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Incorporating Safety Performance into Project Design

Arizona Department of Transportation Research Center

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Prepared by:
Elizabeth Wemple, P.E. and Robert Hull, P.E.
Cambridge Systematics, Inc.
555 12th Street, Suite 1600
Oakland, CA 94607

Jim Schoen, P.E.
Kittelson & Associates, Inc.
2 E Congress St Suite 705
Tucson, AZ 85701

Brelend Gowan, J.D.
Attorney at Law & Legal Consultant
351 B Street
Davis, CA 95616

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16. Abstract

This project provides the Arizona Department of Transportation (ADOT) with recommendations and a framework for integrating the Highway Safety Manual (HSM) methods and tools to quantify safety performance into project planning and scoping and design processes. The research describes and associates types of safety analyses likely to be undertaken at ADOT during the project development process. The research also outlines which of these practices are current and which could be implemented in the long term and preliminary steps to achieve long term implementation. Research for this project was based on interviews with staff from ADOT's safety, planning, design and pre-design, traffic engineering, and risk management and tort liability business units, case studies demonstrating application of HSM procedures to two recent ADOT pavement preservation projects, interviews with two state DOTs considered leaders in integrating the safety analysis into their project development process and the research team's practical experience. The project concluded that ADOT can be successful implementing descriptive and quantitative safety analysis by committing to revise applicable policies and guidance documents, establishing an ADOT champion to lead this effort, and by dedicating funds to a comprehensive training program to ensure Department staff has the appropriate skills to meet the safety analysis requirements.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

Contents

List of Figures

List of Tables

List of Acronyms

AAC............ Arizona Administrative Code
ADOT .... Arizona Department of Transportation
AASHTO...... American Association of State Highway Transportation Officials
AC .... asphalt concrete
ADOA.......... Arizona Department of Administration
ADT............ average daily traffic
AG.............. Attorney General
ALDOT .... Alabama Department of Transportation
ALISS.......... Accident Location Identification Surveillance System
ARS .... Arizona Revised Statutes
CAD............ computer aided design
CARE .... Critical Analysis Report Environment
CMF .... crash modification factor
DCR............ design-concept report
DOT .... department of transportation
EB .... Empirical Bayes
FDOT.......... Florida Department of Transportation
FHWA .... Federal Highway Administration
HSIP .... Highway Safety Improvement Program
HSM........... Highway Safety Manual
IDOT .... Illinois Department of Transportation
IHSDM .... Interactive Highway Safety Design Model
ISP.............. Illinois State Police
KDOT .... Kansas Department of Transportation
LaDOT .... Louisiana Department of Transportation
LTAP........... Local Technical Assistance Program
MPD........... Multimodal Planning Division
NACTO .... National Association of City Transportation Officials
NHI............. National Highway Institute
ODOT.......... Oregon Department of Transportation
OPP .... Office of Planning Programming
PA .... project assessment
PD&E .... Project Development & Environment
PS&E .... plans, specifications, & estimates
PSI.............. Potential for Safety Improvement
RCI .... Roadway Characteristic Inventory
RDG .... Roadway Design Guidelines
S&O .... Safety and Operations
SHSP .... Strategic Highway Safety Plan
SL .... scoping letter
SPF............. safety performance function
SRM .... Safety and Risk Management
TAC .... technical advisory committee
TGP .... Traffic Engineering Guidelines and Procedures
TRSD .... Texas Roadway Safety Design
TWLTL......... two-way-left-turn-lane
TxDOT......... Texas Department of Transportation
WSDOT .... Washington State Department of Transportation

EXECUTIVE SUMMARY

In 2010 the American Association of State Highway Transportation Officials (AASHTO) published the first edition Highway Safety Manual (HSM). The HSM includes a number of different quantitative analysis tools for evaluating safety performance on the highway transportation system. These quantitative safety analysis methods make it possible for a state to identify project level safety improvements, identify potential crash reductions, conduct cost-benefit analyses, and prioritize projects. The analyses are reliable, repeatable, and allow for project prioritization based on safety criteria such as crash frequency or crash severity, and/or economic impacts of safety.

This project provided the Arizona Department of Transportation (ADOT) with recommendations and a framework for integrating HSM methods and tools to quantify safety performance into project scoping and design processes. The recommendations and framework will initially be for projects with limited alternatives analysis, typical of the ADOT typical project assessment process. The framework considers the complete ADOT project development process at a concept level, and includes case study examples from ADOT project work.

The research into requirements for implementing quantitative safety analysis at ADOT was divided in three phases. Initially, selected ADOT staff from traffic safety, planning, design and pre-design, traffic engineering, and risk management and tort liability were interviewed about current ADOT safety analysis activities. The interviews were conducted in person and by phone. Specifically, the interviews were targeted at learning about safety analyses currently conducted at ADOT, the types of projects integrating safety analysis and staff roles and responsibilities related to safety analysis. The interviews produced major themes of interest and opportunity for integrating quantitative safety analysis.

Research was also conducted to assess how other state departments of transportation (DOTs) are integrating quantitative safety analysis into the project development process. An initial set of states were identified based on the researcher's experience in the field of quantitative safety analysis. Washington State Department of Transportation (WSDOT) and Ohio Department of Transportation (ODOT) were selected for comprehensive interviews. There were similarities in how Washington and Ohio integrated quantitative safety analysis procedures by:

- Developing automated safety analysis tools specific to their states,
- Calibrating safety performance functions (SPF), and
- Training and supporting engineers and planners with staff with safety expertise.

Both states encouraged ADOT to:

- Start with small steps such as applying crash modification factors to the design exception process or applying the HSM predictive method on corridor studies;
- Focus on starting to apply the concepts and grow the skill sets, recognizing that first steps won't be perfect;
- Document the analysis and outcomes; and
- Improve data and tools as implementation grows.

WSDOT encouraged ADOT to identify a champion with design and traffic operations experience and advised that champion should have planning/programming responsibilities. At ODOT the Safety Group is responsible for implementation of the HSM methods across business units at the agency. ODOT relies on their Safety Group's relationships with other staff and disciplines to spread application of the HSM.

To demonstrate applying quantitative safety analysis, the project then retroactively applied the HSM predictive method to two ADOT Project Assessments. The case studies demonstrated the amount of time and effort required to complete the advanced safety analysis, showing that it is possible to begin applying predictive safety analysis to current ADOT projects. The case studies show the relatively low level of effort and time resources needed to estimate safety performance and demonstrate the types of conclusions that can be drawn from the safety analysis. For example it took approximately 24 hours to compile the data and conduct a predictive analysis for 18 miles of mountainous two-lane rural highway and 12 hours for 8 miles of flat two-lane highway with few curves. Staff capabilities to conduct these analyses are consistent with those of a planning or engineering analyst and included gathering crash, traffic, and roadway characteristic data from existing databases and applying the HSM methodologies using a software or spreadsheet tool.

After conducting the ADOT staff interviews and external state interviews, the case study demonstration of methods, and the ADOT procedures and processes review, a preliminary framework was developed and refined. The final revised framework presented in Chapter 6 establishes a possible plan for ADOT to succeed in a more widespread application of the Highway Safety Manual and safety analysis overall.

Some key components to this success will be:

- Integrating safety analysis requirements into appropriate policy and guidance manuals. An immediate implementation of adding such language to Project Assessment policy 88-2 and the *Project Development Process Manua*l will provide a solid foundation for the continued advancement of safety analysis.

- Documenting in these manuals the current safety analysis practices already implemented by different ADOT groups within the project development process.

- Concurrently establishing safety analysis methodology training for ADOT staff. By providing training in the near term, ADOT could achieve within five years the inclusion of safety analysis in additional phases of the project development process and in the planning phase of projects.

CHAPTER 1. INTRODUCTION

The American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM), published in 2010, provides transportation planners, engineers, and designers with fundamental safety knowledge, methods for quantifying safety performance of roadways and intersections, and methods for estimating the changes in crash frequency or severity that can be associated with particular road treatments. The manual's developers focused on ensuring all its concepts and methods could be readily integrated into a state department of transportation (DOT) project development process.

While the purpose of the HSM is clear and the Federal Highway Administration (FHWA) has provided resources to integrate the HSM into state practices, it is also difficult for any organization to adapt to and adopt new policies and procedures. There is a need to develop tools, training, policies, and procedures appropriate to the agency. It also is necessary to demonstrate the value of the new techniques and to build staff interest. The challenge of integrating quantitative safety into standard practices is exacerbated by common concerns with risk and liability issues.

In this context the Arizona Department of Transportation (ADOT) has a long term goal of integrating the HSM methods and tools into project scoping and design processes. Recognizing the above challenges, ADOT is adopting a phased approach. Initially, ADOT would like to provide staff guidance on integrating the HSM into project scoping and design for projects with limited alternatives analysis typical Project Assessment (PA) process. The research for this project was conducted by:

- Reviewing ADOT policies and procedures to understand current recommended safety practices
- Interviewing ADOT staff to understand actual safety analyses undertaken and opportunities and barriers associated with those analyses
- Applying the HSM methods to two ADOT example projects to understand data availability, analysis outcomes and level of effort
- Learning how other state Departments of Transportation have successfully integrated quantitative safety analysis into their project development process
- Developing a framework for how ADOT can grow its quantitative safety analysis processes, procedures, and policies

Certain terms are used throughout the document and are defined as follows:

- Descriptive safety analysis – counting and summarizing crashes by type, severity, contributing factors, or environmental conditions
- Quantitative safety analysis – applying methods, such as HSM methods, that estimate a numerical change in crash frequency or severity
- HSM safety analysis – using methods documented in the AASHTO Highway Safety Manual
- Predictive Method (or HSM Predictive Method)– the Predictive Method documented in Part C of the First Edition AASHTO Highway Safety Manual

CHAPTER 2. EXISTING GUIDELINES AND POLICIES FOR SAFETY ANALYSIS AT ADOT

This chapter summarizes the project team's review of existing ADOT policies and guidelines to develop a snapshot understanding of how ADOT is integrating safety into the project design process. The following documents were reviewed to identify current ADOT policies, procedures, and guidelines for evaluating safety in the project development process:

- Traffic Engineering Policies, Guidelines, and Procedures (PGP) - – Now referred to as the Traffic Engineering Guidelines and Procedures (TGP).
- Policy on Project Assessments
- Project Scoping Document Guidelines
- Guidelines for Scoping Pavement Preservation Projects
- Design Exception and Design Variance Process Guide
- Roadway Design Guidelines (RDG)
- Planning to Programming (P2P) Link Methodologies and Implementation Plan
- Project Assessment Procedure Bulletins – No relevant bulletins were identified.
- Roadway Design Memorandums – No relevant memoranda were identified.
- Arizona Revised Statutes §12-820.03, §28-333, §41-192, §41-621 et seq., §41-4802
- Arizona Administrative Code, Title 2, Chapter 10
- Arizona Department of Administration Risk Management Division Fiscal Year 2013 Annual Report
- Arizona Department of Administration Risk Management Division websites re: "Property & Liability" and "Risk Management Overview"
- Arizona Department of Transportation Policies and Procedures: SUP-6.07, Automobile Accident Reporting Procedure
- Arizona Department of Transportation Policies and Procedures: PER-11.06, Motor Vehicle Safety, Record Review, and Restrictions
- Arizona Department of Transportation Policies and Procedures: SAF-14.01, Incident Reporting, Investigation and Review
- Arizona Department of Transportation Project Development Process Manual
- Organization Chart for ADOT Safety and Risk Management (SRM)
- Risk Management Presentation for Operations
- Risk Management Presentation for Resident Engineers Academy
- Example Project Assessments (Pas)
- *Glazer v. State*, 237 Ariz 160, 347 P. 3d 1141 – Ariz. Supreme Court 2015

The outcome of the review is summarized below.

ADOT PROJECT DEVELOPMENT PROCESS

The project development process typically includes the following steps or phases:

- Initiation – A project to address an existing need or an expected future need is identified. Projects to address existing needs are typically initiated by a District Maintenance engineer, Regional Traffic Engineer, local city or county engineer, or an elected official. Projects to address future or statewide needs are identified through the ADOT Multi-modal Transportation Planning Division.
- Planning – In this phase each project is technically evaluated to more clearly identify needs, develop a scope, identify environmental impacts, and estimate project costs. The level of detail depends on the complexity. Project evaluations range from scoping letters, to project assessments (PA), to design concept reports (DCR). Projects are prioritized and programmed (i.e. funding is obligated) in this phase.
- Implementation – Upon environmental clearance and inclusion in the ADOT Five-Year Construction Program, final design and preconstruction activities, including acquisition of right of way and preparation of contract documents are completed, followed by construction.

SAFETY EVALUATION IN THE PROJECT DEVELOPMENT PROCESS

Safety evaluations are conducted by the Traffic Engineering Group in the project scoping activities of the planning phase of the project development process. The evaluations are conducted either as part of a project assessment (PA) or a design concept report (DCR). The evaluations are intended to identify needs and opportunities to improve multi-modal safety as part of a roadway project, potentially adding safety improvements to the project scope. Safety evaluations are also conducted to compare project alternatives and to support design exception or variance requests.

At the PA level, 5-years of crash data are assembled and reviewed to summarize crashes by type, severity, and contributing factors. There is particular emphasis on roadway features and other factors that may be associated with fatalities. If a crash pattern related to a roadway feature can be identified, a safety improvement is typically recommended either for inclusion in the project scope, or potentially a stand-alone project.

While federal guidelines require a reasonable degree of safety enhancement as part of pavement preservation projects, funding limitations typically allow only spot safety improvements at locations warranted by a crash review. The type and level of usage of the facility is also a consideration in determining the level of safety improvement included in pavement preservation projects. Typical safety enhancements implemented with pavement preservation projects include rumble strips, wider pavement markings, raised pavement markers, reflective delineators at obstacles within the clear zone (i.e. headwalls) and on curves, additional/upgraded signing, and upgrading guardrail and/or end treatments.

At the DCR level, a safety evaluation involves a more detailed investigation of crash trends, crash locations, or factors that may be associated with serious injury and fatal crashes. The results of the safety evaluation are used to assess the benefit of project alternatives in addressing safety issues.

In addition to identifying safety issues and improvement opportunities to be considered in the scope of a project, a safety evaluation is also required should a design exception or design variance from ADOT standards be requested for a project. Current design exception guidance provided in the Traffic Engineering Guidelines and Procedures Manual notes that a design exception should not be granted if there is a discernible crash pattern clearly related to the proposed roadway geometrics.

PLANNING TO PROGRAMMING (P2P) LINK

ADOT's Multimodal Planning Division (MPD) has developed a performance based approach to the project development and prioritization process. P2P is intended to ensure that project prioritization and programming decisions are performance-based and optimize utilization of transportation funding to improve overall system performance. Projects are prioritized based on their performance across various criteria defined for three general project types – preservation (pavement and bridge rehabilitation and reconstruction), expansion (increase capacity to serve existing and future needs), and modernization (improve efficiency, operations, and safety).

In the prioritization process, safety performance is directly assessed only in modernization projects, however it is intended that safety performance be an important criteria also in preservation projects. The recommended safety performance measure is expected crash reduction. The method for calculating this measure is to use crash modification factors to estimate crash reduction over a 5-year period.

The P2P implementation plan recognizes that new methods for estimating performance criteria may be required to improve the comparison and prioritization of projects. Consideration and assessment of a method to predict crash reduction resulting from infrastructure improvements by the ADOT Traffic Group is noted in the P2P implementation plan.

GUIDANCE ON SAFETY EVALUATIONS

The documents reviewed provide general guidance on when safety evaluations should be conducted within the project development process, however, little guidance is provided on evaluation methodologies or safety performance criteria. Safety evaluations conducted by ADOT are based primarily on a review of five years of crash data by type, severity, location and environmental conditions to identify potential safety issues within project limits, review of field conditions to assess what improvements might be considered to address the safety issue, and consideration of available funds.

The Traffic Engineering Guidelines and Procedures Manual recommends that an analysis of benefit/cost ratio be conducted for safety improvements being considered for a project. Crash reductions needed for the benefit/cost ratio are estimated using known CMF's selected using the *Annual Report on Highway Safety Improvement Programs* (FHWA, 1996), and *Crash Rate Reduction Levels Which May Be Attainable*

From Various Safety Improvements (Arizona Data) (February 1991). Although the CMF Clearinghouse is not cited, high quality CMF's included in this database are also applied in cost/benefit analyses.

OVERVIEW OF RISK MANAGEMENT

The Arizona Attorney General's Office provides all legal services to the Arizona Department of Transportation. By law, ADOT cannot retain its own counsel except in a few very narrow circumstances and with the permission of the Attorney General.

The Arizona Department of Administration (ADOA) is charged with promulgating rules and regulations to initiate and implement a Risk Management and Loss Control Program for ADOT and all other departments. ADOA is responsible for obtaining liability insurance for ADOT, as well as establishing self-insurance retentions where appropriate. (ADOT pays ADOA approximately $21 million per year for property and liability insurance – about 4 percent of its operations budget.) ADOA also provides risk management services and maintains a risk management revolving fund for paying claims and litigation expenses. ADOA handles and adjusts claims filed against ADOT. Claims that proceed to litigation are handled by the Attorney General's Office, with ADOA providing support in coordination with ADOT.

There is a Safety and Risk Management (SRM) section within ADOT's Administrative Services Division. The Safety Unit, within SRM, is responsible for Safety Training, Safety Consulting and Industrial Hygiene, all of which are primarily concerned with employee safety. Within the SRM, there is another unit responsible for Administrative Programs.

SRM's Insurance Recovery Unit handles losses not covered by ADOA. These losses primarily consist of subrogation actions against third parties responsible for damaging highway structures (e.g. guardrail, signs, bridges, etc.). This unit also processes and prepares all first party property claims for the ADOA.

SRM's Insurance and Contracts Unit is charged with ensuring that all insurance and contracts meet ADOT requirements (e.g. type of insurance coverage, adequate limits, proper indemnity protection, allowable exclusions, etc.). It also advises on contract and insurance clause modification.

The Loss Prevention Unit is continuing to develop its loss prevention program and identifies trends in losses, analyzes crash reports, and develops loss prevention action plans in response to ADOA reports. It also offers multi-hour training courses on risk management, tort liability awareness, loss prevention and safety to ADOT employees, including operations, maintenance and construction personnel. Other courses are more focused on the Resident Engineers Academy and the Winter Readiness Conference.

SRM's Litigation and Public Records Unit responds to public records requests and supports the Attorney General in any litigation that arises from those requests. In major incidents, the unit's litigation investigators will perform an early investigation to preserve evidence, document and photograph the scene, and undertake other activities in support of ADOT's defense. The unit also assists and coordinates in the identification and production of records, in responses to interrogatories, and in identification and preparation of witnesses for interviews, depositions, and court testimony. This support is provided to ADOA at the claims stage and to the Attorney General when the claim becomes a lawsuit.

CHAPTER 3: EXISTING SAFETY ANALYSIS AT ADOT

Interviews with ADOT staff were conducted to develop an understanding of ADOT safety analysis activities. With an understanding of current safety activities, roles and responsibilities, opportunities for integrating the HSM into the ADOT project development process were identified. The interviews were conducted with ADOT staff from safety, planning, design and pre-design, traffic engineering, and risk management and tort liability.

Interview topics for each group of stakeholders were:

- Planning and Design Leadership – role and current policies and practices related to descriptive and quantitative predictive safety analysis
- Traffic Engineering – role, current safety practices in that role, safety analysis tools, and familiarity with HSM related tools and the project development process
- Roadway Engineering – role, current safety practices in that role, opportunities to integrate safety into their role, safety analysis tools and familiarity with HSM related tools, and the project development process
- Risk Management and Tort Liability – role and tort liability and risk management

The complete interview guides and interview participants are documented in Appendix A. The questions listed in the interview guide were used to organize the conversation and serve as a reminder of the array of topics that should be included in each conversation. The questions were not used verbatim. The questions are organized by group of participants; however the groups of participants did not always participate together. In addition, most interviews were conducted in person; however due to scheduling constraints, some were conducted by telephone.

The information gathered from the interviews characterizes the current safety practice at ADOT today. The results of the stakeholder interviews helped the project team understand current conditions of safety analysis at ADOT and understand opportunities for integrating quantitative safety into ADOT procedures. The major points gained from the interviews are as follows:

1. ADOT staff is interest and there is opportunity to integrate descriptive and quantitative predictive safety analysis into ADOT scoping processes, long-term planning, alternatives evaluation, and design exceptions.
2. There was general agreement that staff in the traffic engineering section should be responsible for descriptive and quantitative predictive safety analysis, at least initially.
3. There is a mix of types of safety analyses in use today. The safety section does the majority of the quantitative safety analyses, and most of it relates to managing and deploying the Highway Safety Improvement Program (HSIP). There has been some application of safety performance functions, crash modification factors and the Interactive Highway Safety Design Model (IHSDM). Outside of the safety section, safety analyses are relatively basic applications using descriptive statistics (e.g., crash frequency, crash severity and type).

4. Staff recognizes there will be a need for training to fully integrate descriptive and quantitative predictive safety analysis into project development. ADOT needs to consider a transition from standard-based design referred in the literature as “nominal safety” (i.e., designing the transportation system consistent with appropriate standards and guides) to “substantive safety” (i.e., quantifying the safety impacts of decisions influencing roadway cross-sections and/or roadside design/features)). To achieve this integration, staff will need training, example success stories and repetitive use of methods.
5. ADOT Risk Management Division provides a multitude of services relating to risk management and tort liability, including providing litigation support services to the Arizona Department of Administration and the Arizona Attorney General’s Office, providing risk management and tort liability awareness training to ADOT employees, providing loss trends analysis and Agency Action Plans to management, and ensuring transfer of risk in contracts and encroachment permits though insurance and indemnity.
6. ADOT’s project development staff has a general awareness of tort liability. To the extent it is a consideration in the design process, standards-based design criteria usually drive decisions in order to achieve safety. In other words, staff appears to start from the position that following established design standards is sufficient, and deviation from standards detracts from safety and must be justified.

Details related to these themes are summarized below.

THEME 1 – OPPORTUNITIES IN ADOT PROCESSES

- Many staff members identified the project scoping phase of ADOT processes as the most likely phase of the project development process to include descriptive and quantitative safety analysis. There is opportunity in this stage of project development for safety to be quantitatively considered alongside other typical project evaluation criteria. Staff noted however that in situations where project federal funding has already been programmed, it is challenging to add safety improvements in the scoping phase, particularly for pavement preservation projects.
- ADOT Planning staff see value in incorporating a planning level safety assessment for potential projects. They are moving forward with incorporating safety into at the P2P process at a basic level, however, they are also interested in a simplified method to assess safety performance through basic/standardized crash modification factors. There was also discussion about bringing quantitative safety (CMFs) into the prioritization process for expansion projects. This is consistent with a long term goal of integrating quantitative safety across project categories (modernization, maintenance and expansion)
- There was general agreement that traffic engineering should be responsible for conducting quantitative safety analyses, at least initially, although all staff recognized the Safety Section within Traffic Engineering probably does not have the resources to conduct all of the quantitative safety analyses for project scoping projects. Traffic design section staff could also play a role in conducting and integrating quantitative safety analyses in the project development process, as they are primarily responsible for reviewing design exception requests. A checklist or

prompt list tool presenting analysis options would be useful. In addition, a GIS based tool that allows both the traffic safety and design sections to more readily access and review crash data would enhance the safety review process.

- Roadway engineering staff see an opportunity for applying the IHSDM in the project scoping phase, particularly on those projects that include CADD files at this stage of the project.
- Design exceptions were seen as another place to integrate descriptive or quantitative safety analysis.
- Integrating quantitative safety into local safety programs and project development is another opportunity. Ongoing development of regional safety plans throughout Arizona and implementation of the updated Strategic Highway Safety Plan (SHSP) may provide this opportunity.
- ADOT Leadership sees the opportunities for integrating practical design, context sensitive design, and substantive safety analyses into state processes while still appropriately managing project risks. Safety is a component of this.

THEME 2 – EXTENT OF SAFETY ANALYSIS TODAY

- The Safety Section in Traffic Engineering does essentially all of the descriptive and quantitative safety analysis today. Much of this analysis is associated with managing and implementing the State HSIP. These staff have conducted pilot applications of the IHSDM and applied crash modification factors (CMF) from the Federal Highway Administration (FHWA) CMF Clearinghouse.
- Project scoping includes very basic descriptive safety analysis (i.e. crash summary by type, severity and environmental factors) for a given site. If, based on engineering judgment, the crash frequency looks high, traffic engineers or designers will request the safety section review crash data. Staff availability for a great deal of this analysis is limited.
- Roadway design staff are focused on delivering final project design, and alternatives analyses are not conducted at this stage. To a large extent, the majority of alternatives consideration should be addressed in scoping. In current ADOT processes and procedures, there is limited opportunity for additional alternatives evaluation in final design.
- At the pre-design phase of project development, safety is assessed by both the safety and traffic design sections. The safety section performs an overall crash analysis in the scoping process, while traffic design performs safety assessments for roadway sections that don’t meet current ADOT standards (i.e., design exceptions) These analyses primarily involve descriptive analysis reviewing crash frequency and severity data over the most recent 5-year period.

THEME 3 – CONSTRAINTS TO INTEGRATING DESCRIPTIVE AND PREDICTIVE SAFETY ANALYSIS

- Staff training and limited familiarity with the HSM and safety analysis tools are seen as major constraints to applying predictive safety analysis methods in project development. Staff perceive that some staff members, likely in the Safety Section, need to be experts on the analytical safety evaluation methods and to have experience applying the methods and reviewing results. Such experience could be gained by regularly conducting quantitative safety analyses.
- It was said that the safety culture at ADOT could benefit by transitioning from working only with design guides and standards to also considering quantitative safety tradeoffs of cross-section and/or roadside design features/treatments. Staff suggested that traffic engineers and designers need to embrace and implement quantitative road safety methods and be willing to deploy and report on the results of the analyses.
- In the same vein, interview responses indicated that ADOT needs to recognize the four Es of safety (engineering, enforcement, education, emergency services) and, as appropriate and possible, find opportunities to utilize funds for non-engineering solutions.
- Staff say that they need to develop an approach to reviewing and planning projects with an eye toward how they can enhance safety in addition to achieving other project goals.
- There is desire for pilot projects and case studies demonstrating success and value added by applying quantitative safety analysis methods in Arizona.
- There is a desire and interest at leadership levels to move toward practical design, complete streets, and, where appropriate, National Association of City Transportation Officials (NACTO) type design concepts.

THEME 4 – TOOLS AND MANUALS TO SUPPORT INTEGRATING QUANTITATIVE SAFETY

- ADOT developed calibrated SPF's for two ADOT studies. The I-10 Phoenix Corridor Safety Study developed calibration factors for Phoenix urban freeway basic segments and speed-change lanes. The ADOT State-specific Crash Prediction Models: An Arizona Needs Study, developed a calibration factor equation for two-lane undivided rural roadway segments. ADOT is also in the process of statewide deployment of Safety Analyst, which comes with a calibration tool.
- Safety Section staff have developed an "approved" list of Crash Modification Factors for use in safety analysis on state highways and in developing projects for HSIP funding.
- There is some familiarity with IHSDM; however, more training and regular use is needed.
- As part of applying the HSM through IHSDM, ADOT has developed severity distribution for use with HSM methods.
- There is interest in developing and applying safety analysis checklists to help with project scoping analyses.

- As quantitative safety is integrated into the project development process, ADOT staff indicated that it would be useful to add statewide guidance about descriptive and quantitative safety analysis into the following:
    - Roadway Design Guidelines (RDG)
    - Traffic Engineering Guidelines and Procedures (TGP)
    - Project Development Process Manual

THEME 5 – TORT LIABILITY AND RISK MANAGEMENT

- Arizona's statutory scheme and departmental organization relating to risk management and tort liability are centralized. All litigation is handled by the Attorney General's Office. ADOT has no attorneys on its staff. All claims and lawsuits are paid through the Risk Management Division of the Arizona Department of Administration (ADOA), which obtains and provides insurance protection to the various state departments and agencies. ADOT appears to have relatively little control over the resolution of claims and lawsuits against it. While the ADOA sets insurance premiums annually for other departments based on losses, ADOT's insurance premiums are not adjusted. Historically, ADOT pays ADOA $3-4 million more than what its "calculated" (i.e. adjusted) premium would be. This excess remains with the ADOA each year, not subject to the constraints on the use of state highway funds. This policy results in what appears to be a disconnect between the efficiency of ADOT's proscribed risk management program in controlling payouts for claims and lawsuits and the ability of ADOT to redirect those excess premiums to highway projects that would improve safety for the Arizona traveling public.
- ADOT Risk Management Division provides a multitude of services relating to risk management and tort liability that include litigation support services to the Arizona Department of Administration and the Arizona Attorney General's Office, risk management and tort liability awareness training to ADOT employees, loss trends analysis and Agency Action Plans to management, and ensuring transfer of risk in contracts and encroachment permits though insurance and indemnity. The success of that program can be measured when ADOA does its annual "hypothetical" premium adjustment for ADOT; however, as stated above, those "hypothetical" savings of millions of dollars do not get returned to ADOT or reflected in lower premiums for the following year.
- ADOT's current project development process does not appear to include a prescribed role for its Risk Management Division. Some Roadway Safety Audit teams include a Liability Loss Prevention Specialist. Occasionally, the Risk Management Division may be asked to weigh in on a particular design exception.
- ADOT's risk management training would appear to provide the most proactive approach to instilling tort liability awareness in ADOT employees. The training is primarily focused on maintenance and construction engineering staff.

- ADOT's project development staff has a general awareness of tort liability. To the extent that it is a consideration in the design process, standards-based design criteria usually drive decisions. In other words, the staff position appears be that following established design standards is sufficient, and deviation from standards detracts from safety and must be justified.

- While ADOT staff generally understands the need for documenting decision-making as a potential legal defense, quantitative analysis tools are not widely used to measure substantive safety, inform decision-making, or enhance documentation of decisions.

CHAPTER 4. EXAMPLE PROJECT ASSESSMENTS USING QUANTITATIVE SAFETY ANALYSIS

To illustrate an approach for integrating the Highway Safety Manual (HSM) Predictive Method in the ADOT project development process, case studies were conducted for two pavement preservation projects. The intent was to assess the availability of data required to apply the HSM Predictive Method, identify available tools to apply the method, assess the level of effort to conduct the safety performance analysis, and demonstrate the value of quantitative safety analysis in the project development process.

OVERVIEW OF CASE STUDY PROJECTS

Project assessments for several pavement preservation projects were gathered and reviewed. Of these, two projects were selected to demonstrate the application of the HSM crash predictive methods

Project H7881, State Route 260 McNary to Sunrise Turnoff (MP 360.78 to MP 378.72)

Project H7881 is a pavement preservation project that included full width removal and replacement of 3-inch AC and chip seal (Figure 1). The project length is 17.94 miles. The final project assessment was completed in May 2012.

Figure 1. State Route 260 Case Study Segment

This section of State Route (SR) 260 is a two-lane undivided rural highway with 12-foot travel lanes. The shoulder width varies from 1 to 8 feet. The terrain is mountainous, with significant grade changes, including 78 vertical curves and 25 horizontal curves. Eastbound and westbound climbing lanes are located from MP 375.63 to 377.49. The current ADT on this section of SR 260 is approximately 1,400 vpd.

The safety assessment performed for the PA reported the following crash history (Table 1) for the 5-year period September 1, 2006 through August 31, 2011:

Table 1. State Route 260 McNary to Sunrise Turnoff (MP 360.78 to MP 378.72); Crash Summary 9/1/2006 to 8/31/2011

Type of Crash	Totals
Single Vehicle	73
Angle	2
Head-on	1
Rear-end	7
Other	2
Sideswipe Same Direction	3
Sideswipe Opposite Direction	1
Total (5 yrs)	89

The PA reported that no discernible crash trends or patterns considered to be abnormal were identified for a roadway of this type. No specific safety countermeasures were recommended based on the crash review, however rumble strips at specified locations, replacement of existing guardrail at several locations, and installation of depressed reflective pavement markers and flexible delineators were included in the project.

Project H8124, US 191, Jct State Route 181 to Pearce Road (MP 38.0 to MP 45.8) US 191, Jct State Route 181 to Pearce Road

This is a pavement preservation and safety project which includes mill and replace or overlay of AC, widening to provide 8 foot shoulders for the entire project length, reconstruction of the “flying Y” intersection at Pearce Road to create a right-angle intersection, and adding a two-way left-turn lane just north of Jct SR 181 to serve eight low volume driveways. The project length is 7.8 miles (Figure 2 and Figure 3. The final PA was completed in November 2011.

Figure 2. US Route 191 Case Study Segment

Figure 3. US Route 191 at Pearce Rd

This section of US Route 191 is a two-lane undivided rural highway with 12-foot travel lanes and 2-foot shoulders. The terrain is flat, with 5 horizontal curves. There are three intersections within the project limits.

The safety assessment performed for the PA reported that in the 5-year period July 1, 2005, through June 30, 2010, 21 crashes were reported including five injury crashes and one fatality. Fourteen of the crashes were lane departures. In addition to the shoulder widening and intersection improvements, additional recommended safety features included shoulder rumble strips, raised reflective pavement markers, extending existing culverts beyond the clear zone, and removal of trees within the clear zone.

Safety Performance Methodology

The HSM crash predictive method for rural two-lane, two-way roads, as described in Chapter 10 of the HSM was used for the safety performance evaluation in the two case studies. This method predicts the average crash frequency, $N_{expected}$, of total crashes and by crash severity on the following four facility or site types on a rural roadway:

- Two-lane, two-way undivided roadway segment,
- 3-leg intersection with stop control,
- 4-leg intersection with stop control, and
- 4-leg intersection with signal control.

For the two case studies, only undivided roadway segment and 3-leg intersection sites were present.

The general crash prediction model used for these four facility types is of the form:

$$N_{predicted} = N_{spf} \times (CMF_1 \times CMF_2 \times CMF_n) \times C$$

where:

$N_{predicted}$ = predicted average crash frequency for a site type

N_{spf} = predicted average crash frequency for the base conditions of a site type, calculated using a safety performance function (SPF) for each site type

CMF_1 = crash modification factor (CMF) for a specific site type and specific geometric design or traffic control feature

C = calibration factor to adjust the SPF to reflect local conditions for a specific site type.

Two-lane, Two-Way Undivided Rural Roadway Segments

The SPF for predicted average crash frequency for two-lane rural roadway segments is:

$$N_{spf\ rs} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)}$$

where:

$N_{spf\ rs}$ = predicted total crash frequency for roadway segment base conditions

AADT = average annual daily traffic volume (vpd)

L = length of roadway segment (miles)

The effects of geometric design and traffic control features on the rural roadway segments are incorporated into the methodology using the following thirteen CMFs (Table 2).

Table 2. Application of HSM Predictive Method CMFs for Rural Two-lane, Two-Way Undivided Roadway Segments

Roadway Feature	Base Condition
Lane width	12 feet
Shoulder width	6 feet
Shoulder type	Paved
Roadside hazard rating	3
Driveway density	None
Horizontal curvature (radius, length, spiral transitions)	None
Horizontal curve superelevation	None
Centerline rumble strip	None
Passing lanes	None
Two-way left-turn lanes	None
Lighting	None
Automated speed enforcement	None
Grade	0 percent

3-Leg Intersection with Stop Control on Minor Leg

The SPF for predicted average crash frequency for a 3-legged intersection on a two-lane rural roadway is:

Nspf 3st = exp[-9.86 + 0.79 x ln(AADTmaj) + 0.49 x ln(AADTmin)]

where:

Nspf 3st = predicted average crash frequency for intersection base conditions

AADTmaj = average annual daily traffic volume on major road (vpd)

AADTmin = average annual daily traffic volume on minor road (vpd)

The effects of geometric design and traffic control features on the rural roadway intersections are incorporated into the methodology using the following four CMFs.

Table 3. Application of HSM Predictive Method CMFs for Rural 3-Leg Intersection with Stop Control on the Minor Leg

Roadway Feature	Base Condition
Intersection skew angle	0
Intersection left-turn lanes	none
Intersection right-turn lanes	none
Lighting	none

Safety Performance Evaluation of Case Studies

The HSM predictive method was applied to each roadway section according to the following steps.

1. Data was gathered, including ,
    a. Crash records for the 5-year period noted in each PA were obtained from the ALISS database
    b. Traffic volume data provided in each PA was used. These data were obtained from the ADOT AADT Report for State Routes and US Routes, available online
    c. Roadway characteristics and features were obtained from several sources (see discussion below)
2. Each roadway section was divided into homogeneous segments
3. Predicted and expected average annual crashes were estimated for each segment or intersection using the HSM methodologies for rural undivided two-lane, two-way highways.

Roadway Characteristic and Features Data

Several sources for the roadway and intersection characteristic data required for the safety performance analysis were reviewed, including as-built plans, aerial photography, and the ADOT Roadway Characteristic Inventory (RCI) database.

As-built plans required for each case study included those providing roadway segment cross section, alignment and profile information, pavement marking plans that provided more recent information on lane and shoulder widths, and other roadway and intersection improvement plans (i.e. turn lanes, passing lanes, lighting, etc). Information not available in the as-built plans includes the roadside hazard rating.

Aerial photographs available through Google Earth can be used to gather roadway geometry and feature information. Aerial photographs from 2012 (SR 260) and 2013 (US 191) were available for the case study roadways. In addition to using the aerial photographs to segment the roadway section, all of the roadway geometry and feature information required to apply the crash predictive method, with the exception of grade and superelevation, can be gathered from aerial photographs. This includes horizontal curve radius and length. Manually gathering the data using Google Earth is aided using EarthTools, a spreadsheet tool developed to aide in data extraction. Use of EarthTools provides an accurate and efficient method of extracting the roadway condition information. The tool is available to ADOT.

An example of how information describing a horizontal curve is gathered using Google Earth is illustrated in Figure 4. Pins describing the curve are easily placed and the Google Earth pin files (.kml) are then exported into EarthTools which calculates the curve radius and length. This same method can also be used to gather lane and shoulder width information.

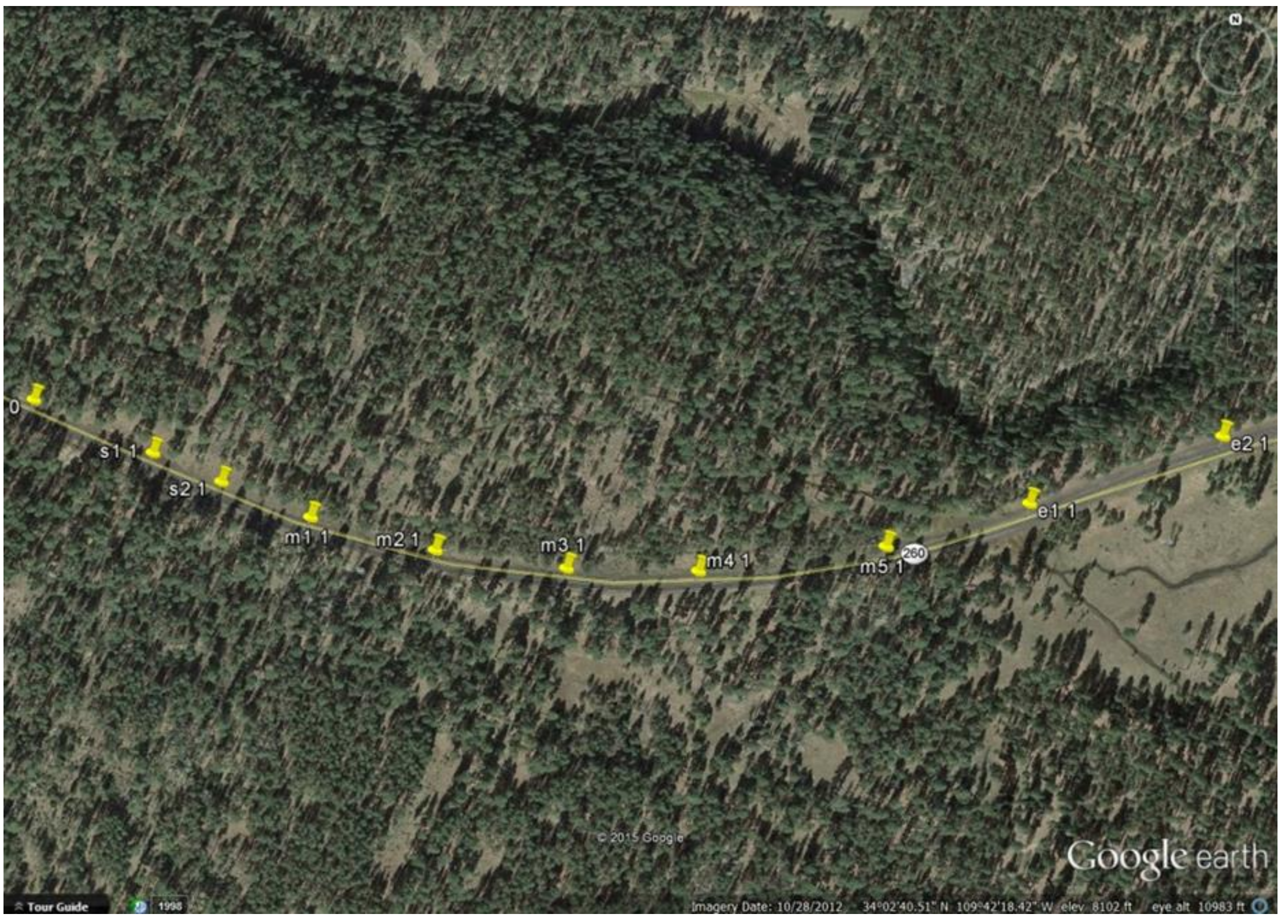

Figure 4. Example of Gathering Horizontal Curve Data Using Google Earth

Roadway geometry and feature information is also available from ADOT's Roadway Characteristic Inventory (RCI) database. The information is provided in a GIS platform and includes shoulder and lane width, horizontal curve length, grade, passing lanes, turn lanes at intersections, and lighting. Note that the RCI database was undergoing a major update when these case studies were conducted and the data for the two sites was not available.

Table 4 summarizes the data available from the three data sources.

Table 4. Data Availability from Each Source

Roadway Feature Data Required for HSM Predictive Method	**Google Earth**	**As-Built Plans**	**ADOT RCI**
Lane width	✓	✓	✓
Shoulder width	✓	✓	✓
Shoulder type	✓	✓	
Roadside hazard rating	✓	✓	
Driveway density	✓	✓	
Horizontal curvature (radius, length)	✓	✓	✓
Horizontal curve superelevation		✓	
Centerline rumble strip	✓	✓	
Passing lanes	✓	✓	✓
Two-way left-turn lanes	✓	✓	✓
Grade		✓	✓
Intersection skew angle	✓	✓	
Intersection left-turn lanes	✓	✓	✓
Intersection right-turn lanes	✓	✓	✓
Intersection Lighting	✓	✓	✓
Roadway Lighting	✓	✓	✓

Segmentation

Each case study roadway section was divided into homogeneous segments based on a visual review using Google Earth and information available from as-built plans. Segments were defined based on significant changes in roadway geometry, primarily cross sectional elements (lane width, shoulder width, clear zone) and horizontal curvature. Changes in grade were not considered since complete data was not available from either as-built plans or the RCI database. Large radius (greater than 1000 feet) horizontal curves were also not considered in the segmentation process. AADT was reviewed and was relatively low and constant on both roadways. The segments defined for each case study are shown in Figure 5 and Figure 6.

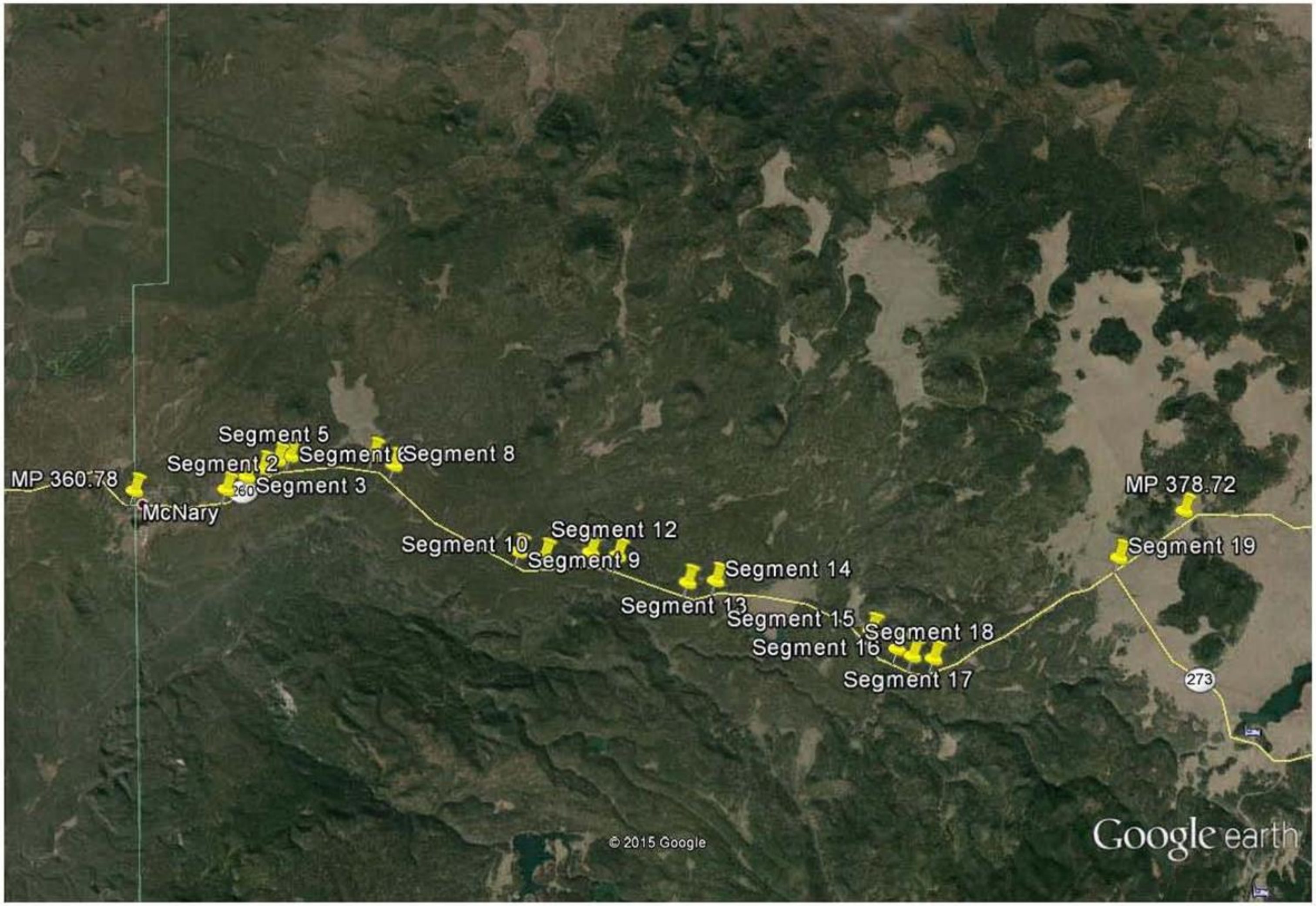

Figure 5. Segmentation of State Route 260 Section

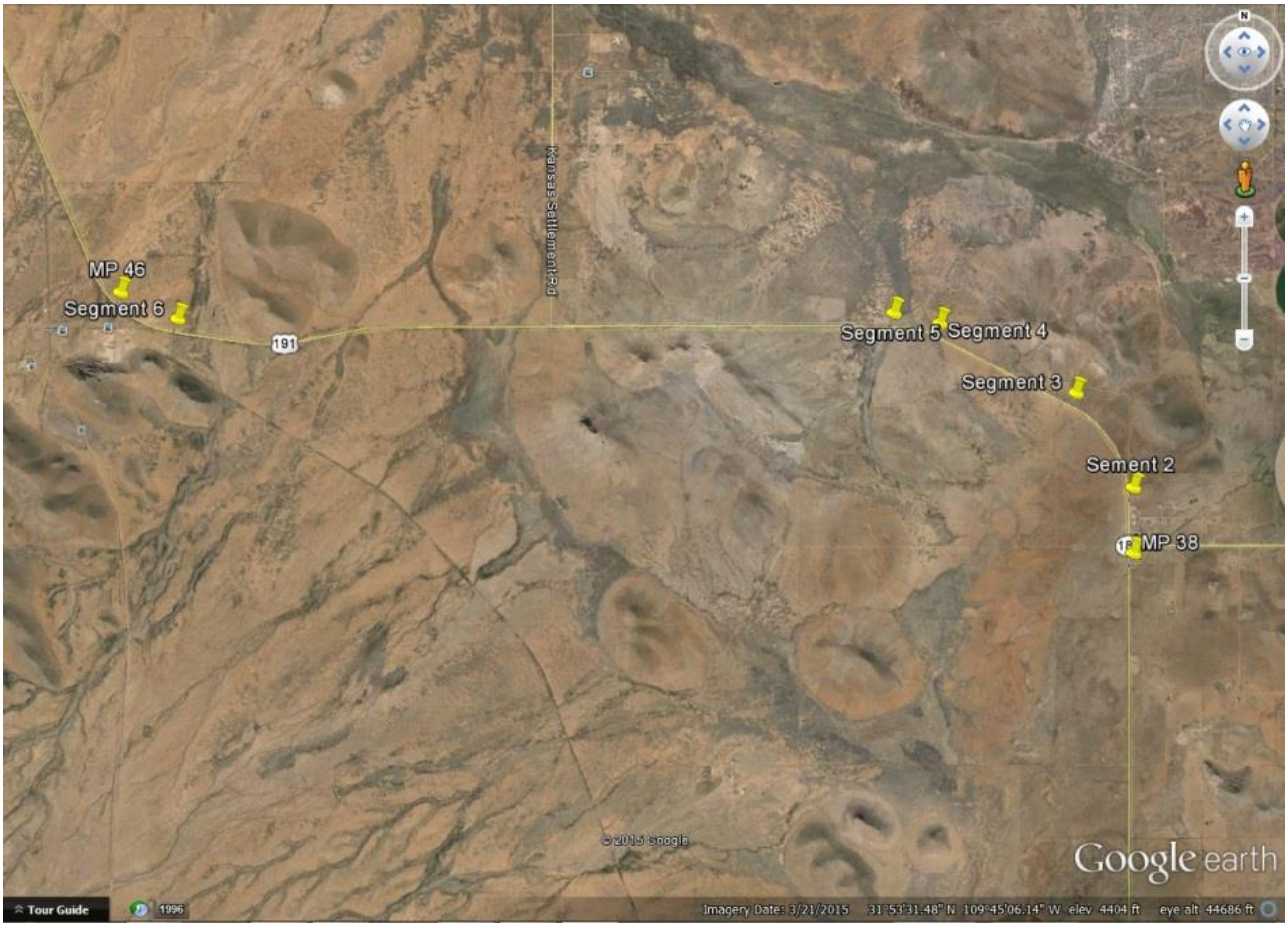

Figure 6. Segmentation of US Route 191 Section

Several tools that apply the HSM crash predictive methods are available, including an Excel-based spreadsheet that was produced in conjunction with the HSM manual; HiSafe, a commercially available software package; and the Interactive Highway Safety Design Model (IHSDM), a decision support model developed by the FHWA that provides comparison of existing or proposed roadway designs based on geometric standards and safety performance. The IHSDM requires detailed geometry for the roadway section being evaluated, typically input via CAD files. As CAD files were not available for either case study and as manually inputting the geometric data into the model would have been very time consuming, the IHSDM software was not utilized for the purposes of the case studies. HiSafe was used to apply the HSM predictive methods.

Safety Performance Assessment of Case Study Highway Sections

State Route 260: McNary to Sunrise Turnoff

Roadway, traffic volume, and observed (reported) crash data were entered into HiSafe for each of the highway segments and the State Route (SR) 273 junction (Sunrise turnoff intersection). A sample HiSafe worksheet for the SR 260 highway segment is provided in Figure 7.

General Information

Analyst	DAT	Analysis Name	SR 260 (Existing)	Date of Analysis	6/8/2015
Agency/Company	Kittelson & Associates, Inc.	Project Number/PIN #	H7881	Comments	Avg annual crashes over 5-year period Sept 2006 - Aug 2011
State	Arizona	Site(s)	SR 260 MP 360.78-378.72		
Region/Area/City/County	Apache County	Jurisdiction	ADOT		

Input Data

Segment name	Seg 8 BMP 364.71
Analysis Year	2011
Length of segment, L (mi)	2.830
AADT (veh/day)	1,431
Lane Width (ft)	12-ft or more (11.8-ft or more)
Shoulder width (ft)	1-ft (0.6-ft to 1.5-ft)
Shoulder type	Paved
Length of horizontal curve (mi)	
Radius of curvature (ft)	
Spiral transition curve	No
Superelevation variance	
Grade (%)	2
Driveway density (driveways/mi)	0
Centerline rumble strips	No
Passing lane in one direction of travel	No
Passing lanes in both directions of travel	No
Two-way left-turn lane	No
Roadside hazard rating	3
Segment lighting	No
Automated speed enforcement	No
Calibration Factor, Cr	1.000

Total Observed Crashes	FI	PDO	Total
By severity level	0.60	1.60	2.20

Summary Results

Crash Severity Distribution	Fatal and Injury (FI)	Property Damage Only (PDO)	Total
Predicted Annual Avg Crash Frequency	0.4	0.8	1.2
Expected Annual Avg Crash Frequency	0.40	0.88	1.31
Crash Severity Distribution	0.321	0.679	1.000
Crash rate (crashes/mi/year)	0.14	0.29	0.43

Crash Severity Distribution

	Fatal and Injury (FI)	Property Damage Only (PDO)	Total
Single-Vehicle			
Collision with animal	0.015	0.152	0.148
Collision with bicycle	0.002	0.001	0.002
Collision with pedestrian	0.003	0.001	0.004
Overturned	0.014	0.012	0.030
Ran off road	0.213	0.418	0.635
Other single-vehicle collision	0.003	0.024	0.026
Total crashes	0.250	0.609	0.845
Multiple-Vehicle			
Angle collisions	0.039	0.060	0.104
Head-on collisions	0.013	0.002	0.020
Rear-end collisions	0.064	0.101	0.173
Sideswipe collision	0.015	0.031	0.045
Other multiple-vehicle collision	0.010	0.025	0.033
Total crashes	0.142	0.219	0.374

Figure 7. State Route 260 Safety Evaluation Worksheet – Roadway Segment

Data for several roadway characteristics were entered as follows:

- Cross sectional element data (lane width, shoulder width) represent typical values within each segment. Minor variations over short distances were ignored.
- Horizontal curves typically defined a complete segment. However, on relatively tangent segments that included one or more large radius curves, the curve with the smallest radius was included.
- Information on spiral transition curves or superelevation was not available.
- Since grades often varied within each segment, the input values represent typical conditions. Grade information was the most difficult to determine, since not all of the as-built plans for this highway section were available for this study. It is expected that the grade information will be readily available from the RCI database.
- Roadside hazard ratings were determined from a visual review and represent typical values within each segment. Note that there was often significant variation of this rating (e.g. clear zone conditions) within a segment.

The calibration factor equation for two-lane rural highways (developed through another ADOT research project) was applied in this project. The calibration factor equation, Observed Crashes= 1.380×(HSM $Pred$icted Crashes)0.694, produced calibration factors ranging from 1.2 to 2.8 for the roadway segments. Since an Arizona calibration factor for unsignalized intersections is unavailable, a factor of 1.0 was used.

Evaluation Results

Expected crash frequencies were generated for each segment and intersection. The expected annual crash frequencies were calculated using the Empirical Bayes method, and reflect the combination of predicted and observed crashes.

Four scenarios were evaluated: existing roadway conditions and traffic volumes, add 6-foot shoulders with rumble strips with existing traffic, and add 6-foot shoulders with rumble strips with future (2030) projected traffic volume. Note that widening the shoulders was not recommended in the project PA; however, this improvement was evaluated in the case study to demonstrate the application of the HSM methods to assess countermeasures. The effect of the safety countermeasures recommended in the PA, including placing reflective pavement markers (RPMs) and post mounted delineators along the roadway was not evaluated since these features were considered already in place prior to the repaving. Therefore, evaluating the effect of adding these countermeasures was not possible using available CMFs.

Expected average annual crash frequencies for the entire highway section are summarized in Table 5.

The expected annual average crash frequency (13.1 crashes/year) for the study section based on existing roadway and traffic conditions is substantially lower than the average annual observed crash frequency (18.0 crashes/year) even with the application of the Arizona calibration factor. This difference suggests that the performance of this roadway section is a high priority for potential safety improvement when compared with typical two-lane highways throughout the state. It may also suggest that a separate calibration factor for rural two-lane highways in mountainous terrain and which experience snowfall and icy roadway conditions is needed.

The results also show the difference in the long term (20-year) crashes estimated using the average annual crash frequency over a 5-yr period compared with the estimate using the HSM quantitative crash prediction method which adjusts for long term variation in crash frequency. In this case, the expected crashes estimated using the HSM method are 75 less (285 vs 360) than using the 5-yr observed annual average. As such, long term crash reduction benefits would be overstated using the 5-yr observed average annual crash frequency.

The expected crash results can be used to quantitatively assess the potential effect of crash countermeasures. For example, widening the shoulders from 1 foot to 6 feet along and adding rumple strips along 14.5 miles of this section of SR 260 is estimated to reduce total annual crashes by 2.9 crashes per year based on current traffic volume (1,400 vpd). As traffic volume increases to 1,700 vpd by 2030, so will the benefit of shoulder widening, estimated to reduce crashes by 3.8 crashes per year. Over 20 years, this improvement is predicted to result in 67 fewer crashes, including 1 fatal, 2 incapacitating injuries, and 19 non-incapacitating injuries. The total potential benefit of the improvement, as shown in Table 6, is nearly $7 million over 20 years, $5.2 million for fatal and incapacitating injury crashes alone. Note that the crash severity distribution used in the benefit calculation reflects the actual observed 5-year crash data for the section of SR 260 being evaluated.

Table 5. SR 260 Case Study Safety Evaluation Results

	Crash Frequency (crashes per year)			**Estimated 20-yr Total Crashes**	**Estimated 20 yr Total Crash Reduction**
	FI	**PDO**	**Total**		
Observed (Reported)	5.8	12.2	18.0		
Existing Roadway					
Expected (2011)	4.2	8.9	13.1	**285**	
Expected (2030)	5.0	10.4	15.4		
Widen Shoulders 6 ft w/rumble strips					
Expected (2011)	3.3	6.9	10.2	**218**	**67**
Expected (2030)	3.8	7.8	11.6		

Notes: Observed crash frequencies are over the 5-year period September 1, 2006 through August 31, 2011.

Table 6. Estimated Benefit of Adding Widened Shoulders with Rumble Strips to SR 260

	K	A	B	C	O	Total
Crash cost; ADOT HSIP Manual	$5,800,000	$400,000	$80,000	$42,000	$4,000	
Proportion of Total Crashes (5 yr observed)	0.011	0.034	0.148	0.114	0.693	1.000
Expected Crashes (Avg over 20 yrs)	3.2	9.7	79.242.0	32.3	196.9	284.0
Widen Shldrs to 6 ft w/rumble strips						
Expected Crash Reduction over 20 yrs	0.8	2.3	9.9	7.6	46.4	67.0
Benefit over service life (20 yrs)	$4,415,909	$913,636	$791,818	$319,773	$185,773	$6,626,909

H8124, US 191, Jct SR 181 to Pearce Road (MP 38.0 to MP 45.8)

Roadway, traffic volume, and observed crash data were input into HiSafe for each of the 6 highway segments and three unsignalized intersections. A sample HiSafe worksheet for one of the intersections is provided in **Error! Reference source not found.**. Similar to the SR 260 case study, roadway characteristic data was collected using Google Earth and as-built plans. The as-builts provided information on superelevation and grade. The calibration factor equation for two-lane Arizona rural highways was applied to roadway segments. Calibration factors ranged from 1.2 to 2.9. Since an Arizona calibration factor for unsignalized intersections is unavailable, a factor of 1.0 was used.

Rural Two-Lane Roads - Intersection - HiSafe US 191.hsmx Mon, Sep 07, 2015 4:54 PM

General Information

Analyst	DAT	Analysis Name	US 191 (Existing)	Date of Analysis	6/9/2015
Agency/Company	Kittelson & Associates, Inc.	Project Number/PIN #	H8124	Comments	
State	Arizona	Site(s)	US 191 MP 38-45.8		
Region/Area/City/County	Cochise County	Jurisdiction	ADOT		

Input Data

Major Street	US 191
Minor Street	Pearce Rd
Analysis Year	2010
Intersection Type	Unsignalized three-leg intersection (3ST)
AADTmajor (veh/day)	1,484
AADTminor (veh/day)	79
Intersection skew angle (degrees)	78
Signalized/uncontrolled approaches with left turn lane	0
Signalized/uncontrolled approaches with right turn lane	0
Intersection Lighting	No
Calibration Factor, Ci	1.00

Total Observed Crashes	FI	PDO	Total
By severity level	0.00	0.00	0.00

Summary Results

	Fatal and Injury (FI)	Property Damage Only (PDO)	Total
Predicted Annual Avg Crash Frequency	0.08	0.11	0.19
Expected Annual Avg Crash Frequency	0.08	0.11	0.18
Crash Severity Distribution	0.415	0.585	1.000

Crash Severity Distribution

	Fatal and Injury (FI)	Property Damage Only (PDO)	Total
Single-Vehicle			
Collision with animal	0.001	0.003	0.004
Collision with bicycle	0.000	0.000	0.000
Collision with pedestrian	0.000	0.000	0.000
Overturned	0.002	0.001	0.003
Ran off road	0.019	0.028	0.047
Other single-vehicle collision	0.001	0.002	0.003
Total crashes	0.023	0.034	0.057
Multiple-Vehicle			
Angle collisions	0.022	0.024	0.046
Head-on collisions	0.007	0.004	0.010
Rear-end collisions	0.021	0.033	0.054
Sideswipe collision	0.004	0.015	0.019
Other multiple-vehicle collision	0.004	0.004	0.008
Total crashes	0.058	0.079	0.137

HiSafe v3.0.2 Page 1 of 1

Figure 8. US 191 Safety Evaluation Worksheet – Intersection

Evaluation Results

Predicted and expected crashes were generated for each segment and intersection. Four scenarios were evaluated for existing traffic volumes: existing roadway conditions, widened shoulders to 8 feet with rumble strips, reconstruction the Pearce Road intersection to eliminate the flying-Y configuration, and adding a Two-Way-Left-Turn-Lane (TWLTL) north of the SR 181 intersection. Each of the improvement alternatives was recommended in the project PA.

Expected annual crash frequencies for the entire highway section are summarized in Table 7. Crash frequencies are calculated for existing (2010) volumes and future 2030 projected volumes.

The expected annual average crash frequency (4.8 crashes/yr) for the study section based on existing roadway and traffic conditions is very consistent with the observed crash frequency (4.6 crashes/yr). Unlike the SR 260 section, topography and weather do not have a substantial impact on crashes on this section of US 191. In this case, the expected crashes estimated using the HSM method are higher (106 vs 92) than using the 5-yr observed annual average. As such, long term crash reduction benefits would be understated using the 5-yr observed average annual crash frequency.

The safety performance evaluation results suggest that reconstructing the Peare Rd intersection and adding a TWLTL will have little effect on reducing crashes on this section of US 191 primarily due to the low daily traffic volume of approximately 1,400 vpd. Future (2030) traffic volumes are projected to increase 1 percent annually to approximately 1,800 vpd. Adding 8-ft shoulders with rumble strips is estimated to result in 21 fewer crashes over 20 years. Note that the effect of adding narrower shoulders and/or eliminating rumble strips can also be evaluated. The total potential benefit of the improvement, as shown in Table 8, is nearly $6.7 million over 20 years, $6.2 million for fatal and incapacitating injury crashes alone.

Table 7. US 191 Case Study Safety Evaluation Results

	Crash Frequency (crashes per year)			**Estimated 20-yr Total Crashes**	**Estimated 20 yr Total Crash Reduction**
	FI	**PDO**	**Total**		
Observed(Reported)	1.6	3.0	4.6	92	
Existing Roadway					
Expected 2010	1.6	3.2	4.8	**106.0**	
Expected 2030	1.9	3.9	5.8		
Remove Flying-Y at Pearce Rd					
Expected 2010	1.6	3.2	4.8	**105.0**	**1.0**
Expected 2030	1.9	3.8	5.7		
Add TWLTL north of SR 181					
Expected 2010	1.6	3.2	4.8	**105.0**	**1.0**
Expected 2030	1.9	3.8	5.7		
Widen Shoulders to 8 ft w/rumble strips					
Expected 2010	1.3	2.6	3.9	**85.0**	**21.0**
Expected 2030	1.4	3.2	4.6		

Notes: Reported crash frequencies are over the 5-year period July 1, 2005 through June 30, 2010.

Table 8. Estimated Benefit of Adding Widened Shoulders with Rumble Strips to US 191

	K	A	B	C	O	Total
Crash cost; ADOT HSIP Manual	$5,800,000	$400,000	$80,000	$42,000	$4,000	
Proportion of Total Crashes (5 yr observed)	0.048	0.048	0.048	0.189	0.667	1.000
Expected Crashes (Avg over 20 yrs)	5.0	5.0	5.0	20.1	70.3	105.40
Widen Shldrs to 8 ft w/rumble strips						
Expected Crash Reduction (Avg over 20 yrs)	0.9	0.9	0.9	3.5	12.4	18.6
Benefit over service life (20 yrs)	$ 5,137,143	$ 354,286	$ 70,857	$148,800	$ 49,600	$ 5,760,686

Discussion

The two case studies demonstrated the application of the HSM predictive method in the PA phase of the project development process. These case studies provide an overview of the predictive method application process, describe how the results can be used to assess the need for and benefit of countermeasures, and identify improvements to increase the value of applying the predictive method on ADOT projects. The following points summarize what was learned through the case studies.

Data Availability – All of the data required to apply the HSM predictive methods is either readily available from existing databases or can be easily gathered.

- Existing and projected future traffic volumes are maintained on databases accessible through the ADOT website.
- High quality crash data is available through the ALISS database and easily accessible through the Safety Data Mart. Processing of the data to identify duplicate crash records, distribute to each segment or intersection defined for the highway section being evaluated and sorting by crash severity (fatal, injury, PDO) is easily accomplished within a spreadsheet.
- Roadway characteristic data is available from several sources. The level of detail required is dependent on the tool used to implement the predictive method.
    - IHSDM requires detailed roadway geometry to construct an alignment, profile, and cross section. This information is available from as-built plans, however implementation can be time consuming, particularly for roadway sections where multiple improvement projects have been made since initial construction. Implementing the information from several projects can be tricky since the roadway geometry is entered by station. If CAD files are available, they can be easily uploaded into the model. Once the roadway data is entered, IHSDM automatically segments the section as required to implement the predictive method.
    - Using Google Earth aerials, roadway sections to be evaluated can be segmented and much of the roadway characteristic data gathered using EarthTools.

- The ADOT RCI database provides much of the roadway geometry information needed to implement the predictive method. The data is referenced by milepost which aides in segmentation.

Safety Performance Evaluation Tools – Tools available to implement the predictive methods include, IHSDM, the FHWA developed spreadsheets, HiSafe and AASHTOWare Safety Analyst. As noted, applying IHSDM requires more detailed roadway geometric information (obtained either from as-built plans or available in a CAD file) than is required using either the spreadsheets or HiSafe. Information gathered using a combination of Google Earth, the ADOT RCI database and as-built plans is sufficient for the application of these two evaluation tools.

Application of the HSM Methods – Application of the predictive methods in the two case studies was conducted using a local calibration factor equation developed by ADOT for two-lane highways in Arizona. While the crash prediction methodology without local calibration can be used to quantify the benefit of potential crash countermeasures, developing calibration factors for roadways with similar conditions provides a more accurate prediction of crashes over the long term. More accurate long term crash predictions will result in better estimates of the cost benefit of implementing alternative crash reduction countermeasures. Calibrating the crash prediction models intersections and other roadway types will allow for comparison of the safety performance of roadway sections between similar highway types throughout the state.

CHAPTER 5: NATIONAL BEST PRACTICES

The project team identified nine candidate states that have made positive strides toward meaningfully integrating safety performance into scoping and design processes based on the team's familiarity with national safety analysis activities. Detailed interviews were conducted with two states.

To select the states for detailed interviews, the project team asked the candidate states to respond to the following qualitative screening criteria:

- Does project design occur at: the DOT Central office, the DOT District Offices, or both. Describe what types of project are designed at the different offices?
- How is safety or the HSM currently being integrated into the project development process? Identify specifics of how the HSM is applied at the DOT.
- How mature is the integration process? How successful has the state been in deploying the HSM? What are some of the successes the DOT has had in implementing quantitative safety analysis?
- What safety software/tools are being used and how?
- Does the DOT have a planning document or guidance for integrating safety into its project development process?
- Is tort liability and reduction of risk a consideration in your project development process and if so, how?

The project team conducted pre-screening conversations/emails with the departments of transportation from nine states:

- Alabama
- Florida
- Illinois
- Kansas
- Louisiana
- Ohio
- Texas
- Utah
- Washington State

After multiple efforts, the team was not able to reach Utah and Washington State. Table 9 through Table 15 summarize the qualitative assessment results for: Alabama, Florida, Illinois, Kansas, Louisiana, Ohio, and Texas. Ohio and Texas were selected for interviews. At a later date it became possible to interview Washington State. Although Washington was not pre-screened, based on familiarity with Washington's work, the team recommended that Washington be interviewed. When Texas was no longer available for interviews, the team made efforts to contact Illinois instead; however they were not available either. In the interest of moving the project along, the choice was made to interview Washington and Ohio.

Table 9. Potential Candidates for State DOT Interviews - Alabama

State: Alabama

Contact: Tim Barnett

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
Design occurs at both the Division/Region Offices and Central Office. A reorganization is in process that will move majority of design into five Regions.	Design Exception Process. Working on integrating safety into all phases of a project, planning through post-construction. Developing a Road Safety Assessment Manual that will guide users on considering safety and how to evaluate projects at all stages of planning, design, construction, maintenance, and operation.	Medium, with a lot of work to do!	Critical Analysis Report Environment (CARE), which houses and provides a tool to analyze crashes on all routes within the state. Working on other tools that will simplify the analysis process, including a Roadway Improvement Safety Evaluation tool, and considering other commercially available tools, such as Vision Zero Suite, SafetyAnalyst, etc.	Yes, there is a Safety and Operations (S&O) Integration Study underway to identify opportunities to integrate S&O at all phases of ALDOT projects, within the management of the various programs within the DOT and with agencies at the local level (counties, MPO/RPO, cities/towns). This project is still ongoing.	Yes, as a Sovereign Immunity State, it is important that we strive to maintain the legal protection that the courts have provided to us. We have current programs and are developing programs that are risk-based and not solely reliant on crash history to justify safety improvements.

Recommendation: Do Not Interview – Design occurs at central and district offices, and the State has been using quantitative safety in design exceptions; however still working on other aspects of the process.

Table 10. Potential Candidates for State DOT Interviews (continued) - Florida

State: Florida

Contact: Joe Santos

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
FDOT is decentralized, so design is done at the District level. Central office does do design for some special projects, but it is rare. Project type depends on the scale of the project and type of contract. Some project work such as design-build is contracted out. Safety design is typically done in-house.	Florida is not as far along as they'd like to be. The PD&E manual has language for alternative alignment analysis that includes safety analysis be done in accordance with the HSM. However, it is optional, so FDOT is not sure how extensively it is being done. The Systems Planning office published a Traffic Analysis Handbook in March that provides guidance on use of the HSM for considering safety in interchange analyses and traffic overall. Districts could follow that process for PD&Es and alternatives analysis.	Medium. Florida considers themselves to be lagging other states who are actively engaged in HSM implementation. They have been very successful in deploying the HSM. The process started with planning meetings to identify focus areas. They identified the need to get management and DOT Secretary support, and this was an important first step. They followed up with statewide training. Challenges include keeping the fire lit and achieving commitment and consistency across different offices (e.g., planning vs. design). One success – they have been initiating the process through design exceptions.	HSM predictive method, 17-38 spreadsheets, and internal screening tools (e.g., high crash cluster analysis using GIS tool). Working to deploy SafetyAnalyst, and they are discussing deploying IHSDM.	Part 1, Chapter 4 of the FDOT PD&E manual addresses HSM, and the Traffic Analysis Handbook provides guidance on use of the HSM for evaluating safety in interchange and traffic analyses.	Unknown

Recommendation: Do Not Interview – The State has developed manuals and provided training. However, they are not sure of degree of usage and consider themselves lagging behind other states.

Table 11. Potential Candidates for State DOT Interviews (continued) - Illinois

State: Illinois

Contact: Priscilla Tobias

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
Project design occurs at the district office primarily. Projects are programmed for the scope of work in collaboration between the district office and the Central Office of Planning Programming (OPP). As an example, the OPP would identify targets for pavement conditions on interstates, give allotments of funding for 3R, SMART (single lift overlays), 3P (2 lift overlays), etc. The districts determine based on a variety of items what projects will go into the multi-year program. Then phase I and phase II are done in the district either by IDOT staff or with consultant staff and oversight by IDOT district office. The district office has to coordinate with IDOT Central Office for design policy exceptions, etc. and presents the project scope, etc. at a bimonthly	<u>Safety Incorporated into our project development process</u>: Our overall funding distribution to the districts is determined on a variety of components but the 5 year average of fatalities within each district is a factor. In addition, the 5 year fatality average is considered when allocating HSIP funding to the districts. We have statewide HSIP funding that is used for statewide safety initiatives primarily. We also put 20% of our HSIP to local roadways for local agencies to apply for funding of safety projects. <u>Utilizing the HSM and safety overall in Project Development Process</u>: We have utilized HSM Part B since 2007. We perform an annual safety analysis/network screening to determine the Potential for Safety Improvement (PSI) value utilizing Illinois Safety Performance Functions (SPF) with weighted K's, A's and B's factored in. Each state route segment and intersection has a PSI. Thus, we have a "100% List" as well as our "5% List" which is used to	Hi–h - Illinois has a robust safety analysis process but we are always looking to build on what we have. The methods of safety analysis have demonstrated significant and continued reductions of fatalities and serious injuries on state routes. We are now expanding safety analysis to local roadways and have created a 5% list for local roadways	IHSDM, usRAP Illinois Enhanced Spreadsheet 17-38 Illinois developed B/C tool. Safety Performance Functions Safety Analyst GIS, Illinois Safety Datamart ISATe	Working on this.	A documented, thought out engineering analysis process that is consistent minimizes liability. Illinois also does have limited liability caps.

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
meeting with Central office and FHWA. Bridge plans are done through a variety of means-Our central Bridge Office or through a consultant on hire by the district. Signing plans may be done in our central bureau of Operations. HSIP/Safety Projects are designed in the district offices.	elevate safety as a consideration for project funding. We have identified a critical PSI and it is those locations that are 5% or have a critical PSI that would be considered as having a high potential for safety improvement. Each district is provided the PSI list for their district so that they can perform analysis-diagnosis. We work closely with Illinois State Police (ISP) to determine what human factors contribute to the roadway crashes. They select countermeasures based on their analysis, perform an economic analysis using our B/C tool, and submit HSIP projects for consideration of funding. Our B/C tool incorporates CMFs. For Projects broader than HSIP, we have recently calibrated Part C SPFs for Illinois. We will be holding a workshop for the districts to demonstrate the use of these so they can better understand their application. Some of the districts require the use of part C in the analysis when doing project scoping and design. We have used ISATe for analysis of interchange alternative designs and safety.	(125,000 miles of roadway for Illinois), heat maps, etc. Our calibrated SPFs include local roadways. The B/C tool can be used for local roadways. We are now testing Safety Analyst to implement in our districts.			

Recommendation: Interview in Lieu of Texas as approved by Project Sponsor. – The State has an advanced HSIP related practice. However, the degree of deployment to other aspects of the project development process is not clear. Representatives from the state were not available for detailed interview within the time frame of the project activities. With approval from the Project Sponsor, this interview was eliminated.

Table 12. Potential Candidates for State DOT Interviews (continued) - Kansas

State: Kansas

Contact: Howard Lubliner

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
Virtually all design occurs at the KDOT Central office. The only projects developed at the Districts are pavement rehabilitation projects.	While safety is considered on every KDOT project there is no formal mechanism by which safety is analyzed on those projects. Our project managers and consultants have generally been educated on the capability of the HSM and through this we have seen inclusion of quantitative safety analysis on our projects.	Medium/High We have seen full scale implementation of HSM analysis for rural two-lane highways, which is the only model we currently have calibrated. Results of this model have informed decisions on major scale projects, which I would say is very mature. We are currently doing research on state related CMFs, calibrating other models, and utilizing other models and CMFs on a project specific basis which I would say is medium maturity.	We primarily use IHSDM on our projects and recently hosted a class on iSATe. We have not historically used any of the spreadsheet tools.	Again, we have no formal inclusion of safety analysis in our design process.	We do not have a formal analysis of risk, including liability, in our project development process. We have historically utilized design exceptions which do, in a manner, document the analyses when design criteria are not met.

Recommendation: Do Not Interview – No formal process for integration yet. The DOT does seem committed to integrating safety into the design activities.

Table 13. Potential Candidates for State DOT Interviews (continued) - Louisiana

State: Louisiana

Contacts: Dan Magri and April Renard

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
At the District level, most design work is limited to projects in their overlay programs. Other projects are submitted to HQ design, who decide whether to do the work in-house or use their retainer contract. If project is big enough, it will be bid out. HQ is working to get Districts to do smaller safety projects. However, these projects sometimes get pushed to the back burner if a higher priority issue comes up. To assist with this, HQ offers support through their retainer contract.	LaDOT is working to expand the knowledge base outside of HQ safety section, but requests for in depth analysis still come to HQ. They recently developed guidelines for Crash Data Analysis, as well as Guidance for Using Crash Modification Factors (CMFs). They find CMFs are easier for other staff to implement because they can pull the CMF value for the type of improvement they want to implement. In addition, they have calibration factors for the State, and they are starting to incorporate those into other types of projects.	Medium maturity within the Safety Group. Outside of safety, maturity is low. They have developed a guidance document on CMFs and posted it to their Highway Safety Analysis Toolbox website, but people aren't using it.	The Vision Zero Suite is still being developed. They have 3-4 SPFs and they have procured the software and done training. They are starting to train Districts and other users on the software. They plan to use the software as a diagnostic tool to analyze crash site characteristics and whether crashes are overrepresented. However, they are still 2 years away from full implementation. LaDOT has developed state calibration factors for all 8 segment types in the HSM. In addition, they are using IHSDM and iSATe. They are finding that iSATe is more complicated to work with and produces the same results as IHSDM, so they prefer IHSDM.	Developed HSM Implementation Plan. Considering a plan to integrate safety into design	Unknown whether LaDOT considers tort liability in the project development process. LaDOT works with the AG office when dealing with traffic crash cases. Attorneys on staff give legal guidance on certain types of projects and contracts, but they don't get involved with cases.

Recommendation: Do Not Interview – There is limited safety analysis or safety specific consideration beyond the safety group at LADOTD.

Table 14. Potential Candidates for State DOT Interviews (continued) - Ohio

State: Ohio

Contact: Derek Troyer

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
Central office no longer completes any design work. District offices have limited design activities. Most design is completed through a general services contract with a consultant that has a set amount of funding each fiscal year and is renewed each year. Districts create this contract and select the consultant.	Safety is integrated only in the design exception process. http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/roadway/Location%20and%20Design%20Manual/Section_100_Jan_2014.pdf http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/Pages/DesignExceptions.aspx.	Medium – Ohio has well-developed analytical processes.	SafetyAnalyst for network screening Ohio custom tools include: GIS Crash Analysis Tool Crash Analysis Module Economic Crash Analysis Tool	Safety is of high importance at ODOT. Luckily our office has strong ties with key players in operations and maintenance that will help us deploy additional safety strategies including implementation of the Highway Safety Manual.	Ohio has not had an issue with this to date. They are following this story though.

Recommendation: Interview – The State has well developed analytical capabilities for network screening, and they are using SafetyAnalyst/HSM extensively for the Highway Safety Improvement Program (HSIP) and long range planning.

Table 15. Potential Candidates for State DOT Interviews (continued) - Texas

State: Texas

Contact: Rory Meza

Screening Results:

Centralized or Decentralized DOT?	How is safety (i.e. HSM) currently being integrated?	Maturity of Safety Integration	What safety software/tools are being used?	What type of HSM Implementation planning has been done?	How is tort liability a consideration in the project development process?
Decentralized – Engineers in Districts review crash data during the project development and design process.	Safety is integrated into the planning & programming, preliminary design, and plans, specifications, & estimates (PS&E) development stages of the project development process. TxDOT Research Project 0-4703 "Incorporating Safety into the Highway Design Process" produced a series of safety prediction models to estimate expected frequency of crashes for various facility types. The models were calibrated using crash and geometric data from the Texas highway system.	High - The safety analysis done by TxDOT on projects is relatively mature at this point compared to other states.	Tools developed under research project 0-4703 include a Roadway Safety Design Synthesis, Interim Roadway Safety Design Workbook, and Procedure for Using Accident Modification Factors in the Highway Design Process. The workbook includes procedures for predicting the crash frequency associated with alternative design components. Designers are able to use these procedures to evaluate the safety impacts of alternative designs. A spreadsheet has been developed to accompany the workbook, which automates the calculation of safety effect and minimizes the time required to complete a safety evaluation. In addition, the procedures are automated in the Texas Roadway Safety Design (TRSD) software.	In addition to the Synthesis, Workbook, and Procedure documents, TxDOT conducted a multi-year workshop series to educate staff on the role of safety in highway design for rural two-lane highways, urban/ suburban arterials, and rural multilane highways and freeways.	Safety is the primary consideration in the design of projects. Tort liability is not a consideration in project design.

Recommendation: Interview – Although design is decentralized, safety analysis has been undertaken for many years. There are workbooks and procedures for integrating safety into projects. After being selected for interviews, there were staff changes as Texas DOT and staff was no longer available for the interview. Illinois dot was selected to replace Texas; however as previously described they were also not available for the interview. With approval from the Project Sponsor a third state interview was eliminated.

State DOT Interview Outcomes

Based on the qualitative pre-screening and staff availability for further conversations, detailed interviews about integrating safety into the project development were conducted with representatives from Ohio and Washington State DOT. The goals for the interviews were to understand:

- What progress has been made to date in integrating quantitative safety into the State's project development process?
- What have been the key first steps in integrating quantitative safety into their project development process? and
- What are the transferable lessons learned?

The complete interview guide is included in Appendix B. The questions listed in the guide were not used verbatim; rather, the questions were used to organize the conversation and serve as a reminder of the array of topics that should be included in each conversation. The interviews are summarized into the following categories of information:

- Project Development Process
- Safety Analysis Tools
- HSM Implementation Planning
- Risk Management and Tort/Liability

Interviews were conducted by telephone on the following dates:

- Washington State DOT, John Milton, December 10, 2014
- Ohio DOT, Derek Troyer, December 15, 2014

Washington State DOT

Project Development Process. WSDOT pointed out several options for integrating safety analysis:

- Implement a process for evaluating safety characteristics of a specific project. The HSM can be used for site safety assessments. Ideally, Empirical Bayes (EB) methods are used to identify locations with a higher than expected crash rate (or frequency), and to prioritize locations projects for safety improvements based on need. If not crash frequencies or rates can be used if sites are properly categorized (e.g. comparable functional classification, geometry and traffic volume);
- Deploy a systemic approach and identify risk factors associated with crashes. Identify treatments and associated Crash Modification Factors (CMFs) for the locations; or
- Associate treatments with specific crash types to be addressed (e.g., rumble strips to run off road crashes) and deploy "standard" treatments for sites with these crash types.

WSDOT also emphasized that ADOT should define what is meant by safety performance and, define methods for assessing performance on different project types. For example, the ADOT Strategic

Highway Safety Plan targets fatalities and serious injuries. ADOT should consider/confirm whether fatalities and serious injuries should be considered the safety performance measure in the project development process.

WSDOT also encouraged ADOT to consider working from the perspective that sites can be evaluated for crash potential. A site's observed crash frequency could be compared to the potential for crashes at the site and countermeasures identified to address sites with potential issues. There are various ways to estimate crash potential at a site: average crash frequency or crash rate, outcomes from SafetyAnalyst, or the HSM Predictive Method.

Safety Analysis Tools. WSDOT uses the HSM Predictive Method for projects with alternatives analysis (e.g., interchange justification reports). Crash Modification Factors are used for project scoping and for smaller projects.

SafetyAnalyst is used for roadway segment network screening. They are very close to implementing SafetyAnalyst for ramps and intersections network screening. They have also developed Washington State specific Safety Performance Functions for many facility types.

HSM Implementation Planning. WSDOT believes that it is necessary to have an internal champion responsible for developing programs, policies, projects, training, etc. for helping ADOT implement HSM analysis methods. WSDOT believes the responsible person should have a design and traffic operations perspective. From WSDOT's perspective, the champion would be within the Planning/Programming group to meaningfully bring quantitative safety into project decision making.

WSDOT advised that over time, ADOT may want to continue studying data availability and gaps to develop a strategic and prioritized data collection program which supports safety analytical needs in the project development process. Ultimately, ADOT would want to be sure that data elements are collected for issues which have the greatest potential impact on reducing fatal and serious injury crashes. WSDOT acknowledged that prioritization of data needs and degree of accuracy of data needs will become easier as ADOT has more experience applying the quantitative safety analysis methods.

No formal safety analysis training is being done at WSDOT, although they did develop pilot courses and a structure of fundamental courses for safety analysis. This included HSM training, sustainable safety, human factors, and analytical training. Ultimately, they found more success through small implementation steps and growing skills through on the job application of safety analyses.

Risk Management/Tort Liability. Application of HSM methods/tools is primarily used for discretionary immunity related issues, as well as providing a defensible position when WSDOT is questioned regarding implementation of one type of project versus another. Project deviation analysis within WSDOT has gone well in terms of demonstrating reasonableness of conduct.

Documentation is an integral part of the decision-making process. From corridor analysis at the planning level to final decision making, WSDOT maintains a single document called a Crash Analysis Report that has input from planning, programming, and design/operations. This report includes descriptive crash statistics and SafetyAnalyst results. The information is given to designers who use it to make decisions regarding design. This approach allows WSDOT to obtain buy-in at critical gateways throughout the project development process.

In terms of tort liability, WSDOT will accept more risk in design elements if there is a substantial safety outcome. Safety is favored above risk assessment. WSDOT suggested that a major success factor in getting away from design standards is to understand crash contributing factors (i.e., what is it we are trying to achieve?).

WSDOT does utilize safety performance evaluation in its design exception process. In the past, it was more of an anecdotal process. Now, WSDOT goes through the HSM process – i.e., what is the anticipated crash reduction? What countermeasures can be used to mitigate the design deviation?

Ohio DOT

Project Development Process. Ohio DOT (ODOT) found it easiest to begin integrating quantitative safety into the project development process within their safety program. For HSIP funding, project locations are identified using SafetyAnalyst. Ohio DOT prioritizes projects for funding based on whether the project location is on the list of high crash locations in the state.

The next step was integrating safety into the design exception process for roadway engineering. During the project development process, roadway engineering staff work with safety staff to determine whether the project location is on the list of high crash locations. If a project location is on the high crash list but doesn't meet the full roadway design criteria, roadway engineering staff must complete a detailed analysis to justify the design exception from safety perspective. If a project location is not on the high crash list, it is not necessary to justify the design exception from safety perspective. ODOT would like to implement a safety performance evaluation process, but there haven't been enough time/resources.

ODOT relied on existing relationships and processes to get roadway engineers to participate in process. ODOT already had a safety screening methodology in place as part of the design process, which required a safety analysis be performed if the project location fell below a certain crash threshold. When redoing the roadway design process, the roadway group approached the safety group for their input. The Safety Group helped the roadway group implement easy-to-understand criteria for the design exception process.

ODOT's long term goal is to integrate quantitative safety into the traffic impact study process. There has been an increase in HSIP funding requests due to an increase in crashes associated with development projects. ODOT's goal is to incorporate HSM criteria into the traffic impact analysis process to assess the safety implications of development projects.

ODOT would like to incorporate the HSM/SafetyAnalyst screening criteria into the long range planning/programming process for projects in the $15M range. ODOT's long range plan was recently updated in 2012. They used the predictive model of SafetyAnalyst to analyze macro corridors with significant increases in traffic volumes. They also used SafetyAnalyst to analyze drug/alcohol crashes in rural areas.

Safety Analysis Tools. ODOT uses safety analysis tools on a regular basis. They have calibrated SPFs for the state, and they have developed the HSM Analysis Tool[1], which is an Excel tool similar to the NCHRP 17-38 spreadsheet, for conducting HSM analysis. The tool is customized to Ohio and also does alternatives analysis (e.g., analysis of crash frequency with a turn lane vs. without). The tool includes crash modification factor (CMF) analysis using Parts C and D of the HSM. Local agencies can use the tool, which provides consistency when local agencies submit funding requests to ODOT.

The Safety Group works hard to provide tools for District and local agencies. Another tool they have provided is the Safety Work Plan Database, which is a Microsoft Access file that is used to manage projects for Districts. When a District does a safety project or implements a systemic improvement, they enter the project data into the database. The Safety Group has developed the following training videos on how to enter data into the database. They have found that training videos with live demonstrations tend to be better received than written documents.

HSM Implementation Planning. Implementation of ODOT's safety studies program at the local agency level started off slowly, but it has gained momentum through development of the HSM Analysis tool that can be used by local agencies to justify improvements. Initially, ODOT did have push back from local agency staff who were seeking design exceptions for basic projects (e.g., repaving a two-lane rural road).

The Safety Group is responsible for the success of integrating quantitative safety into ODOT's project development process. They did this by working with ODOT groups they already had a relationship with. When other groups are aware the Safety Group exists, they come to them for input when they are updating their processes because they have worked with them before. The Safety Group works with these groups to recommend ways to incorporate safety into their processes. Responsibility for implementation and advancement of safety analysis lies with the Safety Group, and they keep building and improving the process as they can. FHWA's Every Day Counts (EDC-3) initiative may help improve the process.

In general, ODOT's preferred approach to initiating new processes is conducting pilots, and if successful deploy things more broadly. They don't tend to write a lot of documents. They also continually work to make the process better.

In addition to building on relationships that are already in place, ODOT noted that another success factor is to demonstrate the positive aspects and successes associated with the changed/improved processes. In terms of ownership of the quantitative safety process, ODOT suggested that as long as a group understands the intention and outcomes, they should be able to incorporate safety analysis into their processes.

[1] (http://www.dot.state.oh.us/Divisions/Planning/ProgramManagement/HighwaySafety/HSIP/Pages/ECAT.aspx)

Risk Management/Tort Liability. In terms of tort liability considerations when using HSM methods for decision making or setting priorities, ODOT makes sure everything related to developing the priority list is documented. This includes what they study, how locations are prioritized, and how locations are addressed (e.g., procedural guidelines on how safety projects receive funding, and how projects are initiated). This documentation is what they take to court.

Federal law allows states to use a priority list to prioritize project locations. Once ODOT has identified a priority location and potential project, they use CMFs along with severity indicators (i.e., severity index) to make decisions on the type of improvement to implement and the various alternatives that are considered. All scoring criteria are documented and made public. For projects that are over $500,000, ODOT requires a full safety study that includes documentation of every alternative under consideration. For these studies, there could be environmental impacts or construction reasons that limit the alternatives considered. ODOT includes every countermeasure based on crash patterns, and then they start eliminating alternatives due to safety, environmental, or funding reasons. In addition, in the process of selecting one improvement/location over another, ODOT includes consideration of high likelihood of a certain crash type occurring. The thought is that if they are doing work at a location anyway, it might be best to go ahead and mitigate that risk.

The ODOT Safety Group gets involved in tory liability only when there is a case. They are not proactive in tort liability risk.

Neither ODOT's risk management nor the Attorney General's office does any training on risk management/tort liability. ODOT noted that its Local Technical Assistance Program (LTAP) might be the best area to do training, since their focus is on assisting local agencies in managing and maintaining the transportation system. LTAP conducts 3 to 5 training workshops on crash countermeasures each year. Ohio has a $200M safety program, and most local agencies are looking for assistance in this area. In addition, all ODOT employees are required to complete an online fraud and ethics training course each year, and this training includes several questions related to tort liability.

Summary

Both Washington State and Ohio have Safety Analyst up and running and are using it on a regular basis. Both DOTs have SPFs available and have state-specific tools available to help practitioners. Both states encouraged ADOT to start with small steps and use the best available data and methods. Data and tools can be developed or enhanced as implementation grows.

The difference in how WSDOT and ODOT have achieved their success was notable. WSDOT encouraged ADOT to identify a champion with a design and traffic operations experience and advised that champion have planning/programming responsibilities. At ODOT the Safety Group is responsible for implementation of the HSM methods. As both states have successful deployment of the HSM, both models, and probably others, can be successful. Table 16 summarizes findings from the Washington State and Ohio DOT conversations.

Table 16. Summary of Interviews

Category	Washington	Ohio
Project Development	• Strive for EB methods when possible. Consider also systemic and treatments associated with specific crash types (e.g., rumble strips to run off road crashes) • Define safety performance for the DOT • Consider perspective of site crash potential	• After integrating HSM analysis methods in safety program, next step was including HSM analysis methods in design exception process. • Staff worked with safety group to conduct analyses • Also looking to integrate HSM analysis into traffic impact analysis process, and long range planning.
Safety Analysis Tools	• SafetyAnalyst for road segments, intersections and ramps next • Predictive method with state specific Safety Performance Functions (SPFs) • Crash Modification Factors for small projects • CMF selection tools	• SafetyAnalyst for road segments, intersections and ramps next • Calibrated SPFs • Spreadsheet tools for predictive method • Crash Modification Factors • Database tool for recording projects
HSM Implementation Planning	• An internal champion is needed. WSDOT believes the champion would have a design and traffic operations perspective, and be located in a planning/programming business group. • No formal safety training is implemented. Build skills through on the job project activities. Have started small and continued to grow. • Monitor data needs compared to data availability and accuracy. Begin working toward a data management program, but focus on applying methods with the best available data first.	• Safety group is responsible for the success of integrating safety in the project development process. • Online tools and tutorials have been helpful to local agencies and districts • Focus on and “market” the value of quantitative safety analysis. • They have an implementation plan timeline with a goal for when safety is integrated. Deploy pilot programs and work with staff to achieve the integration.
Risk Management and Tort Liability	• HSM methods and tools used for discretionary immunity related risk issues • Provides a defensible position for alternatives analysis • Documentation is important; WSDOT maintains a single safety related document called Crash Analysis Report. The report has input from planning, programming through to design/operations • WSDOT will accept more risk in design elements if there is a substantial safety outcome	• Emphasize documentation • Transparency of information • Recognize it may be useful to mitigate risk if working at a site for other purposes • No official training on risk management/tort liability; noted that LTAP program may be a good program for this training.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

ADOT proceeded with quantitative safety analysis to enhance its safety management program and continues that commitment with the effort to include descriptive or quantitative safety analyses within the project development process. The project scoping phase was identified as the most likely phase of the project development process to include descriptive and quantitative safety analysis.

In addition, interviews with ADOT staff showed a recognition of the need for training to fully integrate descriptive and quantitative safety analysis into project development. ADOT staff recognizes a commitment to provide training in safety analysis methodologies will allow for greater acceptance throughout the organization.

To demonstrate the practical application of the HSM, this research project applied the predictive method process to ADOT project case studies. The results showed how to assess the need for and benefit of countermeasures, and to identify improvements that can enhance the value of applying the predictive method on ADOT projects.

A review that sampled best practices at other state DOTs encouraged starting with small steps and using the best available data and methods. This review showed that data and tools can be developed or enhanced as implementation grows and that documentation is essential. Finally, identifying a champion with design and traffic operations experience, plus planning/programming responsibilities, is a key staffing assignment.

The commitment to complete a safety analysis on every project for informed decisions means fitting this analysis into the existing project development process.

ADOT can be successful with implementation of descriptive and quantitative safety analysis by committing to revise applicable policies and guidance documents, establishing an ADOT champion to lead this effort, and by dedicating funds to a comprehensive training program to ensure Department staff has the appropriate skills to meet the safety analysis requirements.

RECOMMENDATIONS

The framework recommended for integrating safety in the project development process is summarized below and in Appendix C. The framework considered the full Arizona Department of Transportation (ADOT) project development process and specifically identified three phases in project development where a safety performance analysis could be completed: planning, scoping, and design of projects. The framework includes specific recommendations on the extent of safety analysis required for each type of scoping document and a potential timeline for overall implementation.

Safety Analysis Methodologies

The framework is based on five types of safety analyses being integrated into ADOT's project development process. The methods range from the most basic effort of objective safety evaluation to the most comprehensive analysis using the HSM Predictive Method. The appropriate analysis method depends on the characteristics of the project and the needs of decision makers for quantitative analysis of traffic safety impacts. The analyses are described below.

Type A – Descriptive Assessment

Identify traffic safety trends based on descriptive assessment of crash data only. Review five-year crash history including frequency, severity, type and location, and trends to determine contributing factors. Use GIS to map crashes in the study area.

Type B – Comparative Assessment

Compare five-year average frequency or crash rate (fatalities and serious injuries) at a particular location to statewide average frequency or crash rate (fatalities and serious injuries) by functional classification and traffic volume range.

Type C – Using CMFs

Apply CMF analysis to estimate the safety performance of proposed roadway design features or the controlling design elements for design exceptions/variances change

Type D – HSM Predictive Method

Apply the HSM Predictive Method using calibrated Safety Performance Functions (SPFs) to estimate change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency.

Type E – Calibrated HSM Predictive Method and Benefit/Cost Analysis

Apply calibrated predictive method to estimate change in crash frequency and severity. Apply results in cost benefit analysis.

Safety Analysis Implementation Phases

Long-Range Transportation Plans

The long range planning phase includes all the transportation planning and analysis required to identify and prioritize transportation projects at the state, regional and local community levels. Planning studies begin with an inventory of current conditions, including traffic safety considerations, in the study area. Once existing conditions are established, the study then proceeds to forecast conditions in a future horizon year and analyzes the ability of the existing transportation system to meet future demand. Deficiencies and needs are subsequently identified. Project planning provides an opportunity to use safety countermeasures and their impact in selecting between different project alternatives. From a traffic safety perspective, this effort could include a range from a descriptive assessment to application of calibrated predictive method. The long range planning safety analysis could include safety analyses Type A, B, C, D, and E depending on the level of safety integration within the planning process.

Scoping Phase Documentation including Design Exception/Variance

The scoping phase was targeted because of the potential value of integrating safety considerations early in the project development process. The scoping phase allows for the consideration of safety elements while establishing the budget, scope, and limits of the project. The scoping phase safety analysis could include Type A, B, C, D, and E depending on the level of safety integration within the project development process.

Design Phase Documentation Including Design Exception/Variance

During the design phase, the final roadway alignment and the design exceptions/variances that are required will be finalized. A design exception is required when existing features left in place or proposed features do not conform to current design criteria as specified in the Roadway Design Guidelines (RDG).

A design variance is required when new construction does not meet design criteria specified in the RDG. Both processes allow for the opportunity to apply quantitative safety analysis to enhance the decision making process regarding these items.

Applicable Project Scoping Documents

Implementation of the framework should be focused on three documents typically prepared during the project scoping phase – scoping letters, project assessments, and design concept reports. These documents are part of the current project development process and can readily be modified to include safety analysis as part of the content. These types of analyses are identified as near-term because the crash data is readily available from ADOT and to a limited extent the analysis methodologies are currently being performed by ADOT staff and project design consultants. The three documents used in project scoping are:

Scoping Letters

The scoping letter is the simplest method of documenting a project's scope, schedule, and budget. It is prepared for all projects not requiring a detailed analysis for project definition. Projects covered by a scoping letter usually involve a single technical discipline. The scoping letter would be a Type A descriptive assessment of the safety items within a project.

Project Assessment

A project assessment is prepared for highway projects requiring physical construction of the roadway and where existing environmental categorical exclusions/environmental determinations are sufficient.

Design exceptions/variances should be included in project assessments. The project assessment safety analysis could include, depending on the characteristics of the project, safety analyses Type A, B, C, D, and E. If the project will include design exceptions within the project assessment, then a Type C or D analysis would be required.

Design Concept Report

A design concept report is prepared for major projects where different roadway alignment alternatives are being considered and would include an environmental considerations beyond a categorical exclusion. Design exceptions/variances should be included in the design concept report. The project assessment safety analysis could include, depending on the characteristics of the project, safety analyses Type A, B, C, D, and E. If the project will include design exceptions within the project assessment, then a Type C or D analysis would be required.

Implementation Time Frame

ADOT wants to continue advancing its safety management program through the implementation of safety performance methods and tools. It is recommended that a phased approach be taken to build this objective safety assessment process to ensure a smooth transition with limited impact to the existing project development process. Included in this phased approach recommendation is the continuation of the ADOT practice to utilize current pilot tests as a beginning stage toward full implementation of the described safety performance methods.

The framework includes timing recommendations for when to implement safety performance methods used on key processes. These implementation time periods are:

- Short term deployment – current practices
- Midterm deployment – current pilot applications moving to full implementation within three years
- Long-term deployment – all methods within five years.

Table 17 combines the information for the ADOT processes with the recommended safety performance analyses. Also, the table shows mid- and long-term deployment of safety performance into ADOT’s project development process as well as current practice and current pilot applications of the HSM.

Table 17. Framework Deployment Summary

	Long Range Transportation Plan	Scoping Letters	Project Assessment	Design Concept Report	Design Exception/ Variance
A. Descriptive Assessment	Current Practice	Current Practice	Current Practice	Current Practice	
B. Comparative Assessment	Current Practice		Current Practice	Current Practice	
C. CMF	Current Pilot Applications		Current Practice	Current Practice	Current Practice
D. HSM Predictive Method			Current Pilot Applications	Current Pilot Applications	Current Pilot Applications
E. Calibrated HSM Predictive and B/C				Current Pilot Applications	

Short-term Mid-term Long-term

Training Recommendations

For ADOT to be successful in achieving the objectives of implementing quantitative safety analysis within the project development process, a comprehensive quality training program is required to ensure the Department's staff has the tools to meet the safety analysis requirements. ADOT has hosted HSM training three times and IHSDM training once. FHWA has developed a series of training courses on specific parts of the HSM that are offered through the National Highway Institute (NHI) which could provide the basis of a training program. It is recommended ADOT staff that is currently performing the safety analysis be the priority for this training to ensure their efforts continue and are enhanced. ADOT must ensure it is on the path to increase quantitative safety analysis training and use of the HSM within the Department staff. To be successful, ADOT must have a larger number of staff that have the knowledge and skills to deliver effective and efficient safety analysis.

Policy and Guidance Revisions

The framework was developed to fit within the existing project development. However, since the framework recommends including safety analysis within the process, it is recommended that the following ADOT documents be updated to include the framework recommendations.

- Policy 88-2: Project Assessments
- Traffic Guidelines and Processes
- Project Scoping Document Guidelines
- Guidelines for Scoping Pavement Preservation Projects
- Design Exceptions and Design Variance Process Guide

By including the framework recommendations in policy and guidelines, there will be a higher level of commitment to complete the necessary safety analysis. In addition to revisions to these documents, it is also recommended that ADOT prepare a safety analysis procedural manual. This manual will describe the Type A, B, C, D, and E analysis procedures in detail, including data requirements and sources, description of available analysis tools, availability of SPF calibration factors and statewide average frequency or crash by functional classification and traffic volume range, and example applications of each analysis type. This manual will be needed to support the application of safety analysis by a broad range of ADOT staff responsible for planning and project development.

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APPENDIX A. ADOT STAFF INTERVIEW GUIDE

PLANNING & DESIGN LEADERSHIP

Interviewees

- Steve Boschen, Deputy State Engineer – Design
- Mike Kies, Director Planning and Programming

Interview Guide

Your Role

- Tell us about your role and responsibilities.

Current Policies and Practice

- On roadway improvement projects, safety is currently addressed through several avenues, including continual review of design standards and assessment of safety issues and potential mitigation measures in the project scoping process.
    - With the greater focus on performance-based safety programs in MAP-21, what potential changes in the current ADOT safety practice do you feel need to be considered?
    - What challenges or impediments do you see with implementing a performance-based safety program at ADOT? Institutional, political?
- Do you feel safety is appropriately addressed at the planning level?
    - How is safety incorporated in the project prioritization process?
- What might be the impacts on current policies and practice with a performance-based safety approach?
- Would you envision any issues with utilizing performance-based safety methods in supporting a design exception?
- To what degree are you aware of the ADOT's tort liability risk and what is your role in reducing that risk? Is tort liability risk a specific consideration in Design? If so, how is it handled? [For Steve Boschen]
- Is tort liability risk a specific consideration in the Planning and Programming process? If so, how is it handled? [For Mike Kies]

TRAFFIC ENGINEERING

Interviewees

- Regional Traffic Engineering –Scott Beck (Tucson)
- Traffic Design – Trent Thatcher and/or one of the design team leaders
- Traffic Safety – Kohinoor Kar

Interview Guide

Your Role

- Tell us about your role and responsibilities.

Current Safety Practices

- Outside of safety specific projects, what types of projects are using quantitative safety performance measures?
- How is the need for safety improvements to existing facilities identified?
- What type of information/sources are used for problem identification and for identifying potential solutions (e.g., informal interaction, formal interaction, system evaluation programs, crash data analysis, other safety-related data, etc.)?
- Does the transportation plan and program include safety-related projects and strategies? Are they appropriately identified in the documents?
- What constraints/issues/challenges would be involved with making safety assessment a more explicit part of project development activities?

Safety Analysis Tools and Familiarity with HSM Related Tools

- What safety analysis tools are used regularly to analyze the potential impacts of prospective strategies and actions?
- What is your familiarity with the HSM and related tools?
- What has been your experience/degree of success integrating AASHTO Highway Safety Manual (HSM) methods and tools into your project activities?

Project Development Process

The ADOT project development process includes project identification of problems or needs by ADOT districts, local governments, politicians, and on-going ADOT planning, project scoping, prioritization and funding, design, and implementation. Given this and thinking of the ADOT project development process as a whole:

- Are there guidelines on the process of obtaining and reviewing crash data?
- Are there guidelines on how to address safety issues as part of the field review process?
- How is the safety of design choices considered or documented?

- How is safety considered in the design exception process when design criteria do not meet established standards?
- How are the safety analysis benefits of design alternatives analyzed?
- Are there follow-up evaluations of facility safety conducted after construction is completed? If so, what is the process?
- What constraints/issues/challenges would be involved with making safety assessment a more explicit part of preliminary design?
- What resources are needed to integrate safety into the transportation planning process (e.g., political permission, funding, administrative support, time, etc.)?
- To what extent do you document your decision-making process?
- Do you document the consideration of different design options and alternative safety treatments and analyses?
- Do you document the policy, engineering and other bases upon which a decision is made?
- Is tort liability risk a specific consideration in the project development process? If so, how is it handled?
- To what degree are you aware of the DOT's tort liability risk and what is your role in reducing that risk?

ROADWAY ENGINEERING (DESIGN & PREDESIGN)

Interviewees

- Roadway Engineering - Annette Riley – Assistant State Engineer
- Roadway Engineering Predesign – Reed Henry and/or staff (Sayed Assad, Hassan Eghbali, Doug Smith, Shahid Bhuiyan)
- Roadway Engineering Design – Mike Phillips and/or staff

Interview Guide

Your Role

- Tell us about your role and responsibilities.

Current Safety Practices in Your Role

- What types of projects are using quantitative safety performance measures?
- How is the need for safety improvements to existing facilities identified?
- What type of information/sources are used for problem identification and for identifying potential solutions (e.g., informal interaction, formal interaction, system evaluation programs, crash data analysis, other safety-related data, etc.)?
- Is some form of prioritization scheme used to rank projects in the programming process? Is safety included as one of the priority factors?
- What, if any, state policies or guidelines influence how safety is integrated into your work?

Opportunities to Integrate Safety into Your Role

- Talk through network screening, alternatives development, evaluation (prediction), evaluating existing conditions (diagnosis, CMFs), and project evaluation. What opportunities do you see for integrating safety into your role?
- What constraints/issues/challenges would be involved with making safety assessment a more explicit part of planning and programming?

Safety Analysis Tools and Familiarity with HSM Related Tools

- What safety analysis tools are used regularly to analyze the potential impacts of prospective strategies and actions?
- What is your familiarity with the HSM and related tools?
- What has been your experience/degree of success integrating AASHTO Highway Safety Manual (HSM) methods and tools into your project activities?

Project Development Process

The ADOT project development process includes project identification of problems or needs by ADOT districts, local governments, politicians, and on-going ADOT planning, project scoping, prioritization and funding, design, and implementation. Given this and thinking of the ADOT project development process as a whole:

- Are there guidelines on the process of obtaining and reviewing crash data?
- Are there guidelines on how to address safety issues as part of the field review process?
- How is the safety of design choices considered or documented?
- How is safety considered in the design exception process when design criteria do not meet established standards?
- How are the safety analysis benefits of design alternatives analyzed?
- Are there follow-up evaluations of facility safety conducted after construction is completed? If so, what is the process?
- What constraints/issues/challenges would be involved with making safety assessment a more explicit part of preliminary design?
- What resources are needed to integrate safety into the transportation planning process (e.g., political permission, funding, administrative support, time, etc.)?
- To what extent do you document your decision-making process?
- Do you document the consideration of different design options and alternative safety treatments and analyses?
- Do you document the policy, engineering and other bases upon which a decision is made?
- Is tort liability risk a specific consideration in the project development process? If so, how is it handled?
- To what degree are you aware of the DOT's tort liability risk and what is your role in reducing that risk?

RISK MANAGEMENT AND TORT LIABILITY

Interviewees

- Sue Olson, solson@azdot.gov
- Sarah Greener, SGreener@azdot.gov
- Lee McCleary, LMccleary@azdot.gov
- Ted Howard (ADOT Risk Management), tedhoward@azdot.gov
- Terry Harrison, Head – Liability Management Section, AG Office, terry.harrison@azag.gov

Interview Guide

Your Role

- Tell us about your role and responsibilities, particularly as it relates to tort liability and risk management.

Tort Liability and Risk Management

- What is your familiarity with the project development process and how tort liability risk is considered as part of that process?
- What policies, procedures or guidelines do you rely on to perform your job as it relates to tort liability and risk management?
- Do you have sufficient policies, procedures and guidelines to assist you in performing your job as it relates to tort liability and risk management?
- How is tort liability awareness instilled in management and staff?
- Are management and staff sufficiently informed on tort liability risk to inform decisions and guide conduct?
- What risk management tools are used to reduce tort liability?
- What input do you have on the handling of tort claims or lawsuits against the DOT?
- With regard to the handling of tort claims and lawsuits, what policies are in place that are intended to reduce future tort claims and lawsuits
- What is the process for management and staff to benefit from lessons learned from resolved claims and lawsuits?
- How successful are the DOT's risk management efforts and how do you measure that success?

APPENDIX B. STATE DOT INTERVIEW GUIDE

YOUR ROLE

- Tell us about your role and responsibilities and your involvement in the project development process.

PROJECT DEVELOPMENT PROCESS

- What has been your experience/degree of success integrating AASHTO Highway Safety Manual (HSM) predictive methods and analytical procedures into the project development process (i.e., project identification, prioritization, scoping, design, construction, safety performance evaluation)? Which specific HSM methods and tools have been used and way?
- How is the HSM used within the state's HSIP program?
- What progress has been made to date in integrating safety performance into the project development process? How difficult or easy was the transition? Other than State DOT projects, has there been any attempt to extend similar applications to local public agency (e.g., county, city) projects (e.g., HSIP-funded projects)?
- What performance measures are used to measure the degree of success?
- What type of projects? What groups at the DOT have been more or less responsive to integrating safety performance? What have been the key first steps in integrating quantitative safety into the project development process?
- Have you modified your project development policies/guidelines in light of HSM predictive methods? If yes, how long did it take to establish them?
- What are the transferable lessons learned?
- What constraints/issues/challenges have been involved with making safety assessment a more explicit part of project development activities?
- What federal funding sources have been used in this process (e.g., SPR, HSIP)?

SAFETY ANALYSIS TOOLS

- What safety analysis tools are used regularly to analyze the potential impacts of prospective strategies and actions?
- Are tools used for program level or project evaluation purposes?
- What are the strengths, weaknesses, opportunities and barriers to using these tools?
- Is there any established process to track and evaluate completed construction projects (before and after)? If so, which HSM methods and tools are being used?

HSM IMPLEMENTATION PLANNING

- Is there a designated champion or team responsible for HSM implementation? What have been key success factors/challenges the champion or team has experienced? If it exists, how frequently does the HSM implementation team meet?

- Does your agency have a formal plan for HSM implementation? If so, what key components are included in the plan?
- What changes in data collection practices, data quality, database structure, IT policies/procedures, etc. have been required to support HSM implementation? In this endeavor, what worked and what did not work?
- What has been your agency's strategy regarding HSM training? Are you extending the HSM training to local agencies (e.g., county, city)?

RISK MANAGEMENT/TORT LIABILITY

- What has been your experience with application of HSM methods and tools in terms of tort liability and departmental priorities?
- To what extent do you document your decision-making process?
- Do you document the consideration of different design options and alternative safety treatments and analyses?
- Do you document the policy, engineering and other bases upon which a decision is made?
- Is tort liability risk a specific consideration in the project development process? If so, how is it handled?
- To what degree are you aware of the DOT's tort liability risk and what is your role in reducing that risk?

APPENDIX C. FRAMEWORK IMPLEMENTATION TABLES

Table C-1. Planning Phase

Step and Purpose	Potential Quantitative Analysis
Long Range Plan (Current Conditions Analysis and Needs Assessment) • The planning phase includes all the transportation planning and analysis required to identify and prioritize transportation projects at the state, regional and local community levels. • Planning studies begin with an inventory of current conditions in the study area. Once existing conditions are established, the study then proceeds to forecast conditions in a future horizon year. Once an estimate of future conditions has been developed, the planning study team analyzes the ability of the existing transportation system to meet future demand, and identifies deficiencies and needs.	**Type A – Descriptive Assessment.** Identify trends based on descriptive assessment. Review five year crash history including frequency, severity, type and location, and trends to determine contributing factors Use GIS to map crashes in the study area. **Type B – Comparative Assessment** Compare five year average frequency or crash rate (fatalities and serious injuries) at a particular location to statewide average frequency or crash rate (fatalities and serious injuries) by functional classification and traffic volume range. **Type C – CMF** Apply CMF analysis to evaluate safety performance of proposed projects or alternatives **Type D – HSM Predictive Method** Apply the HSM Predictive Method using calibrated Safety Performance Functions (SPFs) to estimate change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency. **Type E - Calibrated HSM Predictive Method and Benefit/Cost Analysis** Apply calibrated predictive method to estimate change in crash frequency and severity. Apply results in cost benefit analysis.

Table C-2. Scoping Phase

<table>
<tr><th>Step and Purpose</th><th>Potential Quantitative Analysis</th></tr>
<tr><td>Scoping Letter (SL)

• A SL is the simplest method of documenting a project's scope, schedule, and budget. It is prepared for all projects not requiring a detailed analysis for project definition. Projects covered by a SL usually involve a single technical discipline. Generally they originate within a technical unit.</td><td>Type A – Descriptive Assessment
Identify trends based on descriptive assessment. Review five year crash history including crash frequency, severity, type and location, trends, crash reports, collision diagrams, and field reviews to determine contributing factors. Use GIS to map crashes in the study area..</td></tr>
<tr><td>Project Assessment (PA)

• A PA is prepared for highway projects requiring physical construction of the roadway and where existing environmental categorical exclusions/ environmental determinations are sufficient.
• Design exceptions/variances should be included in the PA.</td><td>Type A – Descriptive Assessment
Identify trends based on descriptive assessment. Review five year crash history including crash frequency, severity, type and location, trends, crash reports, collision diagrams, and field reviews to determine contributing factors. Use GIS to map crashes in the study area.

Type B – Comparative Assessment
Compare five year average frequency or crash rate (fatalities and serious injuries) at a particular location to statewide average frequency or crash rate (fatalities and serious injuries) for comparable site types (by functional classification and traffic volume range).

Type C –CMF
Apply CMF analysis to evaluate safety performance of proposed projects or alternatives

Type D – HSM Predictive Method
Apply the HSM Predictive method using calibrated SPFs, and estimate the change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency.</td></tr>
<tr><td>Design Concept Report (DCR) -

• A DCR is prepared for major projects where different roadway alignment alternatives are being considered.
• Design exceptions/variances should be included in the DCR.</td><td>Type A – Descriptive Assessment
Identify trends based on descriptive assessment. Review five year crash history including crash frequency, severity, type and location, trends, crash reports, collision diagrams, and field reviews to determine contributing factors. Use GIS to map crashes in the study area.

Type B – Comparative Assessment
Compare five year average frequency or crash rate (fatalities and serious injuries) at a particular location to statewide average frequency or rate (fatalities and serious injuries) by functional classification and traffic volume range.

Type C – CMF
Apply CMF analysis to evaluate safety performance of proposed mitigation.

Type D – HSM Predictive Method
Apply the HSM Predictive method using calibrated SPFs, and estimate the change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency.

Type E - Calibrated HSM Predictive Method and Benefit/Cost Analysis
Apply calibrated predictive method to estimate change in crash frequency and severity. Apply results in cost benefit analysis.</td></tr>
</table>

Table C-3. Scoping Phase: Design Exception/Variance

Step and Purpose	**Potential Quantitative Analysis**
Design Exception (DE) Design Variance (DV) • A DE is required when existing features left in place or proposed features do not conform to current design criteria as specified in the Roadway Design Guidelines (RDG). • A DV is required when new construction does not meet design criteria specified in the RDG.	**Type C – CMF** Apply CMF analysis to controlling design elements **Type D – HSM Predictive Method** Apply the HSM Predictive method using calibrated SPFs, and estimate the change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency.

Table C-4. Design Phase: Design Exception/Variance

Step and Purpose	**Potential Quantitative Analysis**
Design Review During the design phase, the final roadway alignment and design elements are reviewed and finalized. Design exceptions/variances may be identified as a result of this review process.	**Type C – CMF** Apply CMF analysis to controlling design elements **Type D – HSM Predictive Method** Apply the HSM Predictive method using calibrated SPFs, and estimate the change in expected average crash frequency. If calibration factors are not available, conduct a relative analysis of predicted average crash frequency.