Strategic Transportation Safety Plan

MAG Contract No. 529 Project No. SP13-01

Technical Memorandum No. 6 – Develop a Strategy to Incorporate Safety Enhancements in Road Infrastructure Projects

6.1 INTRODUCTION

The Maricopa Association of Governments (MAG) is developing a comprehensive update of the 2005 Strategic Transportation Safety Plan (STSP) with oversight from the MAG Transportation Safety Committee and Transportation Safety Stakeholders Group (TSSG). The new STSP will establish regional vision, goals, objectives, strategies, countermeasures, and performance measures for transportation safety. It is a data-driven, multi-year comprehensive plan that establishes goals, objectives, and key action areas and integrates the four E's of highway safety – engineering, education, enforcement and emergency medical services (EMS). The STSP allows MAG safety programs and member agencies to work together in an effort to align goals, leverage resources and collectively address the region's safety challenges. The STSP will also identify strategies for addressing new areas of transportation safety. The development of the STSP will be closely coordinated with the ongoing development of the state's Strategic Highway Safety Plan (SHSP) Update by the Arizona DOT.

This technical memorandum is the sixth in a series to document the effort on the Plan. Technical Memorandum No. 6 summarizes the work completed on Task 6: Develop a Strategy to Incorporate Safety Enhancements in Road Infrastructure Projects. This includes strategies, developed based on current best practices, for facilitating the introduction of Safety Assessment Reviews during project development.

Within MAG, the foundation is in already place for instituting an agency-wide "transportation safety culture." As reported in Technical Memorandum #5, there are numerous ways safety is already promoted throughout the agency. Even so, more can be done to ensure this safety culture exists in daily practice. How? Primarily by developing—and carrying forward on a continuous basis—safety awareness in every step of the planning, programming, and project development process.

Transportation safety has typically resided at the project design level and depended on the design practices being used. That strategy, which placed the responsibility for system-wide safety performance in the hands of the project designers and engineers, is now widely recognized as being insufficient to meet future challenges. . To be serious about the MAG STSP vision of **Zero Deaths – Zero Injuries** and the ADOT SHSP vision of **Toward Zero Deaths by Reducing Crashes for a Safer Arizona** requires a total focus on safety at every level of project development, from the planning and programming a project in the RTP and the TIP, to the point where the project is finally being implemented in scoping, design, and construction. New strategies are needed to incorporate explicit safety considerations within the MPO planning process, as well as during project development and implementation by local agency staff. This requires a new safety conscious culture in all agencies responsible for planning, implementing and operating the transportation system.

Nominal VS. Substantive Safety

In order to develop a culture of safety improvement and awareness, it is critical to understand the concept of substantive safety, and the difference between it and nominal safety. For many years, transportation engineers, guidelines and processes have been driven by the achievement of nominal safety -- does the roadway design or design elements meet a particular minimum requirement?. Many, if not most, roadway design and improvement processes have been geared toward meeting local, state or national criteria, often referred to as "standards" notwithstanding the fact that many, such as *A Policy on Geometric Design of Highways and Streets*, published by the American Association of State Highway and Transportation Officials (AASHTO), are actually guidelines. Thus, roadway design and safety is judged in reference to compliance with standards, warrants, guidelines and adopted design procedures. In the nominal view of a roadway, it is either safe (by meeting these criteria) or it is not (if it fails to meet them).

However, it is clear that roadways meeting these design criteria can have widely ranging crash experiences, and that roadway designs that "meet standards" can have widely varying crash risk. Substantive safety is the expected safety performance of a roadway based on long term crash frequency and severity. The substantive safety of a roadway is judged by how it performs relative to the expected crash experience for a particular type of facility accounting for characteristics which include traffic volume, location, geometric design characteristics and terrain. It is important that comparisons of various roadways be made with similar roadways with respect to surroundings and geometry. This substantive safety concept recognizes that safety performance is a continuum and gradually changes with the varying roadway characteristics. There is no single design element value where the road is deemed safe. For example, if the "minimum" centerline radius for a horizontal curve is required to be 750 feet (based on traditional design standards), does this mean that a road with a centerline radius of 751 feet is always safe? Would a road with a centerline radius of 749 feet then be hazardous? Could this simple difference in this critical design element value actually define safety?

The two graphs depicted in Figure 1 provide a visual representation of the differences between the substantive and nominal view of safety.

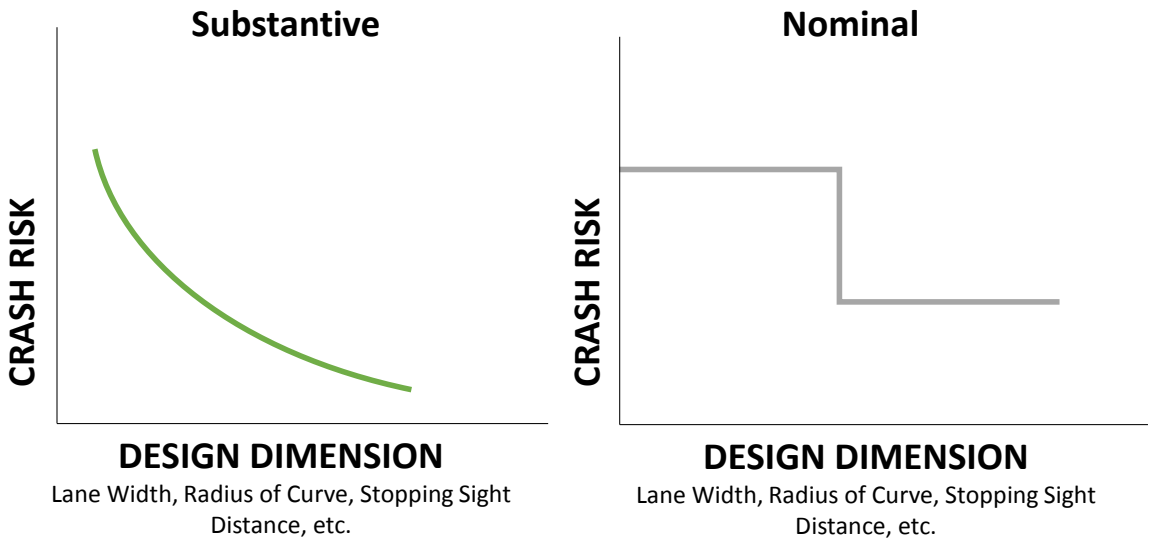

Figure 1 – Substantive versus Nominal Safety

Figure 2 demonstrates how safety assessments, based only on the nominal viewpoint, can potentially limit effective roadway safety performance.

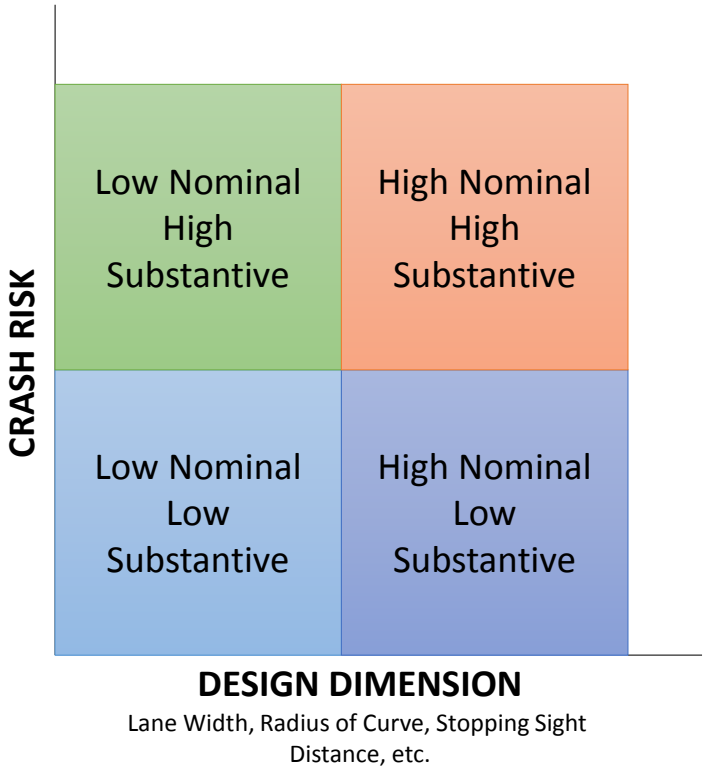

Figure 2 – Substantive Safety Relationships to Nominal Safety

It is possible to achieve high compliance with nominal design dimensions, in many cases to substantially exceed them, and still have a high crash risk relative to other similar roadways. If a roadway design already meets the design criteria, the current "yes" versus "no" nominal safety assessment concept leaves little room for identifying and assessing potential countermeasure effectiveness.

This relatively new concept of substantive safety also has prompted development of a new generation of tools that allow professionals to look beyond "standards" or standard practices with methods to establish "yardsticks" to measure safety performance, identify roadways, segments or intersections with substantive safety issues and to assess countermeasures and weigh design tradeoffs.

6.2 EXISTING TOOLS AND INFORMATION SOURCES

A number of tools are available to use in assessing and improving substantive safety. The most comprehensive approach is provided by the *Highway Safety Manual* (HSM), published by AASHTO. Other useful tools are road safety audits, *NCHRP Report 600 Human Factors Guidelines for Road Systems*, and the Crash Modification Clearinghouse. These tools are discussed in the following sections.

6.2.1 Highway Safety Manual (HSM)

The first edition of the HSM, published in 2010, represents the culmination of a ten-year research and development effort initiated by members of Transportation Research Board (TRB) committees, and supported by TRB, AASHTO, the Federal Highway Administration (FHWA) and the Institute of Transportation Engineers (ITE). The purpose of the document is to provide the information and tools that facilitate explicit safety considerations in the planning, design, operations and maintenances of roadways through validated research which has been adapted and integrated into practice. This includes analytical tools for predicting the impact of countermeasures on road safety.

The vision for the HSM is similar to that of the *Highway Capacity Manual* (HCM), published by the TRB of the National Research Council. The HCM represents definitive, state-of-the-art information, is widely accepted within the professional practice of transportation engineering, is based on science and updated regularly to reflect new research findings.

The HSM itself does not establish requirements or mandates, is not a best practice document and it contains no warrants or standards, nor does it supersede any documents that do establish warrants or standards. It does not establish a legal standard of care nor does it create a duty to the public.

The manual is divided into four main parts in three volumes. It can be somewhat intimidating when taken as a whole, but it is important to understand that many of the sections have valuable information and techniques that can stand on their own as part of a safety improvement process. The HSM does provide tools and techniques that can be used to integrate safety into the design of roadway projects.

The four parts are:

- Part A: Introduction, human factors and fundamentals
- Part B: Roadway safety management process
- Part C. Predictive method
- Part D. Crash Modification Factors

The human factors chapter of Part A includes a discussion of driver characteristics and limitations, the use of positive guidance, and impacts of road design on the driver. The fundamentals chapter addresses the use of crashes as the basis of safety analysis, the data needed for crash estimation and its limitations, the evolution of crash estimation methods and introduces the predictive methods included in the HSM.

Part B explains the network screening process, diagnosing safety issues, selecting countermeasures, economic appraisals, prioritizing projects, and methods to evaluate the effectiveness of safety treatments. In Technical Memorandum No. 4 recommendations were provided for a network screening procedure for use in the MAG region to identify potential locations for improving safety. Some modifications were recommended for the existing MAG network screening methodology for intersections. Other recommendations addressed guidelines for screening roadway segments largely based on HSM techniques.

Part C (volume 2) of the first edition covers methods for predicting the safety performance of rural, two-lane, two-way roads, rural multilane highways, and urban and suburban arterials. Methods for predicting safety performance for other roadway types are under development and should be available soon. The HSM uses Safety Performance Functions (SPFs), which are regression equations used to estimate the predicted crash frequency at a site for a given base condition. Crash Modification Factors (CMFs) are used to adjust the base condition in the SPFs to specific site characteristics. CMFs are also used to determine the impact of changing site specific conditions in a particular way, or for introducing a

countermeasure, such as rumble strips, or widening a shoulder. Calibration factors are used to adjust average crash frequencies calculated using the HSM SPFs to local site conditions.

Part D (volume 3) contains the CMFs for roadway segments, intersections, interchanges, special facilities and geometric situations (such as rail grade crossings, work zones, two-way left-turn elements and passing and climbing lanes). CMFs that can be applied to road networks are also addressed.

6.2.2 Crash Modification Clearinghouse

The development of CMFs is an ongoing process and the Crash Modification Clearinghouse, www.cmfclearinghouse.org, has been funded by FHWA to offer a repository of CMFs. It is regularly updated, and provides a mechanism for sharing CMFs and their proper application. The website provides for searches on keywords, countermeasure, crash type and severity or roadway type. A star rating system is provided to help the user identify the quality of the CMF.

6.2.3 NCHRP Report 600 – Human Factors Guidelines for Road Systems

This report, http://www.trb.org/main/blurbs/159691.aspx, provides a wealth of information to facilitate operational and design decisions based on the best factual information and insight on the characteristics of the road user. It is well-written, well-documented and laid out in a very user-friendly manner. It discusses how to bring road user capabilities into highway design and traffic engineering practice, guidance for roadway location elements (e.g., sight distance, horizontal and vertical curves, intersections, interchanges) and for traffic engineering elements (e.g., signing, markings, and lighting). Information on any given element is contained in two pages, so anywhere the document is opened contains a complete synopsis of the topic. It could be called the Transportation Engineer's desk companion.

6.2.4 FHWA Roadway Safety Professional Capacity Building

The FHWA Office of Safety maintains a website to provide resources to help develop critical knowledge and skills within the roadway safety workforce. The web address is: http://rspcb.safety.fhwa.dot.gov/. The site includes sections on Technical Assistance, Training and Education, Noteworthy Practices and Communities of Practice. The site allows users to search noteworthy practices by topic area and state.

6.2.5 FHWA Office of Safety Proven Countermeasures

FHWA maintains a website (http://safety.fhwa.dot.gov/provencountermeasures/) which promotes the use of proven countermeasures that address crashes that occur in the focus area of intersections, pedestrians and roadway departure. The nine countermeasures are

1) Roundabouts
2) Corridor Access Management
3) Backplates with Retroreflective Borders
4) Longitudinal Rumble Strips and Stripes on Two-Lane Roads
5) Enhanced Delineation and Friction on Horizontal Curves
6) Safety Edge$_{sm}$
7) Medians and Pedestrian Crossing Islands
8) Pedestrian Hybrid Beacon
9) Road Diet

6.2.6 AASHTO Tools for Life – NCHRP Report 500

The AASHTO website includes a section on Tools for Life – Driving Down Fatalities (http://safety.transportation.org/about.aspx). The tools included in the NCHRP 500 series include 23 reports addressing a wide range of safety issues such as head-on, unsignalized intersection, and run-off-road collisions, reducing collisions on horizontal curves, at signalized intersections and those involving utility poles, older drivers, pedestrians, heavy trucks, drowsy and distracted drivers and alcohol. The guides can be viewed in HTML from this site, downloaded from the TRB website www.trb.org or downloaded from the TRB website, http://www.trb.org/main/blurbs/152868.aspx, as NCHRP Report 500 volumes 1-20.

6.2.7 Road Safety Assessments/Audits (RSA)

The 2005 MAG Strategic Transportation Safety Plan established a regional goal to promote Road Safety Assessments (RSA). In 2006, based on a recommendation by the Governor's Traffic Safety Advisory Council, ADOT established an excellent RSA program for the state. The MAG RSA program is based on the ADOT program and was developed in 2010 with the assistance from ADOT and FHWA. The MAG RSA program is an ongoing work item in the annual Work Program. This program provides a funding source for RSAs to be conducted at high crash risk locations at the request of local agencies.

An RSA involves a formal road safety evaluation of either planned or existing roadways, conducted by an independent, multidisciplinary RSA Team. The RSA Team looks for potential safety hazards that may affect any type of road user and recommends measures to mitigate those safety issues. The RSA Team is typically composed of professionals that represent road/traffic engineering, law enforcement, emergency medical services, and human factors. Activities associated with performing an RSA includes review of crash history, conducting both daytime and nighttime field reviews, and preparing a formal RSA report with recommendations for improving road safety that will be provided to the local agency responsible for the facility and who has requested the RSA.

RSAs utilize HSM techniques, particularly CMFs, and NCHRP 600 as idea generators and evaluation tools in the process. CMFs provide a real way to estimate the impacts of countermeasures and are included in the RSA report. The Project Owner can use the provided CMFs to justify implementation of safety improvements recommended in the RSA report using Highway Safety Improvement Program federal aid funding.

6.3 STATE-OF-THE-PRACTICE

This state-of-the-practice review examined national efforts and efforts of agencies within other nations devoted to the integration of multimodal transportation safety in road infrastructure project development.

6.3.1 Austroads (Australia & New Zealand)[1]

Austroads is the association of Australasian road transport and traffic agencies. Austroads' purpose is to improve Australian and New Zealand transport outcomes by: providing expert technical input to national road and transport policy development, improving the practices and capability of road agencies, and promoting operational consistency by road agencies. Austroads publishes a range of Guides which cover the design, construction, maintenance and operation of the road network in Australia and New Zealand. All road agencies across Australasia have adopted the Austroads Guides. The Austroads "Guide to Road

[1] http://www.austroads.com.au/

Safety" provides comprehensive coverage of road safety issues for practitioners involved in traffic engineering, road design and road safety.

Part 1: Road Safety Overview, discusses road crash costs and road authority's duty of care to provide safe travel, different approaches to measuring road safety, the Safe System approach as a conceptual framework for road safety management and the merits of an evidence-based approach to countermeasures.

Part 2: Road Safety Strategy and Evaluation, provides an overview of road safety planning and essential processes. It discusses an evidence-based approach to road safety, strategic partnerships, setting realistic goals, safer roads, vehicles and road users, monitoring and review, and outlines the process of strategy development.

Part 3: Speed Limits and Speed Management, discusses appropriate speed limits to improve road safety, while maintaining the efficiency of the road network. Speed limits need to reflect the varying types of road users, the road environment, types of vehicles driven and the safety, amenity and economic needs of the community.

Part 4: Local Government and Community Road Safety, Covers strategic partnerships and capacity building, developing a road safety strategy, funding a plan and mobilizing resources, implementation, recent case studies of road safety strategies and individual activities, and monitoring, evaluation and review.

Part 5: Road Safety for Rural and Remote Areas, Quantifies the road safety problem on rural and remote roads in Australia and New Zealand, identifies the people most at risk of being involved, factors that contribute to these crashes, possible countermeasures and monitoring and evaluation options.

Part 6: Road Safety Audit, details the road safety audit process and discusses legal liability, costs and benefits, safety principles and technical issues which need to be considered in road safety engineering. Includes updated checklists for use in assessing road designs and inspecting sites at different stages of a project.

Part 7: Road Network Crash Risk Assessment and Management, covers communication and consultation, identifying risks, analyzing, evaluating and treating risks, monitoring and review. Examples of risk are provided, including road trauma, legal risk, and risk from adverse public opinion. Case studies are provided to assist in assessment and management of risks.

Part 8: Treatment of Crash Locations, explains how to identify crash locations, diagnose the crash problem and its causes, select a countermeasure which targets the problem, design a safe remedial treatment and establish its cost effectiveness. It also provides information on sources of road crash data and how engineering improvements fit into a road safety strategy.

Part 9: Roadside Hazard Management, provides guidance in reducing the incidence and severity of run-off-road crashes. Discusses the need to provide a road environment that minimizes potential for loss of vehicle control. Also discusses safety barriers and the need to provide a roadside free of hazards or one which is forgiving, and to take a strategic approach to treating and managing roadside hazards.

6.3.2 Highways Agency (United Kingdom)[2]

The Highways Agency is an Executive Agency of the Department for Transport (DfT), and is responsible for operating, maintaining, and improving the strategic road network in England on behalf of the Secretary of State for Transport. The Highways Agency Design Manual for Roads and Bridges includes a section on requirements for Road Safety Audits[3] which are mandatory for all roadway projects. It describes the stages (preliminary design, detailed design, and construction) at which audits shall be carried out, the procedures to be followed and the requirements for post-implementation crash monitoring.

6.3.3 Federal Highway Administration (FHWA)

The Federal Highway Administration (FHWA) is an agency within the U.S. Department of Transportation that supports State and local governments in the design, construction, and maintenance of the Nation's highway system (Federal Aid Highway Program) and various federally and tribal owned lands (Federal Lands Highway Program). Through financial and technical assistance to State and local governments, FHWA is responsible for ensuring that America's roads and highways continue to be among the safest and most technologically sound in the world.[4]

Within the United States, the full integration of safety into the design process and the adoption of Highway Safety Manual concepts and techniques are both ongoing and evolutionary processes. FHWA provides a number of resources to assist agencies in integrating the Highway Safety Manual into the project development and design process on their website at http://safety.fhwa.dot.gov/hsm/. A number of case studies from Idaho, Ohio, Florida, Illinois and New Hampshire can also be accessed at this site. These cover using predictive methods, safety management processes, safety performance functions and implementation plans.

The document *Integrating the HSM into the Highway Project Development Process* (http://1.usa.gov/1nWDx4V)[5] addresses how HSM techniques can be applied during the planning, alternatives development and analysis, design, and operations and maintenance phases of projects. Example applications are provided. Additionally, specific pages that address these phases and can be found at http://safety.fhwa.dot.gov/hsm/hsm_integration/toc.cfm.

Discussions with FHWA safety officials indicate that no state has completely integrated substantive safety into design, but there are many examples where agencies have integrated explicit safety analyses (as opposed to meeting nominal standards) into the design process.

For example, the Illinois DOT has incorporated safety analysis using the HSM into several alternatives reviews and Environmental Impact Statement (EIS) reports. The Illinois DOT used this technique for projects on I-290 in Chicago, the 159th Street corridor near Orland Park, Illinois and Willow Road near Winnetka, Illinois. The Virginia DOT incorporated HSM techniques into an alternatives analysis for an arterial in Henrico County (http://bit.ly/1ty5Skm)[6]. HSM techniques were employed to evaluate intersection and segment crashes.

---

[2] http://www.highways.gov.uk/

[3] http://www.dft.gov.uk/ha/standards/dmrb/vol5/section2/hd1903.pdf

[4] http://www.fhwa.dot.gov/about/

[5] http://safety.fhwa.dot.gov/hsm/hsm_integration/hsm_integration.pdf

[6] http://www.virginiadot.org/projects/resources/Springfield_Road_Alternatives_Analysis_DRAFT_01-14-2013.pdf

Many of these examples could be considered "high-profile" projects with community, mode choice, environmental, funding or right-of-way considerations. Because many of these issues come to bear on design choices, HSM techniques provided a data-driven and scientific method to assessing impacts of alternatives on safety.

Some states have adopted "practical" or "performance based" design policies that allow modifications to typical nominal standards to build cost-effective roadways and use safety analyses to ensure that safety is not compromised. For example, one of the Missouri DOTs ground rules for using practical design is that "safety will not be compromised. Every project we do will make the facility safer after its completion." The Kansas DOT used HSM techniques including SPFs on a project designed using their "design to budget" strategy to evaluate the impact of design decisions.

Likewise HSM techniques can be used to evaluate design exceptions that are submitted to FHWA.

6.3.4 Colorado Department of Transportation (CDOT)

CDOT has required a safety assessment for all projects, including Resurfacing, Restoration and Rehabilitation (3R) projects for the past 10 years. This is performed by a group of engineers from different specialties, including safety/traffic engineering. Although the funding for the 3R projects may not be sufficient to fund major safety-driven improvements, those needs are identified for later funding.

CDOT calculates the distribution of crash risk for freeways and rural highways. This is done by segmenting the system into like sections based on number of lanes, terrain, and median treatment. Each group of like segments has a scatter diagram of crashes based on volume verses number of crashes (either serious injury or fatal). Then a regression analysis is performed resulting in a non-linear trend line. The original CDOT method was to divide the scatter plot into four groups based on 1.5 standard deviations above and below the line of best fit to define level of service of safety (LOSS) as follows:

- LOSS 1 - that group of intersections below 1.5 standard deviations below the mean;
- LOSS 2 – those between 1.5 standard deviations below the mean and the mean;
- LOSS 3 – those above the mean but below 1.5 standard deviations above the mean;
- LOSS 4 – those above 1.5 standard deviations above the mean.

The most crash-prone intersections are LOSS 4. CDOT has recently moved to percentile distribution rather than referring to standard deviations above and below the mean in the hope of it being more easily understood. The current method for LOSS divides the scatter diagram into four categories based on the segments position within the percentiles of crash risk. LOSS 1 (least crash risk) is assigned to the lowest 20%, LOSS 2 from the 20th to the 50th percentile, LOSS 3 from 50th to 80th and the top 20% are assigned LOSS 4 (most crash risk). Their goal was to provide an easily grasped "evaluation scale" of all freeway and rural road segments to assist in prioritizing segments for improvement. This is a means of network screening which avoids the biases associated with crash frequency and crash rates.

Urban arterials are assessed for crash risk through an analysis of intersection crashes using crash frequency and crash rates.

6.3.5 Texas Department of Transportation (TxDOT)

TxDOT requires that safety be considered in all roadway projects but does not have any requirements for how that consideration should be made. A research project conducted by the Texas A&M Transportation Institute (TTI) developed SPFs for many roadway types based on Texas data. The project included extensive outreach and training to TxDOT District Staff. The SPFs are used primarily to assess design exceptions from nominal standards.

In the Dallas District, TTI has screened all the freeway segments and identified those with higher crash risks. An analysis of specific crash types and countermeasures is currently underway.

6.3.6 Oregon Department of Transportation (ODOT)

Oregon has assembled a team of practitioners to review the HSM and provide guidance on how to apply it. ODOT maintains a webpage (http://1.usa.gov/1uL0hIU)[7] that provides information on the HSM. Information on Oregon-specific calibration factors to use in the predictive methods are detailed here as is the Safety Investigations Manual which provides assistance with project screening and evaluations for practitioners that investigate safety issues and perform highway safety assessments.

6.3.7 Arizona Department of Transportation (ADOT)

Arizona's second Strategic Highway Safety Plan (SHSP) was released in October 2014. It provides a comprehensive framework for reducing fatalities and serious injuries on public roadways and was updated in cooperation with more than 55 local, state, federal and other safety stakeholders. Under the completed Arizona SHSP Update, all highway safety programs in the state can leverage resources to address transportation safety issues. The SHSP identifies the State's key safety needs and guides Highway Safety Improvement Program (HSIP) investment decisions. The Arizona HSIP Manual (2010) is planned to l be updated in 2015. . ADOT plans to develop safety performance functions (SPFs) based on Arizona data that are acceptable for use in the HSM for inclusion in the Arizona HSIP Manual Update.

Reports on Road Safety in Arizona

Periodic reports have been published specific to safety:

- *Annual Arizona Motor Vehicle Crash Facts*[8]. This publication is an annual statistical review of the motor vehicle crashes in the State of Arizona. It contains facts and figures about crashes with sections specific to safety devices, driver descriptions, alcohol related crashes, pedestrian and pedalcyclist crashes, and motorcycle crashes.
- *Arizona SHSP*[9]. This comprehensive statewide safety strategy document guides the State's existing safety planning and programming processes, facilitates the implementation recommended safety strategies and countermeasures, and can be used to modify current planning processes over time to adopt and institutionalize safety culture.
- *Arizona HSIP Manual*[10]. This publication contains information on HSIP legislation and the State's planning, implementation, and evaluation processes for the prioritization and implementation of HSIP funded safety improvement projects.
- *Arizona Highway Safety Plan*. This Plan is developed by the Governor's Office of Highway Safety and submitted to NHTSA.

---

[7] http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/Pages/highway_safety_manual.aspx

[8] http://www.azdot.gov/mvd/Statistics/arizona-motor-vehicle-crash-facts

[9]https://www.azdot.gov/business/engineering-and-construction/traffic/traffic-safety/arizona-strategic-highway-safety-plan

[10]https://www.azdot.gov/business/engineering-and-construction/traffic/traffic-safety/arizona-highway-safety-improvement-program

Research on Road Safety in Arizona

The ADOT Research Center 2014 annual work program includes a project for *Incorporating Safety Performance into Project Design.* The objective of this project is to provide recommendations to ADOT on integrating Highway Safety Manual (HSM) methods and tools (e.g., Interactive Highway Safety Design Model (IHSDM), Crash Modification Factor (CMF) Clearinghouse, SafetyAnalyst) into project scoping and design processes. The framework will initially be limited to projects with limited alternatives analysis, and/or the typical Project Assessment (PA) process.

Safety Review in Project Development

ADOT requires historical crash data be included in the scoping document of all roadway projects but does not require analysis of the data. ADOT does not have any other requirements for safety considerations throughout project development. There have been a few instances where a project lacked crash history and the HSM predictive method was applied. There is a need for safety performance functions (SPFs) specific to Arizona.

In 2006, based on a recommendation by the Governor's Traffic Safety Advisory Council, ADOT established an excellent RSA program for the state. The RSA program conducts RSAs on state, local, and tribal road facilities. An RSA must be requested by the road owner with authority to respond to and implement the RSA findings. They are most often requested for existing facilities, but are sometimes requested by ADOT district engineers (road owner) to determine whether a project is eligible for HSIP funding. The ADOT RSA application does ask whether the type of assessment being requested is for planning, design, construction, or existing. RSAs have not yet been requested for the design or construction of any roadway project.

RSAs are planned to be consistently performed during the eligibility or scoping phase for pavement preservation projects which have simple, limited scopes and are executed in-house. Safety considerations for pavement preservation projects include shoulder width, clear zone, and intersection sight distance.

Arizona's Safety Challenges

FHWA's Safety Office focuses extra resources on cities and states with the highest fatalities and/or fatality rates in three areas that have been identified in providing the greatest potential to reduce highway fatalities using infrastructure-oriented improvements. Arizona is a focus state for Pedestrian, Roadway Departure, and Intersection Safety.

Pedestrian focus cities were selected based on the number of pedestrian fatalities or the pedestrian fatality rate per population. Cities were identified as pedestrian focus cities if they had more than 20 average annual pedestrian fatalities or a pedestrian fatality rate greater than 2.33 per 100,000 population (the annual national average number of pedestrian fatalities is 20 and the average national rate of pedestrian fatalities is 2.33 per 100,00 population). States with a focus city were automatically identified as focus states. Phoenix and Tucson are pedestrian focus cities.

Eligible focus States have access to FHWA assistance in several different formats. They can receive technical assistance such as data analysis and action plan development from initiation to implementation; training in several formats, including classroom-based workshops, online webinars, and various training materials; support for a wide range of analysis tools and countermeasures.[11]

[11] http://safety.fhwa.dot.gov/fas/

6.3.8 State-of-the-Practice: Conclusions

A number of evidence-based, data-driven and scientific tools and techniques are available to transportation professionals for the first time. Application of these techniques require a break from the traditional approach of providing nominal safety through compliance with standards and standard practices and an embracing of the concept of substantive safety. This change in approach is being adopted in an evolutionary manner, and requires more analysis and data than simple reliance on standards. Change typically comes slowly, and adoption of new safety analysis tools is no exception. Nonetheless, many agencies and transportation professionals are beginning to use these techniques to improve roadway safety. Local agencies are developing tools based on HSM techniques to automatically compare similar intersections and roadway segments for network screening purposes that provide a more rigorous comparison than crash frequency or rates. These tools also permit efficient evaluation and comparison of design alternatives based on safety. Other countries, such as Australia and the United Kingdom mandate consideration of safety in the design of all roadway projects and have comprehensive guides and processes that support the concept of substantive safety.

A comprehensive adoption of such techniques seems daunting. Where will the expertise come from? What will the cost be? Will this delay the project development process? These are important considerations, but unless agencies, cities, regions or states commit to using these techniques, there may never be a supply of professionals qualified to do the work. Is the analyses and time that go into improving capacity or roadway surface conditions more valuable than that spent incorporating safety in projects? Can an agency become efficient and proficient at evaluating and incorporating safety if it is only done occasionally? These are questions that can only be answered by each individual agency. Some tools and techniques have been developed and they are being improved every day. Software tools such as the MAG RTSIMS software would enable an agency to have all crash data, for a specified period (e.g. three years), subject to network screening to identify and prioritize locations for road safety improvement. The principles of the HSM can then be applied to evaluate alternative designs for selected intersections and roadway segments.

An initial step towards improved safety assessments and applying safety analysis techniques is to identify essential data needs and develop a strategy for enhanced roadway data collection. Many of the evolving safety procedures can be incrementally applied over time. Systematically developing safety analysis techniques can assist with what may initially seem a challenging task. As an example, SPFs should be either calibrated or developed for specific regional applications. Until the time that an agency has the ability and resources to perform these refinements, they can still use the procedures to develop relative values for safety evaluations (i.e. may not be able to confidently predict 12 crashes for alternative A and 22 for alternative B, but could definitely determine that alternative A would have fewer crashes than alternative B). This type of incremental analysis process will ultimately lead to robust safety assessments and a culture of safety throughout the agency's procedures, discussions, and decisions.

6.4 A FRAMEWORK FOR INTEGRATING SAFETY INTO ROADWAY DESIGN

The following is suggested as a way to describe how to integrate consideration of safety into roadway design.

6.4.1 Approach

1) Think beyond nominal design values
2) Consider safety effects of design variations
3) Consider trade-offs

   a. Design element vs. design element (i.e., potentially counteracting or supplementing safety effects of variations in different design elements)
   b. Safety in addition to other considerations such as drainage, right-of-way, and utilities

4) Evaluate trade-offs using crash experience between design elements and dollars for safety vs. other considerations.
   a. Safety, using HSM tools, NCHRP 600 Human Factors Guidelines for Road Systems and NCHRP Special Report 214 Designing Safer Roads, Practices for 3R
   b. Operational performance
   c. Implementation cost

6.4.2 Project Types and Context

There are two basic types of design projects: (1) those that involve changes to an existing facility and (2) completely new roadways on new alignments.

Every design project exists within a context. For improvements to existing roads, existing (or expected) conditions and constraints set the context. For completely new roadways, the two endpoints and the topography and constraints between those two points establish the context, but there are no existing problems, issues or deficiencies to address.

6.4.3 Setting a Starting Point

Safety can be effectively considered and made to drive the design by establishing a starting point and a basis for assessment, as described below.

1) Changes to an existing roadway
   a. The existing alignment and conditions are the starting point, and examination of the crash experience of the current roadway (minimum of 3 years) will identify a series of incremental improvements and provide a safety performance baseline.
   b. Safety objective: Increase safety performance from the baseline.
2) New
   a. Develop design alternatives that include elements with a known safety performance
   b. Use safety assessment tools to fine-tune alternatives that do better than the “nominal” design
   c. Safety objective: Consider safety performance in the selection of design alternatives; choose alternatives that improve upon baseline safety characteristics in each subsequent alternative/refinement.

6.4.4 Consideration of Safety

Once a single starting point design concept has been determined, develop all designs considering the safety effects of design changes (i.e., design changes to each design element). The designer should assess the effects on safety of changes to each element. This assessment will take into account safety trade-offs between design elements.

Design issues and objectives would be addressed through variations in design elements. Each change would cause an increase or decrease in performance (safety, cost, other) and would be considered by the designer while preparing the design, and later included in a more comprehensive analysis using HSM tools and an overall cost comparison.

6.5 RECOMMENDED STRATEGY FOR FACILITATING THE INTRODUCTION OF "SAFETY ASSESSMENT REVIEW" IN THE PROJECT DEVELOPMENT PROCESS

The project development process includes all engineering, construction, and administrative functions required to advance a highway transportation project from conception through design and construction and into operation and maintenance of the project. The process is accomplished through a systematic interdisciplinary approach involving many stakeholders including local, state and federal agencies. Although the development process varies depending on the specific project requirements and agencies, it generally will comprise of four distinct phases – Scoping, Design, Construction, and Operation/Maintenance. The Pima Association of Governments (PAG) is currently conducting a design level RSA. Based on the lessons learned from the current PAG project a template is to be developed in the near future to be used for all PAG road improvement projects. This template could be considered for use by MAG and local agencies for design level RSAs to be conducted in the MAG region.

6.5.1 Safety Assessment Review – Influencing the Process

The goal of performing formal safety assessment reviews is to promote safety using a more systemic and substantive safety process in addition to relying on design standards/guidelines to provide the level of safety. Design standards provide a consistent, predictable roadway environment, but may not necessarily result in the desired level of safety for a particular roadway environment.

The greatest opportunity for safety benefits tend to occur in the planning and design stages of a project. Changes to improve the safety performance of a facility are typically easier to implement in these early stages. Once a design has progressed into construction, these changes can become more difficult, costly and time-consuming. In addition, safety assessment reviews conducted at the early stages of a project offer greater flexibility for incorporating more large-scale improvements that may offer maximum safety benefit.

6.5.2 Safety Assessment During Project Scoping

Project Scoping usually combines engineering and environmental study into one process to define a project based on informed decision making. Depending on the complexity of the project, a project scoping may involve a multi-disciplinary team working to find solutions that meet the transportation needs within the project environment. An example of a typical project scoping process flow chart is shown in Figure 3.

The scoping of a project usually involves performing studies such as a project assessment (PA), feasibility and corridor studies, and design concept reports (DCRs) that meet the purpose and need of the project. These studies define the scope of the project and recommend a preferred alternative. Typically several project alternatives are developed and evaluated against a set of performance measures to determine the preferred alternative. Therefore it is recommended that safety be included as a performance measure.

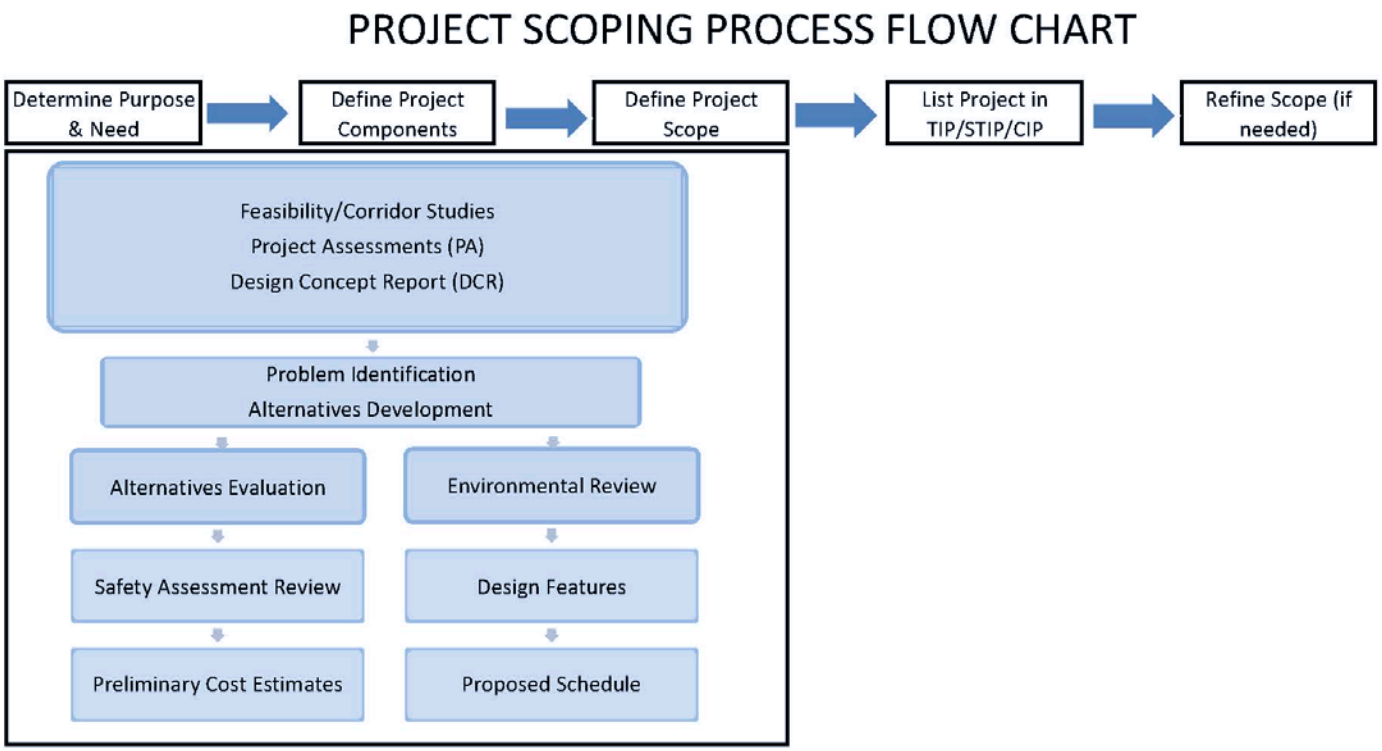

Figure 3 – Example Project Scoping Process Flow Chart

One method of integrating safety as a performance measure is using methods developed in the HSM. The predictive methods in the HSM provide the ability to quantify the anticipated safety performance for each alternative in terms of its anticipated crash frequency and severity.

6.5.3 Safety Assessment During Project Design

The design phase involves developing a set of construction plans for the proposed improvements identified in the scoping phase. The entire design process typically involves several design stages (30%, 60%, 90% and 100%), each building upon the information from the previous stage until the plans and specifications are completed and ready for construction. A formal safety assessment review of the proposed improvements should be conducted during 60% design stage. At this stage the design plans would have sufficient details for the Safety Assessment Review Team (SART) to perform a comprehensive safety evaluation while still being able to incorporate revisions, if necessary, without costly and time-consuming plan changes. An example of a design project development process flow chart is shown in Figure 4.

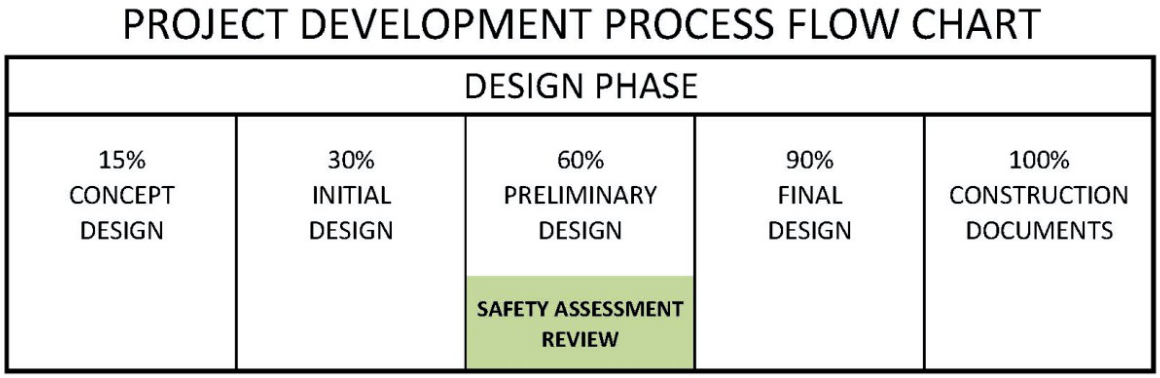

Figure 4 – Example Design Project Development Process Flow Chart

The safety assessment review process may vary depending on the scale and complexity of the project but should include the following basic steps.

- Performed by a team independent of the project
- Performed by a multi-disciplinary team
- Consider all potential road users
- Accounting for road user capabilities and limitations
- Prepare a formal report with recommendations
- Include a formal response from the design team

The safety assessment review should begin with a pre-review meeting to review pertinent information. This meeting allows the team members and facility owner the opportunity to discuss the context and scope of the project being reviewed. The purpose of the pre-meeting is to:

- Hand over all relevant information to the review team
- Review the scope and objectives of the safety review
- Delegate responsibilities
- Agree upon a schedule for completion of the safety review
- Set up lines of communication
- Communicate matters of importance to the review team

Once the safety assessment review is complete, the team finalizes any findings and develops recommendations to improve safety. The findings and recommendations are prioritized and documented in a report.

The owner/design team shall provide a formal response to the recommendations in the report. A formal response allows the owner/design team to document action plans to address the findings and recommendations. Some recommendations may be determined to be feasible immediately while others may not be currently possible due to financial constraints or other limiting factors.

With the tools available in the HSM, the design team can evaluate the design not based on just design criteria but also on quantitative safety performance. The team can refine or adjust one or more design elements and reevaluate the safety performance similar to optimizing the roadway horizontal and vertical geometry.

6.5.4 Safety Assessment During Project Construction

Once construction of a project has begun, safety assessment reviews can still be used effectively to identify potential safety issues and countermeasures prior to project completion. The safety review team can review portions of the constructed project and recommend safety enhancements to be added to the remainder of the project that otherwise may not be included.

6.5.5 Staff/Consultant Qualifications and Resources Needed

The Safety Assessment Review Team (SART) is an independent, qualified and multi-disciplinary team, similar in composition to an RSA Team (see page 6), who can successfully conduct a safety assessment review of the proposed improvements. Team members may consist of individuals from within the local agency, from another public agency, or from other outside sources. These individuals should, however, be independent of the project being reviewed.

There is no defined number of members for a SART. Each individual on the SART should have some background in road safety, traffic operations or road design. Collectively, the team should represent a number of multiple disciplines including traffic, design, construction and maintenance. Depending on the project or facility, it may be desirable to have an expert member on the team in an area particularly related to the facility being reviewed.

6.6 RECOMMENDED MAG & LOCAL AGENCY INITIATIVES FOR IMPLEMENTATION

MAG Initiatives

- Prepare a “best practices” guide specific to the MAG Region for high risk intersections and high exposure bicycle and pedestrian crossing nodes employing safety countermeasures that provide:
    - Consistent traffic signal detection and operations for pedestrians and bicyclists
    - Installation of enhanced crossing treatments (such as improved lighting, shorter crossings, median treatments, widened crosswalks for pedestrians and bicyclists, bulb outs, ladder-style or higher visibility crosswalk markings and consideration of enhanced traffic control devices such as PHBs, RRFBs, advance signing or pavement markings, or two-stage crossings.)
- Encourage submittal of TIP projects that include safety elements, for improving safer access for all modes, by including safety as an explicit project evaluation criteria for all TIP projects that currently have evaluation criteria as a means of prioritizing a list of projects. Exceptions to this practice are those Transit Maintenance and Operations programs funding through the MAG TIP. This could be easily done by MAG with support of committees that evaluate projects that are incorporated into the TIP. MAG staff, with oversight by the Safety Committee, will develop the Safety Evaluation Criteria including guidelines for scoring projects. The actual safety scoring could be done by individual modal committees as part of their normal TIP project review process.

- Prepare a "best practices" guide for Road Diet and Complete Streets projects that incorporates safety countermeasures in project development. The intent would be to outline what kind of corridors would be good candidates for these practices with consideration of connecting or abutting conditions as well as how complete streets policies are implemented/enforced, and incorporating known safety countermeasures.
- Prepare a "best practices" guide for design of pedestrian and bicycle accommodations at roundabouts. The intent would be to provide designers with guidance on infrastructure that has the greatest potential to reduce the risk of serious injury and fatal crashes at roundabouts involving bicyclists and pedestrians, especially for those pedestrians that are visually impaired. This guide would incorporate the proposed Guidelines for Pedestrian Facilities in the Public Right-of-way (PROWAG) that is expected to be adopted in the near future, and could provide guidance on improving safety at existing roundabouts.
- Enhance the existing network screen methodology for intersections and adopt a comprehensive method for performing network screening for segment locations to better identify those intersections or segments that would benefit most from safety improvements. In Technical Memorandum No. 4 recommendations were provided for a network screening procedure for use in the MAG region to identify potential locations for improving safety. Some modifications were recommended for the existing MAG network screening methodology for intersections. Other recommendations addressed guidelines for screening roadway segments largely based on HSM techniques. Software tools such as the MAG RTSIMS software can be updated to enable an agency to have all crash data, for a specified period (e.g. three years), subject to network screening to identify and prioritize locations for road safety improvement.
- Enhance the criteria for nominating RSA sites towards the goal of Elimination of Deaths and Serious Injuries
    - Priority 1: High crash risk locations with an emphasis on those with predominant fatalities and serious injury crashes. Use the MAG Top 100 list as a starting point, local agencies to review for more detail on fatalities and serious injury crashes at the locations they wish to nominate. PAs to be conducted for safety improvements recommended through past RSAs conducted at a location.
    - Priority 2: Locations where there are known high volumes of bicyclists and pedestrians accessing transit stops and stations with a demonstrated safety issue or locations where there is a prevalence of transit/vehicle crashes.
    - Priority 3: Other locations of concern based on input from the MAG Transportation Safety Committee.
- Develop a custom tool or purchase a comprehensive safety assessment tool based on methodologies presented in the HSM for the MAG planning area, which would include all arterial street crash reports for identifying and prioritizing locations having the highest priority for safety improvements. The tool must be user-friendly and have the ability to present results that are easily understandable for MAG staff and local agency staff.

- Develop a tool to conduct benefit-cost analyses and calculate crash reduction factors (CRFs) for a variety of safety projects. The Florida Department of Transportation uses the Crash Reduction Analysis Safety Hub (CRASH) program for this purpose[12]. The intent of this tool is to identify and prioritize project locations for safety improvements based on the benefit-cost analysis. Crash data before and after a project is implemented would provide the basis for calculating CRFs specific to the region. CRFs are generally calculated based on multiple projects in which the same types of project improvements were applied. CRFs could be developed, that do not currently exist, for improvements such as implementation of adaptive signal control technology. MAG staff could enter in project data from the TIP. Local agencies could also choose to submit their locally funded projects for B/C evaluation based on safety improvement.
- Develop local calibration factors for existing national HSM safety performance functions (SPFs) that are specific to the MAG planning area.
- Expand the existing MAG RSA program to include formal safety assessment reviews of proposed improvements conducted during the 60% design phase. At this stage the design plans would have sufficient details for the Safety Assessment Review Team (SART) to perform a comprehensive safety evaluation while still being able to incorporate revisions, if necessary, without costly and time-consuming plan changes. The safety review would be conducted by a multi-disciplinary team independent of the project. The basic steps of this process are provided in Technical Memorandum No. 6. Member agencies could request the formal safety assessment review for proposed improvements within their agency, independent of the project's funding source. Alternatively, MAG could develop a simple and understandable safety assessment process guide that could be used by local agencies to review private developer as well as local agency projects. The Pima Association of Governments (PAG) is currently conducting a design level RSA. Based on the lessons learned from the current PAG project, a template will be developed in the near future to be used for all PAG road improvement projects. This template could be considered for use by MAG and local agencies for design level RSAs conducted in the MAG region.
- Partner with local professional societies to hold workshops on the existing tools that are available to use in assessing and improving substantive safety to educate public agency or private consultant roadway designers. This would be accomplished in conjunction with ADOT via their Local Public Agency Manual (for federally funded projects) or local agencies incorporating safety into the scope for roadway design projects. Using this process would require roadway designers to learn about assessing and improving substantive safety.
- Encourage self-calming features in the design of new roadways such as roundabouts.

[12] http://www.dot.state.fl.us/rddesign/QA/Tools/CRFGuide.pdf accessed November 25, 2014

Local Agency Initiatives

- Partner with adjacent agencies and apply for federal HSIP funds available through the MAG safety planning process for systemic projects, which are those projects that implement systemic road safety improvements across a road network. These are projects that can be implemented with minimal clearances required, usually system-or corridor-wide. See http://safety.fhwa.dot.gov/systemic/ for more information. Projects, based on Strategies developed in Task 3, that could be eligible for MAG HSIP funding for systemic safety improvements include:
    - Bicycle Detection
    - Positive offset striping improvements to address left turn crashes
    - Pedestrian enhancements
- Improve communication within their agency by establishing quarterly safety meetings between planning, engineering, development, and traffic operations staff to coordinate safety improvements in the planning, programming, and design processes. Staff would review projects at every stage of the development process from a safety perspective to identify safety improvements.
- Include safety as a consideration in the formal selection and prioritization of transportation projects. As an example, MCDOT considers five rating categories, including safety, in their Project Rating Process. The safety category counts for 25% of the total weightings.
- Formalize safety in the design process by including a third-party safety assessment review (using agency staff or outside experts who are not part of the design team) to evaluate the design of a project towards the goal of improving traffic safety.
- Individual member agencies could purchase a license for MAG's comprehensive safety assessment tool (once this tool is developed or purchased) for use in network screening and evaluation of design alternatives. The intent of this is for the local agency to have the ability to identify and prioritize locations within their own jurisdiction.
- Review local agency codes, policy, and design standards for changes that may reduce fatal and serious injury crashes. Relevant topic areas may include:
    - driveway spacing
    - traffic signal spacing
    - street cross-section design
    - sidewalk width and buffers
    - bike lanes and related bike facilities
    - bus stop location and design
- Submit traffic volume data collected locally and as part of private development projects to the MAG Transportation Data Management System, the primary data management tool for region-wide traffic volume and turning movement count information. This would allow MAG to have more comprehensive count data for system-wide safety analysis
- Introduce self-calming features in the design of new roadways such as roundabouts.