSA FINDINGS AND SUGGESTIONS:

The RSA findings were divided into two categories:

- general HAWK system issues and suggestions (Issues 1 and 2),
- site-specific issues and suggestions (Issues 3 to 6).

Observations regarding the general HAWK system (Issues 1 and 2) include suggestions that are intended to enhance the HAWK system with a view to national adoption as a useful and effective traffic control device with an intermediate level of control between a traditional flashing amber beacon and a full signal.

[4] Additional funding for further HAWK signals was approved by the City during the RSA.

In its response, the City undertook to consider the RSA team's suggestions and to monitor a number of locations at which safety issues had been identified. For this late-stage RSA, suggestions were declined where they would entail substantial changes to completed works, such as changes to signal equipment or completed electrical works.

TABLE A.10 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS TUCSON RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*use of flashing red signal indication:* Drivers legally entering the crosswalk on a flashing (alternating or "wig-wag") red signal may conflict with pedestrians clearing the crosswalk near the end of the pedestrian clearance phase.	B	• Eliminate the flashing red interval. • Introduce a split pedestrian phase.
2	*duration of pedestrian clearance interval:* The pedestrian clearance interval may be short, particularly for elderly pedestrians.	B	• Reduce assumed walking speed used to calculate clearance interval.
3	*interference from adjacent side streets and driveways:* Drivers turning into the arterial road from adjacent side streets and driveways may interfere with pedestrians in the HAWK crossing.	B	• Enhance signing.
4	*obstructed sightlines:* Sightlines between pedestrians entering the HAWK crossings and approaching drivers may be obstructed.	B	• Post "No Parking" signs on selected approaches. • Relocate near-side bus stops. • Relocate HAWK crossing at one site.
5	*pedestrian desire lines:* Pedestrians may not use HAWK crossings that are located away from apparent pedestrian desire lines.	B	• Observe desire lines before determining HAWK location. • Enhance pedestrian signing.
6	*night-time visibility at Speedway Blvd / Rook Ave:* Drivers may be confused by competing background visual elements at night.	B	• Install reflective border around HAWK signal.

KEY LESSONS LEARNED:

The RSA process can enhance the implementation of innovative road safety measures with the aim of promoting their success. This RSA focused on pedestrian crossing locations where the HAWK device was to be installed. One of the outcomes of the RSA has been a set of suggestions to enhance the HAWK system with a view to its wider (statewide or nationwide) application. In this way, the RSA may have been beneficial as a means of reviewing the HAWK signal in a working environment, identifying possible factors that may compromise its successful implementation elsewhere, and suggesting measures to address them.

See also the discussion of “Key Factors for Success” and “Lessons Learned” in the main text.

RSA NUMBER 9

STANDING ROCK SIOUX TRIBE (NORTH AND SOUTH DAKOTA): RSA OF RESERVATION ROADS

Roads: existing two-lane rural tribal roads

RSA Sites:	• paved and gravel roadways (including secondary highways under State jurisdiction) in rural and low-density urban environments • one small bridge
Environment:	☑ **urban** ☐ suburban ☑ **rural**
Owners:	Standing Rock Sioux Tribe, Bureau of Indian Affairs, North Dakota DOT, South Dakota DOT

Road Safety Audit

Date of RSA:	22-24 May 2005
RSA Stage(s):	☐ design stage ☑ **RSA of existing roads**
RSA team:	staff from the Standing Rock Sioux Tribe, Federal Highway Administration (North Dakota and South Dakota Field Offices), North Dakota DOT, South Dakota DOT, Bureau of Indian Affairs, North Dakota State University, Northern Plains TTAP, and Opus Hamilton

PROJECT BACKGROUND:

The Standing Rock Sioux Tribe (SRST) reservation in North and South Dakota extends over 2.3 million acres, with an extensive rural road network of BIA roads (about 200 miles) and county and state roads (about 1,100 miles). The reservation roads connect the reservation's communities to each other and to the tribal administrative center in Fort Yates, ND. They also serve through traffic, and provide access to the Tribe's two casinos on Highway 24 near Fort Yates, ND (Prairie Knights Casino) and Highway 12 near Mobridge, SD (Grand River Casino).

At the time of the RSA, the Standing Rock Sioux Tribe was actively pursuing improvements to transportation infrastructure on the reservation. Under the SRST Transportation Department, the Tribe had embarked on a long-range program to upgrade community transportation facilities, including streets, sidewalks, street lighting, and storm sewers. The financing for this long-range program, which was expected to cost $26.5 million, involved the innovative use of government, tribal, and borrowed funds.

In addition to planning and implementing these improvements, the Tribe maintained its extensive road network using its own funds as well as funding from sources such as the BIA. Maintenance of tribal roads was a sensitive topic, since funding for maintenance involved an extensive government allocation effort that limited the amounts available to reservations. At the same time, road maintenance was viewed as an important responsibility that directly affected tribal efforts to build a

cohesive reservation community and promote economic activity. Maintenance of the roads on the SRST reservation was a challenge due to their extent (connecting a population of about 9,000 spread over 850,000 acres) and the impacts of the Northern Plains environment (winter road conditions, frost damage, and variations in the underlying water table). Although the SRST reported that it fully utilized available government funds and its own funds, the RSA team observed multiple maintenance-related issues on reservation roads, which are summarized as Issue 1 in TABLE A.11.

Roads studied during this RSA included ND 24 and Highway 1806 (part of BIA 3), US 12, and community access roads. Typical reservation roadways are shown in FIGURE A.13. The RSA team drove these roads to identify safety issues associated with road geometry, traffic operations, and maintenance. Although bridge inspection is not a usual part of the RSA process, the RSA team was asked to observe possible maintenance issues associated with a bridge on BIA 3 at Four-Mile Creek. RSA findings associated with the bridge were included in the RSA report.

BIA3 at intersection with ND24 south of Fort Yates, ND

BIA 3 / Hwy 1806 in Kenel, SD

US 12 at Grand River Casino (left), near Mobridge, SD

BIA 44 west of Mahto, SD

FIGURE A.13 VIEWS OF RSA SITES (STANDING ROCK SIOUX TRIBE RSA)

KEY RSA FINDINGS AND SUGGESTIONS:

The key findings and suggestions of the RSA are summarized in TABLE A.11.

TABLE A.11 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS STANDING ROCK SIOUX TRIBE RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
1	*Road Maintenance:* Limited maintenance on reservation roads contributes to poor pavement conditions and concern regarding bridge stability.	B to D	• control cracking with sawcut and fill • accommodate future overlays • bridge inspection and repair
2	*Access to Grand River Casino:* Drivers turning into and out of the Grand River Casino may interfere with crossing, opposing, and following traffic on US12.	D	• speed reduction • improved signing • westbound left turn bay • access relocation
3	*BIA 31 and ND 24 (School Frontage):* Driver workload is potentially high near the intersection of BIA 31 and ND 24, which accommodates local, school, and through traffic.	B to D	• no-passing zone • crosswalk maintenance • enhanced signing • turning lanes on ND24 • improved lighting • access consolidation • urban cross section
4	*BIA 3 and Highway 1806 (Kenel):* Vehicle and pedestrian traffic may interfere with through traffic on BIA 3 through Kenel.	B to D	• marked crosswalk • regrading • urban cross section • relocation of grocery store
5	*Hwy 1806 and US 12 (Jed's Landing):* Driver workload is potentially high at the intersection, which accommodates high turning volumes and high speeds.	C	• speed reduction • review of turning lanes
6	*BIA 3 and ND 24:* Left-turning vehicles may obstruct through vehicles at highway intersection on a horizontal curve.	A	• left turn bay

KEY LESSONS LEARNED:

The RSA team effectively combined disciplines, and included experts with relevant specialist knowledge. The core disciplines that must be represented on any RSA team are traffic operations, geometric design, and road safety. Beyond these core requirements, the Standing Rock RSA team included members with a range of backgrounds and specialties, including State DOT members, a member with specialist knowledge of pavement maintenance issues, and members familiar with issues associated with tribal policies, practices, and conditions. This combination of backgrounds and skills contributed to the Team's understanding of the issues and constraints unique to this RSA.

See also the discussion of "Key Factors for Success" and "Lessons Learned" in the main text.

RSA NUMBER 10

YELLOWSTONE NATIONAL PARK: RSA OF IMPROVEMENTS TO OLD FAITHFUL AREA

Project: replacement of existing interchange with new access

Planned Improvements:	• replacement of existing "interstate-style" interchange with at-grade access • revisions to existing parking facilities and circulation		
Project Environment:	☐ urban	☐ suburban	☑ **rural**
Project Design Stage:	☑ **conceptual (0 to 30%)**	☐ preliminary (40 to 80%)	☐ advanced (over 80%)
Project Cost:	☐ < $100,000	☐ $100,000 - $1,000,000	☑ **>$1,000,000**
Project Owner:	National Park Service		

Road Safety Audit

Date of RSA:	31 May to 2 June 2005	
RSA Stage(s):	☑ **design stage**	☑ **RSA of existing roads**
RSA team:	staff from Federal Highway Administration Resource Center, Federal Highway Administration Federal Lands, and Opus Hamilton	

PROJECT BACKGROUND:

Yellowstone National Park, the world's first national park and a designated World Heritage Site, accommodates about 3 million visitors every year. The Old Faithful area (FIGURES A.14 and A.15) is a popular destination within the Park, attracting about 85 percent of all Park visitors. Peak visitor months are July and August, when the Old Faithful road network accommodates an average daily traffic volume of about 6,000 vehicles.

At the time of the RSA, two planning-level concepts (FIGURE A.16) had been developed to replace the existing Old Faithful interchange, which provided the only public access to Old Faithful Road from the Grand Loop Road:

- new east and west entry/exit points using two two-lane roundabouts that provide access to and from Grand Loop Road and Old Faithful Road ("Concept 2B"),
- a one-way circulation scheme connecting the Grand Loop Road and Old Faithful Road with ramps ("Concept 8/8A").

These two concepts were reviewed as part of the RSA. At the time of the RSA, these and other alternative concepts were still under development, and were subject to substantial changes pending completion of resource surveys and other data collection efforts.

FIGURE A.14 RSA SITE (YELLOWSTONE NATIONAL PARK)

Old Faithful Road

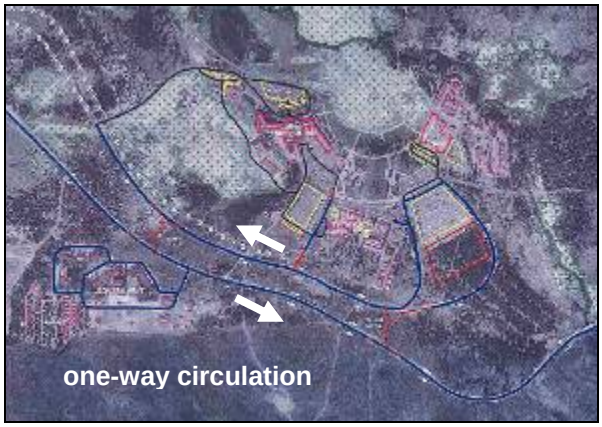
part of main parking area near Old Faithful geyser

FIGURE A.15 VIEWS OF RSA SITE (YELLOWSTONE NATIONAL PARK)

KEY RSA FINDINGS AND SUGGESTIONS:

Since construction of the interchange replacement was expected to start no sooner than 2009, about four years after the RSA, the RSA also included a review of existing roads to identify low-cost countermeasures that could be implemented on an interim basis before the start of the planned improvements. The focus of the RSA was the existing Old Faithful Road between the Old Faithful interchange and the geyser site, including the geyser parking area, as shown in FIGURES A.14 and A.15. The key findings and suggestions of the RSA are summarized in TABLE A.12. In its response, the owner undertook to consider the RSA team's observations in the final choice of design options for access to the Old Faithful area, and to incorporate the RSA team's interim suggestions for pedestrian safety into planned improvements to the Old Faithful area.

Option 2B



Option 8A

FIGURE A.16 PROPOSED IMPROVEMENTS TO OLD FAITHFUL AREA

TABLE A.12 SUMMARY OF SELECTED SAFETY ISSUES AND SUGGESTIONS YELLOWSTONE NATIONAL PARK RSA

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
RSA of Conceptual Plans			
1	*Issues Associated with Concept 2B:* • driver unfamiliarity • two-lane roundabouts • mixing through and Old Faithful traffic streams • traffic volume spikes • large vehicles in roundabouts • possible limited sight distance • downhill approach • pedestrians and cyclists in roundabouts	B	▪ signing ▪ conservative design speed and design volume ▪ single-lane roundabouts with right-side bypass lane ▪ appropriate design vehicle ▪ control of roadside vegetation ▪ anti-skid pavement
2	*Issues Associated with Concept 8/8A:* • short weaving segments • mixing through and Old Faithful traffic streams • traffic volume spikes • possible limited sight distance • downhill approach	C	▪ grade-separated ramps ▪ conservative design volume ▪ control of roadside vegetation ▪ signing ▪ anti-skid pavement

SELECTED SAFETY ISSUE (Number and Description)		RISK RATING	SUGGESTIONS
RSA of Existing Roads			
3	*Pedestrian Conflicts:* • in parking area • at crosswalk on Grand Loop Road	D	*Parking Area:* • curb extensions • parking restrictions • curb ramps • raised crosswalks • conversion of roadway to pedestrian zone *Grand Loop Road:* • raised median • lighting
4	*Conflicts in Old Faithful Loop Parking Area*	B	▪ restrictions on large vehicle parking ▪ removal of front-in angle parking stalls
5	*Signing and Wayfinding:* • driver guidance • pedestrian guidance	C	*Vehicle Signing:* • formal review of signing *Pedestrian Signing:* • signing for geyser viewing area and parking sub-areas
6	*Old Faithful Interchange*	D	*Interim measures:* ▪ roadside barriers ▪ crash attenuators ▪ improved signing and pavement markings *Ultimate measure:* ▪ replacement of existing interchange (as planned)

KEY LESSONS LEARNED:

The RSA team and process may need to accommodate very specific demands and conditions. The Old Faithful area represented a challenging environment in which to plan and implement road improvements. Any proposed improvements were subject to environmental and historical constraints, including fragile hydrothermal features and a desire to stay within existing roadway footprints. At the same time, demands on the transportation infrastructure were considerable. The roadways had to accommodate high concentrations of visitors, which often mixed with wildlife using the roadway corridors. About 90 percent of Old Faithful vehicle traffic was composed of Park visitors, with the result that a large proportion of drivers were unfamiliar with the road network, and potentially were elderly retirees or were distracted by navigation demands. Traffic volumes varied widely, reflecting large seasonal variations and, on Old Faithful Road, substantial outbound peaks associated with a mass exodus following geyser eruptions. Similarly, within the Old Faithful visitor and parking area, conflicting pedestrian and vehicle traffic both peaked following the regular geyser eruptions. These factors, which were unique to the Park roadway environment, resulted in specific demands and constraints, particularly regarding suggested mitigation measures.

See also the discussion of “Key Factors for Success” and “Lessons Learned” in the main text.