THE ARIZONA HIGHWAY SAFETY IMPROVEMENT PROGRAM MANUAL

Arizona Department of Transportation
Highway Enhancements for Safety (HES) Section
Traffic Engineering Group
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TABLE OF CONTENTS

1. HIGHWAY SAFETY IMPROVEMENT PROGRAM

The specific purpose of the Highway Safety Improvement Program (HSIP) is to achieve a significant reduction in traffic fatalities and serious injuries on public roads. This is to be accomplished through the development and implementation of the Strategic Highway Safety Plan (SHSP) which is a statewide-coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads. SHSP is intended to identify the State's key safety needs and guide HSIP investment decisions.

1.1 HSIP Legislation

The first major efforts at the federal level include the *1966 Highway Safety Act (23 United States Code (U.S.C.) 402) and Highway Safety Act of 1973 (Title II of Public Law No. 93-87).* While safety has long been a consideration in transportation project development, the role and significance of safety in transportation policy has evolved over time.

1.1.1 Current HSIP Legislation and Regulations

The current legislation, the *Safe Accountable Flexible Efficient Transportation Equity Act – A Legacy for Users* (SAFETEA-LU), established the HSIP as a core Federal-aid program under 23 U.S.C. 148. SAFETEA-LU nearly doubled the funds for infrastructure safety, allowed increased flexibility in program funding (10% Flex), and required a focus on results.

The HSIP Core Program (23 USC 148) requires each state to develop and implement an SHSP, provide an annual Transparency Report describing not less than five percent of the state's roadway locations exhibiting the most sever safety needs, develop and implement a State HSIP which includes Railway-Highway Grade Crossing Program (23 U.S.C. 130) and High Risk Rural Roads Program (HRRRP) .

Title 23 Code of Federal Regulations (CFR) Part 924, effective January 2009, reflects changes to the State HSIP that resulted from SAFETEA-LU as well as changes in the overall program from the originally published 23 CRF 924. A new HSIP manual has been published by the Federal Highway Administration (FHWA) in January 2010 and is available online at <http://safety.fhwa.dot.gov/hsip/resources/>.

The Arizona Department of Transportation is responsible for administering the HSIP in Arizona. The purpose of the Arizona HSIP manual is to provide basic guidance to all public agencies including the State, city, county and tribal government and will be updated as federal requirements or State procedures change.

1.1.2 Components of the HSIP

The Core HSIP requires the development and implementation of an SHSP, State HSIP, High Risk Rural Road Program, and Railway-Highway Grade Crossing Program which are detailed below:

Strategic Highway Safety Plans

The SHSP is required to be data-driven and developed in collaboration with a broad range of stakeholders. It is a multi-disciplinary plan addressing the 4Es of Safety – engineering, enforcement, education, and emergency medical services (EMS). It is performance-based with the adoption of strategic and performance goals which are coordinated with other state safety programs.

Arizona DOT is ultimately responsible for the SHSP and the State HSIP projects and programs should be aligned with the emphasis areas of the SHSP. In Arizona, the SHSP was developed through the collaborative efforts of the Governor's Traffic Safety Advisory Council consisting of the necessary stakeholders. The Arizona SHSP is available at ADOT HES website: <http://azdot.gov/highways/traffic/9620.asp>.

State Highway Safety Improvement Program

The State HSIP should be consistent with the SHSP emphasis areas and strategies. Requirements for an HSIP are defined in 23 CFR 924. The State HSIP may be flexible to meet the needs of the State but must include the following components:

- **Planning** – Collect and maintain data, identify hazardous locations and elements, conduct engineering studies, and establish priorities
- **Implementation** – Schedule and implement projects
- **Evaluation** – Determine the effectiveness of safety improvements

Findings resulting from the **Evaluation** process shall be incorporated as basic source data in the **Planning** process.

High Risk Rural Road Program

The High Risk Rural Roads Program (HRRRP) provides set aside funds for construction and operational improvements on high risk rural roads. High Risk Rural Roads are defined as any roadway functionally classified as a rural major or minor collector or a rural local road:

A. on which the accident rate for fatalities and incapacitating injuries exceeds the statewide average for those functional classes of roadway; or

B. that will likely have increases in traffic volume that are likely to create an accident rate for fatalities and incapacitating injuries that exceeds the statewide average for those functional classes of roadway.

Implementation of the HRRRP requires comprehensive roadway and crash data for all public roads. For States that do not currently have the capability of locating crashes on all public roadways, the State may adopt interim practices that utilize the best available data resources until a comprehensive statewide roadway and crash data system is implemented[1].

Railway-Highway Grade Crossing Program

The Railway-Highway Grade Crossing Program (RHGCP) reduces the number of fatalities and injuries at public railway-highway grade crossings through the elimination of hazards and/or the installation/upgrade of protective devices at crossings. Each state is required to conduct and systematically maintain a survey of all railway-highway grade crossings to identify those crossings which may require separation, relocation, or protective devices, and establish and implement a schedule of projects for this purpose. At a minimum, the crossings identified through the program will have standard signing and striping following guidance from the latest edition of the Manual on Uniform Traffic Control Devices (MUTCD).

1.1.3 HSIP Reporting Requirements

State DOTs are required to submit reports to the FHWA on several elements of the HSIP. Reporting requirements include:

- Annual assessments of the progress and effectiveness of HSIP and HRRRP;
- Progress on implementing the RHGCP; and
- A *Transparency Report* (*Five Percent Report*) which includes a description of not less than five percent of locations exhibiting the most severe safety needs, an assessment of potential remedies for these locations, estimated costs associated with remedies, and impediments to implementation other than cost.

Reporting guidance for the HSIP, RHGCP and the 5% reports are provided on the FHWA Office of Safety web site <http://safety.fhwa.dot.gov/>.

1.1.4 Related Legislation

Title 23, Part 409 of the *United States Code* (**23 USC 409**) establishes a policy for the discovery and admission as evidence of certain reports and surveys. This policy protects the information obtained, compiled, and maintained for the use of the HSIP. Protected information includes reports, surveys, schedules, lists, queries, or any data

[1] FHWA Memorandum, High Risk Rural Roads Program Guidance Requirements under 23 U.S.C. §148 (a)(1)&(f), May 16, 2006

compiled or collected for the purpose of identifying, evaluating, or the planning of safety enhancements as outlined in **23 CFR 924.** Data used to develop any highway safety improvement project, which may be implemented utilizing Federal Aid highway funds, shall not be subject to discovery or admitted into evidence in a Federal or State court proceeding, or considered for other purposes in any action for damages, arising from an occurrence at a location mentioned or addressed by such data.

1.2 Funding

SAFETEA-LU provides funding to the HSIP as a core federal-aid program, no longer a set-aside from STP funds. There is also a flexibility provision whereas a state may use up to 10 percent of the amount of funds apportioned to the state under the HSIP for a fiscal year to carry out safety projects under any other section of Title 23, *United States Code*, as provided in the state's SHSP if the state certifies that:

A. The state has met its needs relating to railway-highway crossings; and
B. The state has met its infrastructure safety needs relating to highway safety improvement projects

1.2.1 Federal Apportionment

Railway-Highway Grade Crossing Program (Section 130)

Before apportioning HSIP funds, $220M is set-aside for the *Railway-Highway Crossing Program* under 23 USC 130. Apportioned funds are to be distributed based on the following factors (1) 50% based on the formula factors for the Surface Transportation Program in 23 USC 104(b)(3)(A) and (2) 50% based on the number of public railway-highway crossings. Of the Section 130 funds apportioned, a state must spend a minimum of 50 percent of its apportionment for the installation of protective devices at railway-highway crossings. The remaining funds may be spent for other types of improvements as defined in Section 130. SAFETEA-LU also contains a provision to use up to 2 percent of the Section 130 funds apportioned to a state for compilation and analysis of data for the required annual report to the secretary on the progress being made to implement the railway-highway crossings program.

HSIP Funds

After the Section 130 Funds are apportioned, the remainder is apportioned to States based on the following factors:

- 33⅓ % based on the ratio of lane miles of Federal-aid highways in each State to total lane miles of Federal-aid highways in all States.
- 33⅓ % based on the ratio of vehicle miles traveled on lanes on Federal-aid highways in each State to total vehicle miles traveled on lanes on Federal-aid highways in all States.

- 33⅓ % based on the ratio of the number of fatalities on the Federal-aid system in each State to the number of fatalities on the Federal-aid system in all States.

Each State's apportionment of HSIP funds is also subject to a set-aside for construction and operational safety improvements on High Risk Rural Roads.

HSIP Flexibility Provision

The HSIP also contains a provision that, to further the implementation of a state SHSP, a state may use up to 10 percent of the amount of funds apportioned to the state under Section 104(b) (5) for a fiscal year to carry out safety projects under any other section as provided in the state SHSP, if the state certifies to the secretary that:

- The state has met needs in the state relating to railway-highway crossings; and
- The state has met the state's infrastructure safety needs relating to highway safety improvement projects.

1.2.2 Federal Share

The Federal Share of HSIP projects on Interstate highways is applied by the sliding scale rate for Arizona of 94.34% of the total project cost, with the remaining 5.66% funded by the project Sponsor. The Federal Share on non-Interstate roadways is 94.3%, with the remaining 5.7% funded by the Sponsor.

As stated in Section 1.3, in accordance with 23 USC 120(c), projects such as roundabouts, traffic control signalization, safety rest areas, pavement markings, or installation of traffic signs, traffic lights, guardrails, impact attenuators, concrete barrier end treatments, breakaway utility poles, or priority control systems for emergency vehicles or transit vehicles at signalized intersections may be funded at up to a 100 percent Federal share, except not more than 10 percent of the sums apportioned under 23 U.S.C. 104 for any fiscal year shall be used at this Federal share rate.

The Federal Share of railway-highway grade crossing projects may amount up to 100 percent for projects for signing, pavement, pavement markings, active warning devices, and crossing closures, subject to the 10 percent limitation for funds apportioned under 23 USC 104 in a fiscal year.

1.3 Eligible Projects – Highway Safety Improvement Program

Under 23 U.S.C. 148(a)(3), a variety of highway safety improvement projects are eligible for funding through the HSIP. In order for an eligible improvement to be funded with HSIP funds, States shall first consider whether the activity maximizes opportunities to advance safety. States shall fund safety projects or activities that are most likely to reduce the number of, or potential for, fatalities and serious injuries.

Improvements to virtually any type of public surface transportation facility, including bicycle and pedestrian facilities, may be approved for the use of HSIP funding, provided

that the project is consistent with the State SHSP that corrects or improves a road location or feature, or addresses a highway safety concern. Federal safety funding is also available for the upgrade of existing substandard roadway features to conform to national standards or guidelines; such as those outlined in the MUTCD, by the Institute of Traffic Engineers (ITE), by the American Association of State Highway and Transportation Officials (AASHTO) and others, that have been adopted because they have been shown to measurably improve safety.

Per 23 CFR 924.3, safety enhancement project might include one or more of the following representative examples of eligible project activities:

(1) An intersection safety improvement.

(2) Pavement and shoulder widening (including addition of a passing lane to remedy an unsafe condition).

(3) Installation of rumble strips or other warning devices, if the rumble strips or other warning devices do not adversely affect the safety or mobility of bicyclists, pedestrians and persons with disabilities.

(4) Installation of a skid-resistant surface at an intersection or other location with a high frequency of crashes.

(5) An improvement for pedestrian or bicyclist safety or for the safety of persons with disabilities.

(6) Construction of any project for the elimination of potential safety concern at a railway-highway crossing that is eligible for funding under 23 U.S.C. 130, including the separation or protection of grades at railway-highway crossings.

(7) Construction of a railway-highway crossing safety feature, including installation of highway-rail grade crossing protective devices.

(8) The conduct of an effective traffic enforcement activity at a railway-highway crossing.

(9) Construction of a traffic calming feature.

(10) Elimination of a roadside obstacle or elements that may pose a road safety concern.

(11) Improvement of highway signage and pavement markings.

(12) Installation of a priority control system for emergency vehicles at signalized intersections.

(13) Installation of a traffic control or other warning device at a location with high crash potential.

(14) Transportation safety planning.

(15) Improvement in the collection and analysis of safety data.

(16) Planning integrated interoperable emergency communications equipment, operational activities, or traffic enforcement activities (including law enforcement assistance) relating to work zone safety.

(17) Installation of guardrails, barriers (including barriers between construction work zones and traffic lanes for the safety of road users and workers), and crash attenuators.

(18) The addition or retrofitting of structures or other measures to eliminate or reduce crashes involving vehicles and wildlife.

(19) Installation and maintenance of signs (including fluorescent yellow/green signs) at pedestrian-bicycle crossings and in school zones.

(21) Construction and operational improvements on high risk rural roads.

(22) Conducting road safety audits.

In accordance with 23 USC 120(c), projects such as roundabouts, traffic control signalization, safety rest areas, pavement markings, or installation of traffic signs, traffic lights, guardrails, impact attenuators, concrete barrier end treatments, breakaway utility poles, or priority control systems for emergency vehicles or transit vehicles at signalized intersections may be funded at up to a 100 percent Federal share, except not more than 10 percent of the sums apportioned under 23 U.S.C. 104 for any fiscal year shall be used at this Federal share rate. Eligibility of funding for traffic control devices is subject to a State and/or local jurisdiction's substantial conformance with National MUTCD or FHWA approved State MUTCD. Activities ancillary to projects including any of the above safety enhancements such as design, right-of-way purchase, utility relocation, construction, and before- and after-studies are also eligible for Federal safety funding.

2. ARIZONA HSIP

The Arizona Department of Transportation (ADOT) is the State agency responsible for the adoption and administration of the HSIP in Arizona. ADOT's Highway Enhancements for Safety (HES) Section is responsible for the development, implementation, and maintenance of Arizona's HSIP.

2.1 Funding

Arizona receives an annual apportionment of HSIP funds and Railway-Highway Grade Crossing Funds.

2.1.1 Application of Federal Safety Funds

For HSIP, ADOT has chosen to set aside 20 percent of the apportionment to the local and tribal government HSIP, 70 percent to the State highways and 10 percent flexible funds for non-infrastructure safety programs identified in the SHSP. Figure 1 shows the HSIP funding allocations. There are also funds set aside for the High Risk Rural Road Program and Railway-Highway Grade Crossing Program. In addition, there is a Road Safety Assessment (RSA) program funded through HSIP, including managing the RSA program, conducting RSAs and implementing recommendations on all public roads.

Other Federal-aid funds are eligible to support and leverage the safety program. Improvements to safety features that are routinely provided as part of a broader Federal-aid project should be funded from the same source as the broader project. States should address the full scope of their safety needs and opportunities on all roadway categories by using other funding sources such as Interstate Maintenance (IM), Surface Transportation Program (STP), National Highway System (NHS), and Equity Bonus (EB) funds in addition to HSIP funds.

Approved safety enhancements may be consolidated or added-on to existing nearby, abutting, or overlapping projects. In this situation, although the supplementary safety enhancements would be constructed along with the rest of the project, which would normally be combined and bid under a single construction contract, they can be developed independently. HSIP funds would be applied to the safety enhancements at the appropriate participation rate.

The maximum dollar amount of HSIP funds that can be applied to a State Highway HSIP project is $10 million per project, but this number can be increased by request to, and approval by, FHWA.

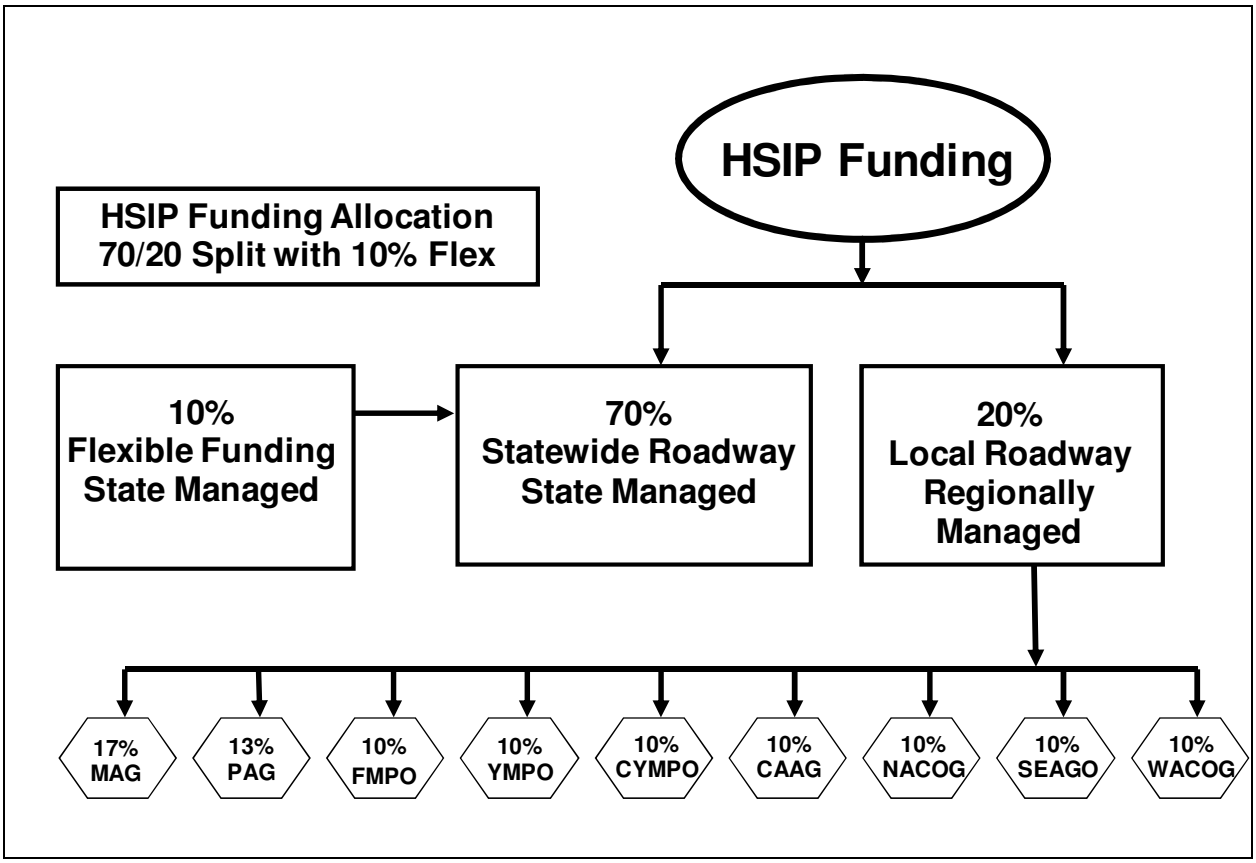

Figure 1. HSIP Funding Allocations

2.1.2 Flexible Funding

Because Arizona DOT has adopted the SHSP, SAFETEA-LU allows Arizona DOT some flexibility to use up to 10 percent of HSIP funds for non-infrastructure safety projects when all infrastructure needs, including those for railway-highway grade crossings, have been met for a particular year.

Arizona DOT submits a written request for approval to the FHWA Arizona Division Office for each year that Arizona DOT certifies that the requirements have been met.

2.2 HSIP Program Overview

The summary of the HSIP programs administered and managed by ADOT are shown in the subsequent sections. All of these programs are in alignment with SAFETEA-LU compliant Arizona SHSP, which was developed in August 2007 with the following emphasis areas: Restraint Use, Speeding, Young Drivers, Impaired Driving, Roadway/Roadside (lane departure and intersections), and Data Improvement (Traffic Records Coordinating Committee).

2.2.1 HSIP – State Managed (State Highway System)

ADOT HES identifies potential locations for safety enhancements and develops safety projects on the State Highway System. Funding allocation for these projects include 70% of HSIP funds, which also includes funding the positions of the Road Safety Assessment Program Manager and HSIP Local Government Coordinator. The program guidelines are detailed in Section 3.

2.2.2 HSIP – Regionally Managed (Local Government Roadways)

MPOs and COGs identify potential locations for safety enhancements projects on Non-State Highway System, such as, county, city/town, tribal roadways. HSIP Local Government Coordinator provides assistance to local agencies throughout the process of identifying and developing the projects. Funding allocations for these projects include 20% of HSIP funds. Funding not obligated in the current FY is rolled into the State HSIP for the following FY. The program guidelines are detailed in Section 3.

2.2.3 Road Safety Assessment Program

The Road Safety Assessment (RSA) Program Manager administers and conducts RSAs throughout Arizona. HSIP funds are utilized for the RSA Program Manager position, travel expenses for team members, and consultant participation on RSAs. HSIP funds may also be used to implement RSA recommendations. High Risk Rural Road Program funds can also be obtained for implementing RSA recommendations. The program guidelines are detailed in Section 3

2.2.4 High Risk Rural Road Program

A High Risk Rural Road is any roadway functionally classified as a rural major or minor collector or a rural local road on which the accident rate for fatalities and incapacitating injuries exceeds the statewide average for those functional classes of roadway; or that will likely have increases in traffic volume that are likely to create an accident rate for fatalities and incapacitating injuries that exceeds the statewide average for those functional classes of roadway.

2.2.5 Railway-Highway Grade Crossing Program

The ADOT Utility & Railroad Section administers and manages this program funded through SAFETEA-LU allocation of approximately $2 million per year. ADOT maintains the inventory of all public railroad crossings, which are ranked based on the Relative Hazard Exposure Index. A diagnostic review team consisting of representatives from ADOT, the ACC, FHWA, the Railroad and the Road Sponsor (State, City, County, or Tribe) evaluates the identified railroad crossings through an on-site diagnostic review. A list of projects is developed through this process. The program guidelines will be available through ADOT's Utility & Railroad Section.

3. STATE MANAGED HSIP PROGRAM

The State Managed Highway Safety Improvement Program focuses on locating and addressing potential safety concerns on State Highway Systems. There are three key components in a successful HSIP – Planning, Implementation and Evaluation as shown in Figure 2. The processes of identification, development, design, construction, and evaluation of highway safety enhancement projects begin with **Planning**.

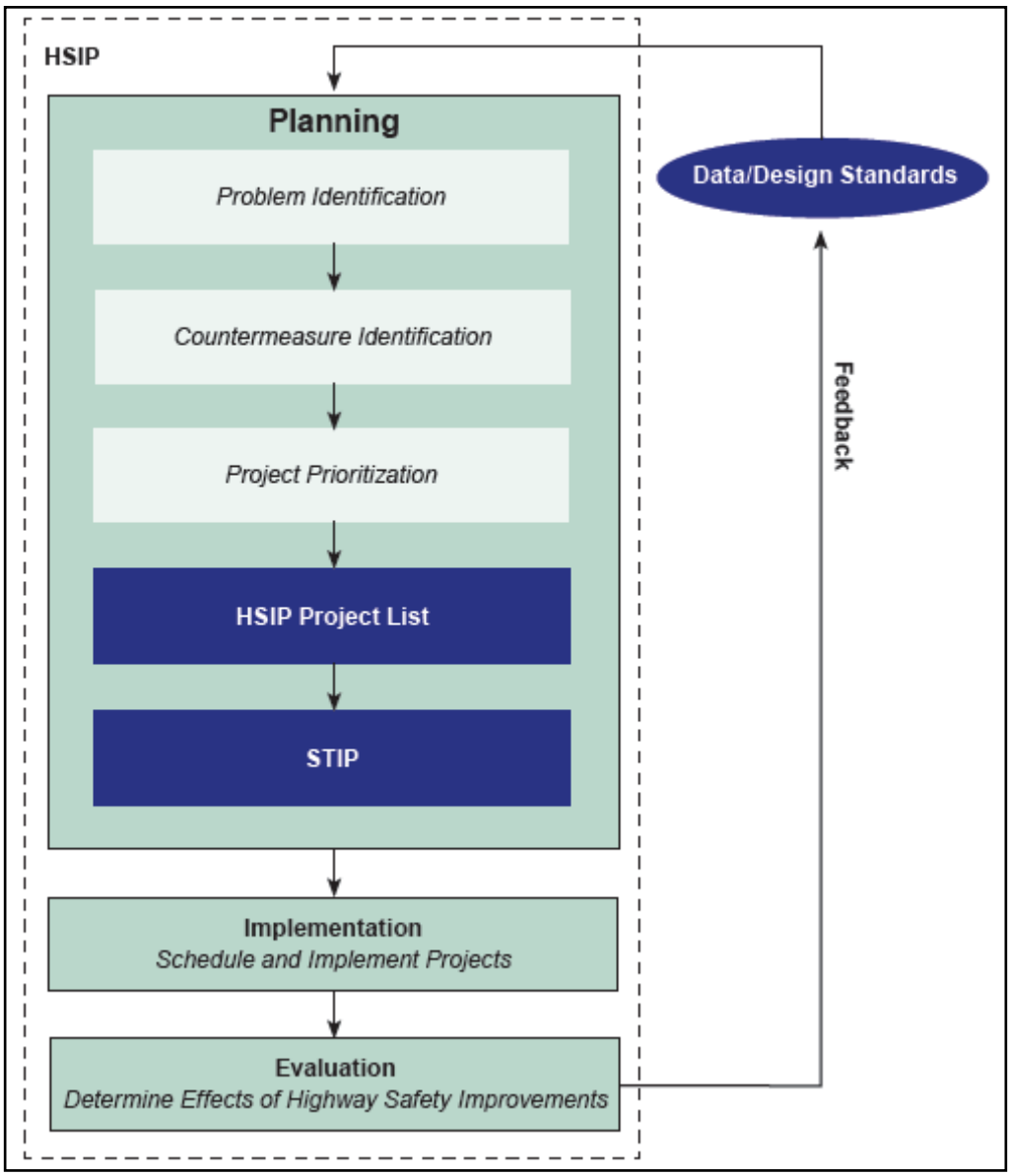

Figure 2. HSIP Components[1]

[1]Source: FHWA Highway Safety Improvement Program Manual, USDOT, January 2010.

3.1 Planning

ADOT's planning process shall incorporate the following four key components: Data collection, data analysis, safety evaluation, and program/project prioritization.

3.1.1 Data Collection

This process involves collecting and maintaining the records of crash, roadway, traffic and vehicle data on all public roads. Input on crash and other data relevant to identifying road safety concerns is obtained by ADOT HES Section through ADOT data warehouses.

Crash Data

In 1973 a motor vehicle crash database known as the Accident Location Identification and Surveillance System (ALISS) was put into use by ADOT. This system was initially developed in response to the general requirements set forth by the National Highway Safety Act of 1966, and a sincere desire by the state of Arizona and local governments to take positive action against the soaring numbers of tragic deaths and their accompanying economic losses[1]. This automated system compiles all the individual crash records at the local jurisdictional level and is compatible with Federal crash record systems.

Under Arizona law, all State agencies that prepare motor vehicle crash reports, meeting the minimum requirement of injury or $1000 of property damage, must send a copy of the report to the ADOT Traffic Records Section[2,3]. The Arizona Crash Report Form has been updated effective January 1, 2009 to be Model Minimum Uniform Crash Criteria (MMUCC) compliant. The Traffic Records Section personnel enter each of over 108 data elements, including driver, vehicle, and roadway and weather characteristics, from incoming reports into the ALISS database.

Roadway and Traffic Data

The ADOT Multimodal Planning Division (MPD) Geographic Information System for Transportation (GIS-T) Section is responsible for administering an FHWA program known as the Highway Performance Monitoring System (HPMS) in the state of Arizona. The HPMS is America's national database of highway information. Each state maintains an HPMS and annually submits state information to FHWA for inclusion in the national HPMS. Made up of over 100

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[1] *Arizona's Date with ALISS, An introduction to the Arizona Traffic Records System,* Traffic Records Coordinating Committee, February 1971

[2] *Arizona Criminal and Traffic Law Manual, 2000-2001 Ed.*, Chapter 3, "Traffic and Vehicle Regulation", Article 4, Section 28-667, 2000

[3] Although ADOT encourages crash report submittal by Tribal Governments and Federal agencies (such as National Parks and military bases) that have jurisdiction over roadways used by the public, reporting of crashes that do not take place on State highways is discretionary to the jurisdiction.

data elements, this database contains information pertaining to the physical roadway, including road beginning and ending location, length, use, and condition; as well as performance data such as traffic volume and vehicle classification information.

The HPMS is derived from several databases including the State Highway Log and the Arizona Transportation Information System (ATIS), which provides the base centerline for the system. ATIS contains roadway location and name. The State Highway Log provides the number of lanes, lane widths, shoulder type and width, pavement type, etc. Traffic Data is collected and processed by the MPD Data Group and provided to HPMS on an annual basis. ATIS is a geographic information system (GIS) and is the Arizona Base Centerline Map. Originally, ATIS developed out of the ALISS base map and was maintained by the ADOT Photogrammetry and Mapping Section. As ATIS developed with changing technology, it ultimately was made independent from the ALISS System, although crashes currently entered on ALISS are located on roadways using ATIS as the reference. Since ATIS is a GIS-based system, ATIS is now maintained by the GIS-T section of MPD

ADOT HES personnel trained in the use of GIS technology have the ability to query the HPMS database and retrieve roadway data pertinent to a safety analysis of a location or to compare against other locations.

Maintenance Data

Maintenance data, such as labor, equipment, material resources and descriptions of work performed, is entered and maintained in ADOT's Performance Controlled System (PECOS). PECOS is the Highway Maintenance Management System developed and implemented by the ADOT Intermodal Transportation Division (ITD).

Each ADOT Engineering District monitors and records repeat maintenance items, which can indicate the location of a potential safety concern. For example, records indicating a single light pole is continually in need of repair due to repeated vehicle impacts, might point to a problem with the pole location. In this way, maintenance data can be used to identify and locate problem areas.

Feature Inventory

The ADOT Asset Management Section plans to maintain an inventory of all features, such as signs, signal and light poles, and street furniture, related to each segment of roadway on the State system. These data are used to find out what features are present in an area where a large number of crashes is occurring.

Special Requests

Historically, requests have come to the HES Section via telephone calls, reports, letters, and emails from essentially anyone with a concern about the safety of a particular location(s) on a State highway, including the general public. This has been, and continues to be an important source of information for the HES

Section staff. A new requirement directs HES staff to document all requests in the form of a Special Request form[1]. The Special Request form solicits specific information pertinent to initial screening and prioritization of the Request.

3.1.2 Data Analysis and Problem Identification

ADOT identifies candidate locations (either segments or intersections) for spot improvements as well as systematic improvements using one of the recommended network screening methods and available crash and exposure data.

There are 13 recommended problem identification methods such as crash rate, relative severity index, and critical crash rate. Details of each are provided in the FHWA HSIP Manual.

Since it is the intent of the State managed HSIP to reduce the frequency and overall severity of motor vehicle collisions that occur within the State, remediation efforts must be focused primarily to address collisions resulting in serious injury or death, and their attendant circumstances and causes.

In the analysis process, graphical and statistical relationships can be developed which are expected to yield the following information:

- The type or manner of collision that results in the most serious injuries and death
- The driver errors that contribute to these collisions
- The number and frequency of these collisions
- The locations in which these collisions occur
- The roadway and traffic characteristics of these locations

This process ultimately allows for the extrapolation of the key causal factors of the most harmful collisions within the State. It is the ultimate goal of the State managed HSIP and HES Section to be able to quantify the characteristics and relationships associated with each type of collision from the most harmful to least; i.e. property damage only. For example, for a given collision type, head-on, the HES Section would have statistical data indicating: The relative severity of injury; the predominating physical characteristics of the locations; the average volume on roadways of this type; the typical driver error leading to the collision; if correctable, what type of remediation has been most successful in addressing the error(s); and what does it cost? The foregoing is intended to answer the questions:

- *What are the biggest contributors to injury and fatal accidents?*
- *Where do they tend to occur?*
- *Why do they tend to occur?*
- *What, if anything, can be done to correct them?*

[1] A sample of the current *Special Request* form is included in Appendix B.

This allows ADOT HES Section personnel to analyze trends, establish expected averages, find statistically significant anomalies, and anticipate problem areas. It also allows for rational, unbiased prioritization of projects; that are clear and comprehensible to all ADOT personnel.

3.1.3 Safety Evaluation Candidacy and Prioritization

Per Title 23 CFR 924, the process for establishing priorities for implementing HSIP projects should have the following considerations:

(i) The potential reduction in the number of fatalities and serious injuries;

(ii) The cost effectiveness of the projects and the resources available;

(iii) The priorities in the SHSP;

(iv) The correction and prevention of hazardous conditions;

(v) Other safety data-driven criteria as appropriate in each State; and

(vi) Integration with the statewide transportation planning process and statewide transportation improvement program, and metropolitan transportation planning process and transportation improvement program where applicable.

Candidate projects can be developed through data analysis, Special Requests, and Pavement Preservation projects safety evaluation.

Locations identified through data analysis:

ADOT HES will identify locations through a problem identification methodology and rank them accordingly. Prioritization of locations to be considered for the detailed study of a Safety Evaluation, whether the Evaluation is for a spot location or for systemic/systematic improvements, is based almost exclusively on a ranking of locations that have the greatest potential to improve safety, as defined by abnormally high crash rates and crash severities, regardless of the method in which the location was identified.

Locations identified through Special Request:

ADOT HES will evaluate Special Request locations and a project could be developed if it has the potential to mitigate crashes.

Locations identified through Pavement Preservation projects:

ADOT HES will evaluate Pavement Preservation projects having a history of fatal or severe-injury crashes to evaluate if they have the potential to enhance safety. All Pavement Preservation projects are to include certain standard safety enhancements,

such as: Addition of edge rumble strips; addition of signing, marking, and delineation; and upgrade of existing safety hardware to conform to current standards[1],

A balance is needed in the HSIP among spot locations (e.g. intersections, segments) and systemic/systematic improvements to ensure that the best mix of safety solutions are implemented. Systemic/systematic evaluations are performed based on proven effectiveness measures (e.g. CRF, AMF) applied regionally as opposed to spot locations. Prioritization of spot locations requires a detailed economic analysis, such as, B/C Ratio, Net Present Value, Cost-Effectiveness, for justification of funding.

3.1.4 Safety Evaluation

Once candidacy for an evaluation has been established, an HES Section member will begin a detailed Traffic Safety Evaluation that includes engineering studies or investigation in a variety of areas. A detailed Safety Evaluation takes a similar approach to the collection and correlation of data as that in the **Data Collection** and **Data Analysis** sections detailed previously, for an in-depth location investigation. The Evaluation, which is summarized in a Traffic Safety Evaluation Report[2], consists of investigation in each of the following areas:

- Roadway Features
- Traffic Characteristics
- Crash History
- Improvement Alternatives
- Quantitative analysis to compare projects/alternatives by
    - Simple ranking based on factors, such as, CRF, AMF
    - Benefit-Cost Ratio (B/C)
    - Incremental Benefit-Cost Ratio
    - Cost-effectiveness
    - Net Present Value

Roadway features, traffic characteristics, and crash history are all elements that require scrutiny when establishing causal factors for areas with a high and/or severe injury crash rate. A holistic investigation of all the components that are unique to each location yields the most accurate assessment of the factors influencing driver behavior, which in turn leads to the most effective improvement alternatives.

Roadway Features

The physical characteristics of the subject roadway are a composite of the roadway section and location; roadway type and general conditions; roadway geometrics,

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[1] *Guidelines for Scoping Pavement Preservation Projects*, ADOT Roadway Engineering Group, November 2008

[2] *Safety Evaluation Report Format Guidelines* (Appendix C)

traffic control type and location, adjacent development, available stopping, passing, and intersection sight distance, location and type of signing, striping, delineation, grade, superelevation, and all other existing physical features of, on, and around the roadway[1]. Some or all of these characteristics, where appropriate and applicable, must be investigated and documented, presented both in the text of the Report and graphically in a Condition Diagram, as part of every safety evaluation.

These data may come from any or all of the following: The HPMS database, the Maintenance and/or the Feature Inventory database, as-builts that encompass the subject area and any additional information contained in a Special Request. The Roadway Features investigation should also include research into any previous work done to mitigate a safety concern in the subject area, and the effect, if any, this had on the safety of the area.

Traffic Characteristics

To understand traffic movement through the subject roadway, existing and forecasted traffic volumes, vehicle size distribution, vehicle speed distribution, pedestrian and bicycle activity/volumes, capacity, delay, gaps, and conflicts need to be identified. Some of this information is measured and published yearly by ADOT's Multimodal Planning Division (MPD) or can be found in the HPMS database, and some may be obtained by a prior study. Additional information may also be contained in a Special Request. However, it may be necessary to measure any or all of these quantities, as applicable, for each safety evaluation. Additionally, an engineering speed study, a 12-hour traffic count, and a turning movement survey may be required for each location, as applicable, to obtain a complete and thorough representation of existing traffic characteristics.

Crash History

Crash history is perhaps the most vital element in establishing the presence of a potential safety concern. Collision reports for the subject area for the most recent five-year period are obtained from the ALISS database by ADOT Traffic Records personnel. Each collision report contains valuable information regarding the condition of each driver and vehicle involved in the crash; an officer's assessment of specific driver error(s) contributing to or responsible for the crash; weather, light, and road-surface conditions at the time of the crash; a detailed description and usually a sketch of the location at which the crash occurred, and many other data elements. Crash information obtained for the subject location is summarized and presented both in the text of the Report and graphically in a Collision Diagram. Tabulation of crash data elements by year is essential to the Safety Evaluation and the economic analysis of safety improvements to the subject location; and the calculation of a ten-year crash rate provides the

[1] It may also be relevant to evaluate barrier warrants, adequacy of turn lane storage and transition lane taper lengths, accessibility to disabled persons and "friendliness" of the subject roadway to pedestrians and bicyclists.

opportunity for comparison to other locations with similar physical roadway or traffic characteristics. All of the foregoing is critical to both micro-scale spot or location study and project development, and macro-scale State- and system-wide Subprogram development.

Improvement Alternatives

A holistic investigation of all the components unique to each location should resolve the data gathered into pairs or groups of similarity, indicating a pattern or patterns in driver behavior, manner of collision, prevailing weather or road conditions, etc.; and the possible deficiency of elements of design or function of the existing roadway. Pairings or patterns in data usually make it possible to identify critical causal relationships, which in turn promote the development of one or more countermeasures to address adverse conditions that led to collisions on the subject roadway. In this way, HES staff can generate proposed safety improvement alternatives, incorporating multiple safety enhancements into unified strategies to improve user safety. The Safety Evaluation report will include all the improvement alternatives resulting from the Safety Evaluation, and define a recommended alternative. The safety enhancements that compose the recommended alternative may also be presented graphically in an Improvement Diagram, as appropriate.

Benefit-Cost Ratio (B/C) Analysis

The benefit-cost ratio analysis is an economic evaluation that is the basis for establishing the relative need for and the feasibility of implementing recommended safety improvements. The B/C is the ratio of expected benefits accrued (assessed in dollars[1]) to the cost to construct and maintain the recommended alternative.

Using crash data obtained and tabulated previously in the Evaluation, for each crash severity type: Fatal, Incapacitating Injury, Non-Incapacitating Injury, Possible Injury, and Property Damage Only (PDO) and Unreported, an Annual Average is calculated. The Annual Average (in number of accidents per year) is multiplied by the estimated Crash Reduction Factor (CRF)[2] to obtain the Total Reduction (in number of accidents per year). Crash Reduction Factors, published by FHWA[3], and by the state of Arizona[4], and any additional publications are the statistical numbers extrapolated from before-and-after studies that evaluate the efficacy of specific countermeasures used to mitigate potential safety concerns.

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[1] Although it is not possible to assign a value to human life or to the fullness of function of human faculty, the Federal government requires a quantification of the costs associated with the loss of these.

[2] Sample Crash Reduction Factors are given in Appendix D

[3] *FHWA-SA-96-040*, "1996 Report on Highway Safety Improvement Programs", Table 1 (Appendix D)

[4] "Accident Rate Reduction Levels Which May Be Attainable from Various Safety Improvements", February 1991, Lists 1-4 (Appendix D)

The Total Reduction is multiplied by the unit cost for the crash severity to obtain the Total Annual Benefit (in dollars). Currently used crash costs by severity are shown in Table 1.

Crash Type	Unit Cost
Fatal	$ 5,800,000
Incapacitating Injury	$ 400,000
Non Incapacitating Injury	$ 80,000
Possible Injury	$ 42,000
Property Damage Only	$ 4,000
Unknown	$ 4,000

Table 1. Motor Vehicle Crash Costs by Severity

The costs associated with implementation of the recommended safety improvements are resolved into annual construction and maintenance costs, considering the estimated project life in years, the interest factor for annual compounding, and a capital recovery factor, and summed for a Total Annual Project Cost.

The Total Annual Benefit divided by the Total Annual Project Cost is the B/C[1]. Assuming the value of the B/C for doing nothing (no addition of safety enhancements) in the subject location is equal to one, a B/C equal to or greater than one is an indication that it is economically favorable to implement the recommended safety enhancements in consideration. However, it should be noted that some system-wide improvements may have a B/C greater than one for the entire project rather than individual segments that constitute the project (usually multi-year projects).

Incremental Benefit-Cost Ratio (B/C) Analysis

The benefit/cost ratios of the individual safety improvement projects are the starting point for an incremental benefit/ cost analysis. When the individual projects with a BCR greater than 1.0 are ranked in increasing order based on cost, with the smallest cost listed first, the ratio of the difference between the first and second project's benefits, and respective costs would give an incremental benefit/cost ratio. If the incremental BCR is greater than 1.0, the project with the higher cost is ranked higher and compared with the next project on the list, meaning the magnitude of the benefits of the higher-cost project outweighs the higher cost. The best economic investment is the project selected in the last pairing. In instances where two projects have the same cost, the project with the greater benefit should be selected.

[1] Benefit-Cost Economic Analysis Guidelines are presented in Appendix D.

Net Present Value

The net present value (NPV) method, or net present worth (NPW) method, expresses the difference between the discounted costs and discounted benefits of a safety improvement project. The costs and benefits are discounted by converting to a present value using a discount rate.

A project is economically justified if the NPV is greater than zero. This method identifies the most desirable countermeasure(s) for a specific site, and it also can be used to evaluate multiple projects across multiple sites.

Cost Effectiveness Analysis

In situations where it is not possible or practical to monetize countermeasure benefits, a cost-effectiveness metric may be used. Cost-effectiveness is the ratio of amount of money invested to the benefit in crash reduction. It is expressed as the cost for crash avoided with a certain countermeasure. Thus, countermeasure with the lowest value is ranked first.

3.1.5 FHWA Approval

Safety Evaluations concluding that improvements at the subject locations may significantly reduce the occurrence of and/or the potential for fatalities and serious injuries resulting from crashes on all public roads are submitted to FHWA for approval and funding. Only those candidate projects that receive FHWA approval are developed as safety improvement projects in the Highway Safety Improvement Program.

3.2 Implementation

The **Implementation** component of Arizona's HSIP encompasses the development of projects, identified for implementation and prioritized in **Planning.** The Project Development process comprises four phases: Project Scoping; Design and Pre-Construction Activities; Construction; and Operation and Maintenance.

3.2.1 Development of State Projects

The project development process for State safety projects is the same as for all other Federal-Aid projects as defined in the *ADOT Project Development Process Manual*. The following is a brief synopsis of the elements of project development detailed in the *Project Development Process Manual.*

Scoping

In this phase, a Scoping Document or a more comprehensive Project Assessment report is developed, and contains specific project information about existing conditions at the subject location, defines the need for the project, identifies the proposed activities which address this need, and establishes an initial timeline for project completion. In this phase any conditions which will affect the proposed timeline and construction of the project, including right-of-way constraints or the need for purchase of additional right-of-way; environmental considerations such

as the presence of any elements of historical, archeological or biological significance or concern; geotechnical limitations; potential or actual utility conflicts; and any other relevant considerations are addressed.

Data from the Scoping Document or the Project Assessment are the basis for preparing the annual *Five-Year Highway Construction Program*, or simply the "Five-Year Program". The Multimodal Planning Division and the State Transportation Board use the individual project objectives, estimated costs, and development of timelines to establish priorities for construction of the candidate projects.

The funding source is also identified in this phase. Funding for HES Projects on the State Highway System is included in the Five-Year Program as a lump sum until such time as the project is approved for HES funds and converted to a line item project in the Program.

Design and Pre-Construction

Following acceptance into the Five-Year Program, projects advance to the Design Phase and Pre-Construction phase. The Design phase consists of the staged development of design and construction documents. The ADOT design process consists of submittals at the Scoping Document or Project Assessment report phase, and design documents in five stages, representing the 30%, 60%, 95%, 100% design completion (Stages I – IV), and Plans, Specifications & Estimate (P S & E – Stage V). As part of Stage I design activities, it is recommended that environmental clearances, which are required on all Federal-Aid projects, be secured. Design of the project is by ADOT (In-House) or by an ADOT-designated consultant. All environmental clearances and any right-of-way acquisition must be secured prior to bid advertisement. Pre-Construction includes the final acceptance of the construction documents, and the bid advertisement and award of contract. Bid advertisement is in accordance with the State law by the ADOT Contracts and Specifications Section. Award of contract is to lowest qualified bid, at an open public meeting.

Construction

After the contract is awarded, the contractor is responsible for constructing the project in accordance with the terms, conditions, and provisions set forth in the contract. Contract administration, construction surveillance, and work inspection is done through the appropriate ADOT Engineering District[1]. A consultant, either the consultant that designed the project—if consultant-designed, or one contracted specifically for the purpose, provides post-design services during construction. Project acceptance concludes the construction phase and is completed by the appropriate ADOT District Engineer or his designee.

[1] Arizona is divided by region into Engineering Districts, thus the location of the project determines the appropriate District.

Operation and Maintenance

ADOT includes a 1-year period of operation and maintenance in the Project Development Process, to ensure a high level of communication and feedback to the design and construction staff regarding the project quality and appropriateness of design.

3.3 Evaluation

Arizona's HSIP includes a process for **Evaluation** of its Program and projects. The intent of this process is to determine the effectiveness of the Program, its adherence to Federal regulations, and to utilize data obtained by **Evaluation** in the **Planning** process.

Annual Program Review Report

A report is submitted annually to FHWA that evaluates ADOT's Highway Safety Improvement Program in total. The report includes a review of specific systemic/systematic and spot location projects. A project listing, with a synopsis of activity for all projects for the previous year includes information such as: Project name, estimated cost, bid information, date when the project was closed, number of crashes before and after construction, and final construction costs. The annual report will also include the Railway-Highway Grade Crossing program.

Semi-Annual Review

The ADOT HES Section and FHWA conduct a semi-annual review to discuss prioritization of projects, evaluate the processes of the HSIP, present new research in safety/crash reduction, and others.

Before-and-After Studies

The ADOT HES staff conducts reviews, called "Before-and-After Studies", of safety improvement project locations, comparing various features and characteristics of the subject location before construction and after. The results of Before-and-After Studies are prepared for and included in the annual report to FHWA. One element of these Studies is a comparison of crash rate and severity in the *before* and *after* conditions. This is the most fundamental and the most important comparison to be made in the evaluation of safety improvement projects. The "success" of a project is defined by a drop in the severity and number of crashes.

Another element of the Study is an evaluation of the actual Benefit/Cost achieved by the project. By comparing the actual cost of construction with the estimated cost, and the crash frequency and severity in the "after" condition with the frequency and severity estimated prior to construction, a direct comparison of B/C_{BEFORE} and B/C_{AFTER} can be made.

From an analysis of *before* and *after* B/Cs versus *before* and *after* crash numbers and severities, an estimation of the reduction percentages for the safety countermeasure, or combination of countermeasures, for each project can be extrapolated. By collecting and maintaining before-and-after crash data for every safety improvement project, more

accurate reduction percentages can be derived, and from these more reliable CRFs can be established. Reliable CRFs lead to more realistic statistics for future projects.

Information derived from the **Evaluation** process, such as reliable Crash Reduction Factors, and an evaluation of the efficacy and benefits of projects are critical to the **Planning** process and to the success of the HSIP in Arizona.

4. REGIONALLY MANAGED HSIP PROGRAM

4.1 Planning

The Local Government HSIP Coordinator will be available to administer the projects including providing assistance in developing and managing projects. The following sections provide the local government planning process for developing HSIP funded projects.

MPO/COG Prioritization and Selection of Safety Projects

- Network screen roadways to identify site with a potential for safety improvement – Can be done using any analytic process and/or a call for safety projects
- Identifies potential countermeasures at selected locations and/or systematic improvements – Potential countermeasures can be presented to the Technical Advisory Committee (TAC) members
- Prioritize and select projects – TAC can prioritize and select the projects based on an acceptable ranking method (verified by ADOT HES through e-mail/phone conversation)

Submittal of Safety Projects to ADOT

- Submit prioritized list of projects with summary of safety need and proposed countermeasures – Submit to ADOT HES (Local Government HSIP Coordinator)
- ADOT HES, ADOT MPD, and FHWA evaluate the project and proposed countermeasures
- ADOT HES sends a letter of eligibility or a letter requesting clarifications, as applicable, to MPO/COG

Funding

- The Local Government HSIP is set-aside for each MPO/COG in the amount of $600,000 except MAG ($1,000,000) and PAG ($750,000)
- The funding cycle is on the State Fiscal Year (July 1 through June 30)
- When the funding needs to be obligated in the current State FY, the cut-off date for submission of the completed application with all necessary clearances to ADOT HES for federal-aid authorization is May 1st
- MPOs and COGs may transfer funds amongst themselves with prior notification and/or approval of ADOT MPD
- The funding not obligated under the Local Government HSIP will be moved to the State HSIP line item in the 5-year construction program

- The MPOs and COGs will be able to plan for future years and have adequate time to develop projects that will be in the queue for future FYs

Systematic Projects

1. IMPROVE ROADWAY SEGMENT SAFETY

    a. Milled in shoulder rumble strips
    b. Milled in centerline rumble strips – head-on crashes
    c. Milled in transverse rumble strips
    d. Incorporate Safety Edge on pavement projects
    e. Install roadside delineation for barriers and obstacles
    f. Upgrade guardrail end treatments – installation, conversion or upgrading to energy absorbing systems
    g. Upgrade pavement markings (more durable materials)
    h. Installation of raised/recessed pavement markers
    i. Upgrading regulatory and warning signs rehabilitation (including compliance with new reflectivity requirements)
    j. Establish or upgrade mileposts and milepost system

2. IMPROVE SIGNALIZED INTERSECTION SAFETY

    a. Converting from 8-inch to 12-inch signals
    b. Installation of LED Signal Heads
    c. Installation and/or upgrading street name signing
    d. Installation of advance street name signing

3. IMPROVE UNSIGNALIZED INTERSECTION SAFETY

    a. Upgrade STOP sign – larger and/or retroreflective upgrade
    b. Install advance stop ahead pavement marking

4. IMPROVE PEDESTRIAN SAFETY

    a. Install pedestrian crosswalk countdown signals
    b. Install and/or upgrade pedestrian crosswalk pavement markings
    c. Enhanced school crossing signals, signing and/or pavement markings
    d. Provide mid-block crosswalk advance stop bars
    e. Provide pedestrian refuges

Such improvements typically do not involve or require lengthy or complicated environmental review. Many would qualify for Group 1 or Condensed Group 2 Categorical Exclusions. These improvements do not normally involve additional right-of-way and most do not involve utility coordination or adjustments.

FHWA also suggests consideration of area-wide projects that accomplish the same or very similar improvements over wide areas and multiple jurisdictions.

Please refer to FHWA memo on Eligibility of Sign Replacement (February 27, 2008) requiring these projects to have a documented safety benefit <http://safety.fhwa.dot.gov/hsip/policy_guide/memo022708.cfm>.

4.2 Implementation

MPOs and COGs will include the selected projects in their Transportation Improvement Program (TIP). The Local Government HSIP Coordinator will assist MPOs and COGs through the project development process. With FHWA approval, ADOT may delegate to the Local Government the authority to self-administer projects under the certification acceptance program. If approved, the Local Government is granted authority to design, advertise and award, and administer construction of local projects. Responsibility for the review and approval of the project DCR and environmental determination, provision of the environmental clearance, and the processing of Federal funds would remain with ADOT.

4.3 Evaluation

All HSIP funded local government projects will be evaluated using "before-and-after" analysis method by the Coordinator.

5. HIGH RISK RURAL ROADS PROGRAM

In Arizona, High Risk Rural Roads Program (HRRRP) will kick off in FY 2011. The program will be statewide and anticipated to be managed primarily by the Local Government agencies.

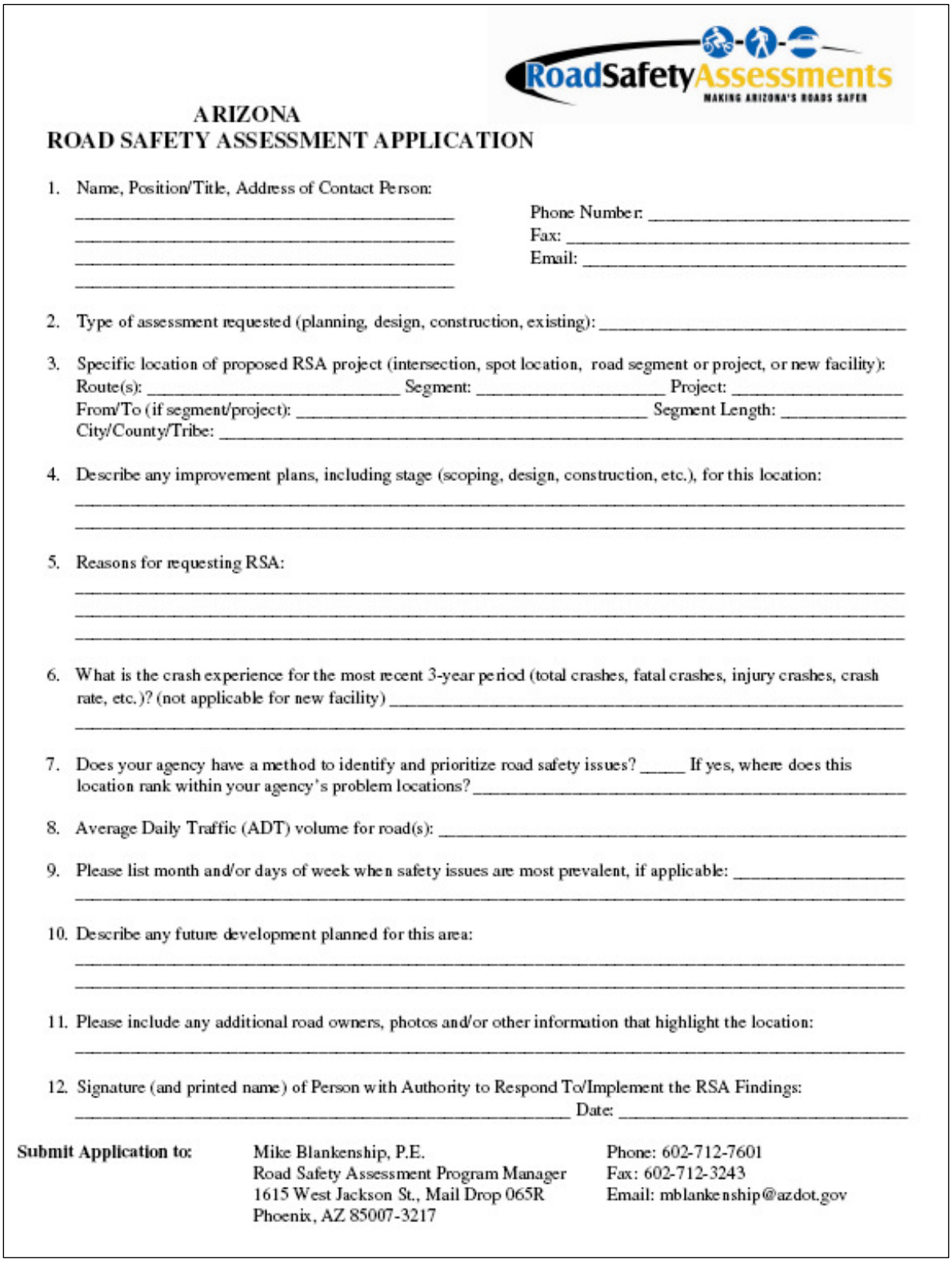
The Planning, Implementation and Evaluation will follow the guidelines to be developed at a later date by the Local Government HSIP Coordinator.

6. ROAD SAFETY ASSESSMENT PROGRAM

The Arizona Road Safety Assessment (RSA) Program activities include conducting RSAs, providing training, marketing the program through presentations, and evaluating the success of the program. The RSA Program Manager administers and conducts RSAs throughout Arizona. HSIP funds are utilized for the RSA Program Manager position, travel expenses for team members, and consultant participation on RSAs. HSIP funds may also be used to implement RSA recommendations. High Risk Rural Road Program funds can also be obtained for implementing RSA recommendations.

An RSA is a formal examination of user safety of an existing or planned road or intersection by an independent, multi-disciplinary team. The characteristics of RSAs include analysis of crash data, day and night field reviews, and identification of existing and potential safety concerns. The RSA application form is shown in Figure 3. For additional information, please visit <http://azdot.gov/highways/traffic/9620.asp>.

Initially, the RSA Program will allocate $500,000 HSIP funding per year for statewide safety projects.



ARIZONA
ROAD SAFETY ASSESSMENT APPLICATION

1. Name, Position/Title, Address of Contact Person:
   _____ Phone Number: _____
   _____ Fax: _____
   _____ Email: _____
   _____

2. Type of assessment requested (planning, design, construction, existing): _____

3. Specific location of proposed RSA project (intersection, spot location, road segment or project, or new facility):
   Route(s): _____ Segment: _____ Project: _____
   From/To (if segment/project): _____ Segment Length: _____
   City/County/Tribe: _____

4. Describe any improvement plans, including stage (scoping, design, construction, etc.), for this location:
   _____
   _____

5. Reasons for requesting RSA:
   _____
   _____
   _____

6. What is the crash experience for the most recent 3-year period (total crashes, fatal crashes, injury crashes, crash rate, etc.)? (not applicable for new facility) _____
   _____

7. Does your agency have a method to identify and prioritize road safety issues? _____ If yes, where does this location rank within your agency's problem locations? _____

8. Average Daily Traffic (ADT) volume for road(s): _____

9. Please list month and/or days of week when safety issues are most prevalent, if applicable: _____
   _____

10. Describe any future development planned for this area:
    _____
    _____

11. Please include any additional road owners, photos and/or other information that highlight the location:
    _____

12. Signature (and printed name) of Person with Authority to Respond To/Implement the RSA Findings:
    _____ Date: _____

Submit Application to:

Mike Blankenship, P.E.
Road Safety Assessment Program Manager
1615 West Jackson St., Mail Drop 065R
Phoenix, AZ 85007-3217

Phone: 602-712-7601
Fax: 602-712-3243
Email: mblankenship@azdot.gov

Figure 3. Arizona RSA Application Form

7. THE FUTURE OF ARIZONA'S HSIP

The main objective of the HSIP is to reduce the overall frequency and severity of motor-vehicle collisions, as well as the potential for collisions, on public roads. All of the foregoing describes the ADOT HES plan for locating and addressing potential safety concerns on Arizona's highways. However, assessing the *potential* for collisions is a somewhat difficult mission since it requires preventing collisions that have not yet occurred. How do we find locations with potential safety concern that do not yet have an obvious and traceable collision history? How do we assess the potential safety concern(s) in these locations without collision reports indicating the factors contributing to the crashes? The answers are in the **Evaluation** and **Planning** components of the HSIP.

The **Evaluation** component is critical to the prevention of future collisions, because of the valuable information derived from Before-and-After Studies. These Studies provide information on the characteristics and attendant safety concerns of locations with histories of a high number and/or severity of collisions. Before-and-After Studies also provide information on the type of safety countermeasures chosen to mitigate these safety concerns, their effectiveness in reducing the number and severity of collisions, and their relative benefit to the System. This information can then be used to refine the **Planning** process, allowing HES personnel to isolate critical characteristics shown to create a potential for collisions, and to apply safety countermeasures proven to be the most effective in addressing this potential.

The ongoing success of Arizona's Highway Safety Improvement Program is reliant on this process of iteration and refinement of goals and priorities to ensure that efforts are directed to realize the greatest overall safety benefit to Arizona's State Highway System.

APPENDIX A - ABBREVIATIONS

ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACC	Arizona Corporation Commission
ADOT	Arizona Department of Transportation
AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ALISS	Accident Location Identification and Surveillance System
ATIS	Arizona Transportation Information System
B/C	Benefit-Cost Ratio
CFR	Code of Federal Regulations
COG	Council of Government
CRF	Crash Reduction Factor
DCR	Design Concept Report
ECS	(ADOT) Engineering Consultant Services
FHWA	Federal Highway Administration
FY	Fiscal Year
GIS	Geographic Information System
GIS-T	Geographic Information System for Transportation
HES	(ADOT) Highway Enhancements for Safety
HPMS	Highway Performance Monitoring System
HRRRP	High Risk Rural Roads Program
HSIP	Highway Safety Improvement Program
IGA	Intergovernmental Agreement
ISTEA	Intermodal Surface Transportation Efficiency Act
ITD	(ADOT) Intermodal Transportation Division
ITE	Institute of Transportation Engineers

MPD	(ADOT) Multimodal Planning Division
MPO	Metropolitan Planning Organization
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
PDO	Property Damage Only
PECOS	Performance Controlled System
PSE	Plans, Specifications, & Estimate
RHGCP	Railway-Highway Grade Crossing Program
RSA	Road Safety Assessment
SAFETEA-LU	The Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SHS	State Highway System
STIP	Statewide Transportation Improvement Program
STP	Surface Transportation Program
TAC	Technical Advisory Committee
TEA-21	Transportation Equity Act for the 21st Century
URL	Uniform Resource Locator
URR	(ADOT) Utility & Railroad Engineering Section
USC	United States Code

APPENDIX B - SPECIAL REQUEST FORM

For Office Use Only
HES Project # _____

Highway Safety Improvement Program – Special Request Form

Arizona Department of Transportation
Traffic Engineering Group
Highway Enhancements for Safety (HES) Section

STUDY REQUESTOR: _____ DATE: _____

SUBJECT LOCATION: _____

ENGINEERING DISTRICT: _____ CITY: _____ COUNTY: _____

ROUTE NO: _____ HIGHWAY/STREET NAME: _____

MP FROM: _____ TO: _____ OR CROSS STREET: _____

STATE HIGHWAY ☐ OR LOCAL AGENCY FACILITY ☐

EXISTING, PROGRAMMED, OR FUTURE PROJECT? YES ☐ NO ☐

If YES, TRACS # _____

1. Describe the problem.

2. Describe the proposed solution.

3. What is the estimated project cost?

4. Has an engineering-type study of the problem area been conducted? ☐ Yes ☐ No
   If yes, please attach a copy.

5. What are the frequency, type, and severity of crashes (or conflicts) that will be mitigated by the proposed project? Include dates.

6. What is the average daily motor vehicle, pedestrian, or bicycle volume exposed to the hazard for the same time period as above?

7. Please describe the local agency and citizen support for the proposed project.

8. Please attach any other information that is pertinent to the investigation/evaluation of this issue.

APPENDIX C - SAFETY EVALUATION REPORT FORMAT GUIDELINES

SAFETY EVALUATION REPORT FORMAT GUIDELINES

Safety Evaluation Reports are technical documents that present specific information, conclusions, and recommendations for the subject location. Each report should present only that information which is pertinent to the Evaluation subject location and should stand alone as a complete and unique document. The Report may or may not be sealed by a Professional Engineer (PE), depending on the Report type and content.

The following Report format is a guide intended for use by those who are responsible for organizing and conducting engineering studies and for implementing their findings. This guide has been established to promote uniformity and to assure that essential study parameters are addressed. However, it is a *guide* only, and topics should be included, omitted, or altered as appropriate for each Evaluation.

I. Cover Letter
   a. Executive Summary
   b. Recommendations
   c. Signature of Endorsement

II. Title Page

III. Location and Vicinity Maps

IV. Introduction
   a. Purpose of Evaluation/Problem Statement
   b. Evaluation Requestor
   c. Pertinent Background Information
   d. Identification Method

V. Physical Roadway Features
   a. Subject Location and Description
   b. Roadway Features and Conditions
      i. Classification
      ii. Roadside Development and Access
      iii. Section
      iv. Geometrics
      v. Signed Speed(s)
      vi. Passing Zones
      vii. Safety Features (e.g., rumble strips, guardrail)
      viii. Sight Distance Considerations
      ix. Any Other Pertinent Physical Features of the Subject Location

SAFETY EVALUATION REPORT FORMAT GUIDELINES

VI. Traffic Characteristics
- a. ADT, AADT
- b. Vehicle Classifications
- c. Traffic Volumes (including turning movements, where applicable)
- d. Projected Volumes
- e. Pedestrian and Pedal-cycle Volumes
- f. Capacity
- g. Delay
- h. Conflicts
- i. Any Other Pertinent Characteristics of the Subject Location

VII. Speed Studies

VIII. Traffic Collision History
- a. Collision Summary
- b. Trends/Patterns
- c. Any Other Pertinent Collision Information

IX. Improvement Alternatives
- a. Presentation of Possible Countermeasures
- b. Discussion of the Strengths and Drawbacks
- c. Identification of Most Appropriate Alternative(s)

X. Economic Analysis of Viable Alternatives
- a. Cost Analysis
- b. Benefits Obtainable Analysis
- c. Calculation of the Benefit-Cost Ratio

XI. Discussion and Summary
- a. Evaluation of Safety at the Subject Location, Based On Findings
- b. Factors Contributing to the Problem
- c. Improvement Alternatives Considered, Chosen, and Rejected
- d. Result of Economic Analyses
- e. Conclusions
- f. Recommendations

XII. Appendices
- a. Condition Diagram
- b. Collision Diagram
- c. Economic Analyses
- d. Any Other Supporting Documentation and References

APPENDIX D - BENEFIT-COST ANALYSIS GUIDELINES

BENEFIT-COST ANALYSIS GUIDELINES

The purpose of the accident-based B/C economic analysis is to provide an economic assessment of the extent to which a project or program may achieve its ultimate goal of reducing the number and/or severity of accidents. The B/C analysis ultimately provides a means of selecting the most cost-effective countermeasure(s) for any given project.

The procedure involves the economic evaluation of improvement alternatives to develop effective improvement projects from the candidate alternatives. It is one of the most widely used methods of screening programs and projects that are being considered for development.

The accident-based B/C analysis should be made for those situations that are conducive to its use. The conclusion and recommendations for candidate projects should be based on the results of the B/C analysis.

The accident-based B/C method uses the ratio of expected benefits accrued (accident savings, reduced user costs, etc.) to the costs incurred for a countermeasure.

Annual Benefit

The safety benefit is the anticipated reduction in the total annual number of accidents or accident frequency per countermeasure. The total annual accident cost saving (benefit) is obtained using FHWA's comprehensive motor vehicle accident costs (see page D-7) and an appropriate Crash Reduction Factor (CRF). The benefit should be evaluated for each countermeasure.

A comprehensive source for Crash Reduction Factors is not available at this time. Available data and engineering judgment should be used to select appropriate accident reduction factors. *(See Exhibit E for existing CRFs.)*

Annual Cost

The cost of each alternative countermeasure is calculated as follows:

1. Determine the total construction cost (initial design, right-of-way, construction, and other costs associated with the projects).
2. Determine the service life of the countermeasure from the listing on page D-8.
3. Obtain or assume an interest rate, which is appropriate for current economic conditions, in percent.
4. Compute the annual construction cost by multiplying the total construction cost by the appropriate capital recovery factor, based on the interest rate and service life of the countermeasure, from the table on page D-7, D-8.
5. Determine the annual estimated operating and maintenance cost for the countermeasure, and subtract the existing annual operating and maintenance cost to obtain the annual maintenance cost difference.

6. Compute the total annual cost of the project (annual construction cost + annual maintenance cost difference).

Benefit/Cost Analysis

The B/C is computed by dividing the annual benefit by the annual cost. The procedure is detailed on the worksheet on page D-6.

When one alternative improvement involves several countermeasures, the following procedure should be used to calculate the total Crash Reduction Factor (CRF) for that alternative improvement:

$$CRF_{Total} = 1 - (1 - CRF_1) * (1 - CRF_2) * (1 - CRF_3) * (1 - CRF_4) * (1 - CRF_5)$$

Where, CRF_1, CRF_2, CRF_3, etc. are Crash Reduction Factors for countermeasures 1, 2, 3,…n, respectively.

Incremental Benefit/Cost Analysis ($\Delta B/\Delta C$)

The incremental B/C method may be used to determine whether extra increments of cost (e.g., widening the curve plus roadside improvements vs. curve widening only) are justified for a particular location or for considering improvements at two or more locations. This method assumes that the relative merit of a project is measured by its change in benefits and costs, compared to the next lower-cost alternative.

The steps for using the incremental B/C method are as follows:

1. Determine the benefits, costs, and the resulting B/C for each countermeasure.
2. List countermeasures with a B/C greater than 1.0 in order of increasing cost.
3. Calculate the incremental B/C of the second lowest-cost countermeasure compared to the lowest-cost countermeasure. Pick the second lowest-cost countermeasure if this ratio is positive; or else pick the lowest-cost countermeasure.
4. Continue in order of increasing costs to calculate the incremental B/C for each countermeasure compared to the last-picked countermeasure.
5. Stop when the incremental B/C (disregarding negative ratios) is less than 1.0.

To illustrate the use of this method, consider the costs and benefits in the following example. Notice that options must be ordered from lowest to highest cost. Each option may consist of a single countermeasure or a combination of countermeasures.

Illustration of Incremental B/C Analysis

Counter-measure	Annual Benefit	Annual Cost	B/C	Comparison of Counter-measures	Incremental Benefit	Incremental Cost	Incremental B/C Ratio (ΔB/ΔC)
B	$15,200	$1,510	10.1				
				B and C	$-2,400	$200	-12.0 (Pick B)
C	$12,800	$1,710	7.5				
				B and A	$25,600	$19,750	1.3 (Pick A)
A	$40,800	$21,260	1.9				
				A and D	$12,000	$3,240	3.7 (Pick D)
D	$52,800	$24,500	2.2				

From the foregoing example, countermeasure B (lowest-cost countermeasure) is first compared with countermeasure C, and countermeasure B is preferred to countermeasure C ($\Delta B/\Delta C$ = -12.0). Countermeasure C is then excluded from further consideration. Countermeasure B is next compared with countermeasure A, and countermeasure A (the higher cost countermeasure) is preferred, since $\Delta B/\Delta C$ = 1.3 (greater than 1.0). In this case, spending an additional $19,750 on countermeasure A will yield $25,600 of additional benefits. Countermeasure B is then eliminated from further consideration. Finally, countermeasures A and D are compared, and the additional $3,240 in cost from countermeasure D is compared with the $12,000 of additional benefits from countermeasure D. Thus, $\Delta B/\Delta C$ = 3.7 between countermeasures D and A, and countermeasure D is the optimal solution based on incremental benefits and costs. Notice that countermeasure D was selected with a simple B/C of 2.2, even though countermeasures B and C had B/Cs of 10.1 and 7.5, respectively. This solution would be subject to funding availability, political considerations, environmental constraints, etc.

Application

The B/C method requires that dollar values be placed on all estimated costs and the expected benefits related to the countermeasure. A countermeasure that has a B/C greater than 1.0 is considered to be economically justified. The countermeasure with the highest B/C is normally the recommended alternative, unless the incremental B/C method is used.

The B/C method is recommended only when a set of costs for highway accidents (fatalities, injuries, property damages, etc.) has been established. ADOT has adopted FHWA's Motor Vehicle Accident Costs.

The method may be applicable to either an individual countermeasure or one consisting of several improvements. The B/C should be evaluated for each alternative countermeasure. The selection of a countermeasure shall consider the highest B/C, unless the incremental B/C method is used.

Standard Worksheet and Tables *(Pages D-6 to D-9)*

ARIZONA DEPARTMENT OF TRANSPORTATION TRAFFIC ENGINEERING GROUP TRAFFIC DESIGN SECTION		
BENEFIT/COST ANALYSIS WORKSHEET		
Project Number	Date	Compiled by
Route	from Milepost	to Milepost
Alternative of	Type of Improvement	

BENEFITS					
Crash Types	Annual Average	Crash Reduction Factor	Total Reduction	Unit Cost	Annual Benefit
Fatal				5,800,000.00	
Incap. Injury				400,000.00	
Non-incap. Inj				80,000.00	
Possible Inj.				42,000.00	
PDO				4000.00	
Unknown				4000.00	
			Total Annual Benefit		

COSTS	
Total Construction Cost	
Project Life (Years)	
Interest Rate (%)	
Capital Recovery Factor (CRF)	
Annual Const. Cost = CRF x Total Const. Cost **(A)**	
Annual Maintenance Cost Difference (if applicable) **(B)**	
Total Annual Cost: **(A + B)**	

BENEFIT/COST		
Annual Benefit	**Annual Cost**	**Benefit/Cost Ratio**

Motor Vehicle Crash Costs by Severity

Crash Type	Unit Cost
Fatal	$ 5,800,000
Incapacitating Injury	$ 400,000
Non Incapacitating Injury	$ 80,000
Possible Injury	$ 42,000
Property Damage Only	$ 4,000
Unknown	$ 4,000

Interest Factors For Annual Compounding Interest
(Equal Payment Series)

CAPITAL RECOVERY FACTOR

Year	8%	10%	12%	14%	16%
2	0.5608	0.5762	0.5917	0.6073	0.6230
4	0.3019	0.3155	0.3292	0.3432	0.3574
6	0.2163	0.2296	0.2432	0.2572	0.2714
8	0.1740	0.1874	0.2013	0.2156	0.2302
10	0.1490	0.1627	0.1770	0.1917	0.2069
15	0.1168	0.1315	0.1468	0.1628	0.1794
20	0.1019	0.1175	0.1339	0.1510	0.1687
25	0.0937	0.1102	0.1275	0.1455	0.1640
30	0.0888	0.1061	0.1241	0.1428	0.1619

SAFETY IMPROVEMENT CODES, DESCRIPTIONS, & SERVICE LIVES USED IN EFFECTIVENESS EVALUATIONS

Code	Description	Service Life (Years)
	INTERSECTION PROJECTS	
10	Channelization, left-turn bay	10
11	Traffic Signals	10
12	Combination of 10 and 11	10
13	Sight distance improvement	10
19	Other intersection improvements, except structures	10
1A	Combination of 10 and 19	10
1B	Combination of 11, 13, 19, and 65	10
	CROSS SECTION PROJECTS	
20	Pavement widening, no lanes added	2
21	Lanes added without new median	20
22	Highway divided, new median added	20
23	Shoulder widening or improvement	20
24	Combination of 20 - 23	20
25	Skid treatment - grooving	10
26	Skid treatment - overlay	10
27	Flattening, clearing side slopes	20
29	Other cross section or combinations of 20 - 27	20
2A	Combination of 20 and 26	15
	STRUCTURES	
30	Widening bridge or major structure	20
31	Replace bridge or major structure	30
32	New bridge or major structure (except 34 and 51)	30
33	Minor structure	20
34	Pedestrian over- or under-crossing	30
39	Other structure	20
	ALIGNMENT PROJECTS	
40	Horizontal alignment changes (except 52)	20
41	Vertical alignment changes	20
42	Combination of 40 and 41	20
49	Other alignments	20
	RAILROAD GRADE CROSSING PROJECTS	
50	Flashing lights replacing signs	10
51	Elimination by new or reconstructed grade separation	30
52	Elimination by relocation of highway or railroad	30
53	Illumination	10
54	Flashing lights replacing active devices	10
55	Automatic gates replacing signs	10
56	Automatic gates replacing active devices	10
57	Signing, marking	10
58	Crossing surface improvement	10
59	Other railroad grade crossing improvement	10
5A	Any combination of 50, 54, 55, 56, 57, and 58	10
	ROADSIDE APPURTENANCES	
60	Traffic Signs	6
61	Breakaway sign or luminaire supports	10
62	Road edge guardrail	10
63	Median barrier	1
64	Markings, delineators	2
65	Lighting	15
66	Improved drainage structures	20
67	Fencing	10
68	Impact attenuators	10
69	Other roadside improvements	10
6A	Combination of 60 - 64	10
6B	Combination of 64 and 68	10
6C	Combination of 60 and 62	8
6D	Combination of 60 and 64	4
6E	Combination of 62 and 69	10
6F	Combination of 62, 66, and 69	10
6G	Combination of 60 and 63	10
	OTHER SAFETY IMPROVEMENTS	
90	Safety provisions for roadside features and appurtenances	20
99	All projects not otherwise classifiable	20
9A	Combination of 11, 26, and 69	10
9B	Combination of 26 and 66	15
9C	Combination of 27, 30, 62, and 99	20
9D	Combination of 11 and 60	8
9E	Combination of 11 and 64	6
9F	Combination of 23, 26, and 62	15
9G	Combination of 27, 61, 62, and 64	10
9H	Combination of 22, 39, and 65	20
9I	Combination of 23, 61, 62, 64, 65, and 66	15

BENEFIT-COST ANALYSIS GUIDELINES

EVALUATION OF SAFETY IMPROVEMENTS BY CONSTRUCTION CLASSIFICATION 1974 –1994

Construction Classification	Percent Reduction in Accident Rates After Improvements		
	Fatal	Nonfatal Injury	Combined Fatal + Nonfatal Injury
INTERSECTIONS AND TRAFFIC CONTROL			
Turning lanes & Traffic Channelization	48	26	26
Sight Distance Improvements	*56	*43	*43
Traffic Signs	32	15	15
Pavement Markings & Delineators	15	5	6
Illumination	38	14	14
Upgraded Traffic Signals	40	22	22
New Traffic Signals	*53	22	23
STRUCTURES			
Widen or Modify Bridge	49	30	31
New Bridge	86	69	70
Replace or Improve Minor Structure	36	20	21
Upgrade Bridge Rail	75	29	33
ROADWAY			
Construct Median for Traffic Separation	71	28	30
Widen or Improve Shoulder	21	12	12
Realign Roadway	63	41	42
Overlay for Skid Treatment	18	18	18
Groove Pavement for Skid Treatment	33	15	15
ROADSIDE			
Relocated/Breakaway Utility Poles	32	45	44
Upgrade Guardrail	36	8	9
Upgrade Median Barrier	*65	20	22
New Median Barrier	64	12	15
Impact Attenuators	*38	34	34
Flatten Side Slopes	*26	27	27
Remove Obstacles	60	23	25
RAILROAD-HIGHWAY CROSSINGS			
Upgrade Flashing Lights	85	35	44
New Flashing Lights	87	79	81
New Flashing Lights & Gates	92	85	86
New Gates	92	74	78

Note: * indicates no significant change at the 95 percent confidence level. Adapted from The 1996 Annual Report on Highway Safety Improvement Programs, Publication No. FHWA-SA-96-040

APPENDIX E - CRASH REDUCTION FACTORS

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

ACCIDENT REDUCTION FACTOR CATEGORIES

1. ROADWAY IMPROVEMENTS
    - 1-1 Lane Addition
    - 1-2 Lane Widening
    - 1-3 Shoulder Widening
    - 1-4 2-Way Left-Turn Lane
    - 1-5 Realignment
    - 1-6 Shoulder Grooving
    - 1-7 Overlay
    - 1-8 Truck Escape Ramp
    - 1-9 Brake Check Area
2. ROADSIDE IMPROVEMENT
    - 2-1 New Guardrail
    - 2-2 Upgrade/Extend Guardrail
    - 2-3 Drainage Structure Extension
    - 2-4 Slope Flattening
    - 2-5 Vegetation/Obstacle Removal
    - 2-6 New/Upgrade Median Barrier
    - 2-7 Impact Attenuators
    - 2-8 Object Markers
    - 2-9 Delineation
    - 2-10 Animal Fencing
    - 2-11 Animal Reflectors
    - 2-12 Snow Fencing
    - 2-13 Rockfall Containment
    - 2-14 Illumination
3. INTERSECTIONS AND INTERCHANGES
    - 3-1 New Signal
    - 3-2 Geometric Changes
    - 3-3 New Signal & Geometric Changes
    - 3-4 Changes to Existing Signal
    - 3-5 Changes to Existing Signal & Geometry
    - 3-6 Left–Turn Phasing
    - 3-7 Turn Lanes
    - 3-8 Illumination
    - 3-9 Sight Distance Improvement
    - 3-10 Channelization Pavement Marking
    - 3-11 Channelization Signing
    - 3-12 Crossroad/Sideroad Signing
    - 3-13 Stop Signs
    - 3-14 Yield Signs
    - 3-15 Signal Removal

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

ACCIDENT REDUCTION FACTOR CATEGORIES

4. TRAFFIC CONTROL DEVICES
    - 4-1 Edgeline Markings
    - 4-2 Raised Pavement Markers
    - 4-3 Rumble Strips
    - 4-4 New Curve Signing
    - 4-5 Upgrade Curve Signing
    - 4-6 "Icy Pavement" Signing
    - 4-7 "Slippery When Wet" Signing
    - 4-8 "Narrow Bridge" Signing
    - 4-9 "Watch For Rocks" Signing
    - 4-10 Animal Warning Signs
    - 4-11 Interstate Signing

5. PEDESTRIANS
    - 5-1 Sidewalks
    - 5-2 Pedestrian Overpass
    - 5-3 Pedestrian Signing

6. STRUCTURES
    - 6-1 Bridge Widening
    - 6-2 Bridge Replacement
    - 6-3 New Bridge
    - 6-4 Upgrade Bridge Barrier

7. RAILROAD – HIGHWAY CROSSINGS
    - 7-1 New Flashing Lights
    - 7-2 Upgrade Flashing Lights
    - 7-3 New Gates Replacing Cross-Bucks
    - 7-4 New Gates Supplementing Flashing Lights
    - 7-5 Crossing Surface Improvement
    - 7-6 Signing
    - 7-7 Pavement Markings

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
			ALL	FATAL	INJURY	FATAL & INJURY	PDO
1 - ROADWAY IMPROVEMENTS							
1 - 1 LANE ADDITION	30						
All Crashes		2719	25	39	23	23	27
Rear-End		931	32	67	28	28	35
Sideswipe (Same)		248	30	100	36	37	28
Sideswipe (Opp) & Head-On		80	53	100	39	70	59
Run-Off-Road		542	44	55	44	45	44
1 - 2 LANE WIDENING	6						
All Crashes		491	56	58	57	57	54
Sideswipe (Same)		31	52	0	43	43	54
Sideswipe (Opp) & Head-On		10	70	0	100	100	25
Run-Off-Road		59	49	100	35	41	54
1 - 3 SHOULDER WIDENING	16						
All Crashes		600	57	48	59	58	57
Sideswipe (Same)		34	41	100	75	78	28
Sideswipe (Opp) & Head-On		24	75	33	80	72	83
Run-Off-Road		242	60	25	57	54	65
Pedestrian		14	71	86	57	71	0
1 - 4 2-WAY LEFT TURN LANE	19						
All Crashes		1254	30	40	20	20	35
Left-Turn		147	33	100	0	2	48
Rear-End		407	36	0	38	38	34
Sideswipe (Opp) & Head-On		25	36	0	50	50	27
Run-Off-Road		134	37	100	**3**	0	49
Pedestrian		53	19	0	19	18	50
1 - 5 REALIGNMENT	26						
All Crashes		459	48	33	56	55	42
Rear-End		71	37	0	42	42	34
Sideswipe (Same)		26	54	0	57	57	53
Sideswipe (Opp) & Head-On		27	85	67	89	83	87
Run-Off-Road		190	66	33	71	69	62
1 - 6 SHOULDER GROOVING	18						
All Crashes		1210	18	15	18	18	17
Run-Off-Road		711	27	12	27	26	26

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
1 - ROADWAY IMPROVEMENTS								
1 - 7	OVERLAY	177						
	All Crashes		11278	9	2	4	4	13
	Rear-End		3047	19	25	18	18	20
	Run-Off-Road		2500	13	**16**	11	10	15
	Wet Pavement		1191	39	61	25	27	43
1 - 8	TRUCK ESCAPE RAMP	3						
	All Crashes		111	18	**75**	28	20	16
	Rear-End		9	33	0	71	71	**100**
	Defective Brakes		7	**14**	**100**	0	**100**	20
1 - 9	BRAKE CHECK AREA	2						
	All Crashes		42	45	100	55	58	50
	Defective Brakes		1	100	0	100	100	0
2 - ROADSIDE IMPROVEMENTS								
2 - 1	NEW GUARDRAIL (G/R)	43						
	All Crashes		409	19	47	12	15	21
	Run-Off-Road		191	30	56	23	26	34
2 - 2	UPGRADE/EXTEND GUARDRAIL	152						
	All Crashes		3257	15	9	13	13	16
	Run-Off-Road		1600	26	10	27	25	25
2 - 3	DRAINAGE STRUCTURE EXTENSION	26						
	All Crashes		1634	36	18	34	33	38
	Run-Off-Road		1027	44	27	36	36	50
2 - 4	SLOPE FLATTENING	11						
	All Crashes		647	**4**	30	**15**	**12**	2
	Run-Off-Road		252	10	30	18	19	**2**
2 - 5	VEGETATION/OBSTACLE REMOVAL	16						
	All Crashes		92	61	0	59	58	64
	Run-Off-Road		64	77	100	76	77	76

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
2 - ROADSIDE IMPROVEMENTS								
2 - 6	NEW/UPGRADE MEDIAN BARRIER	2						
	All Crashes		541	36	60	26	28	39
	Sideswipe (Opp) & Head-On		1	0	0	0	0	0
	Run-Off-Road		116	35	50	11	13	46
2 - 7	IMPACT ATTENUATORS	15						
	All Crashes		61	41	**100**	55	50	36
	Run-Off-Road		22	45	0	30	30	58
2 - 8	OBJECT MARKERS	368						
	All Crashes		416	16	41	17	19	14
	Run-Off-Road		171	29	60	24	29	29
2 - 9	DELINEATION	106						
	All Crashes		663	11	8	19	18	4
	Sideswipe (Opp) & Head-On		15	67	100	25	63	71
	Run-Off-Road		133	34	14	43	40	24
	Nighttime		112	25	14	41	38	10
2 - 10	ANIMAL FENCING	16						
	All Crashes		295	**12**	0	**17**	**15**	**9**
	Animal		68	66	0	91	91	61
2 - 11	ANIMAL REFLECTORS	2						
	All Crashes		61	10	0	6	6	11
	Nighttime Animal		4	25	0	0	0	25
2 - 12	SNOW FENCING	1						
	All Crashes		17	71	0	83	83	64
	Snowy Pavement		12	58	0	67	67	56
2 - 13	ROCKFALL CONTAINMENT	1						
	All Crashes		7	14	0	0	0	25
	Striking Rocks		1	100	0	0	0	100
2 - 14	ILLUMINATION	2						
	All Crashes		154	19	0	8	8	23
	Nighttime		50	30	100	35	42	23

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES: ALL	FATAL	INJURY	FATAL & INJURY	PDO
3 - INTERSECTIONS AND INTERCHANGES								
3 - 1	NEW SIGNAL	73						
	All Crashes		1024	**17**	**14**	**20**	**20**	**15**
	Angle		443	42	60	39	40	45
3 - 2	GEOMETRIC CHANGES	25						
	All Crashes		75	43	0	71	71	20
	Angle		23	17	0	58	58	**27**
	Left-Turn		3	67	0	50	50	100
	Improper Turn		12	100	0	100	100	100
	Rear-End		15	60	0	100	100	33
	Sideswipe (Same)		3	67	0	100	100	50
	Run-Off-Road		18	67	0	80	80	50
3 - 3	NEW SIGNAL & GEOMETRIC CHANGES	23						
	All Crashes		419	21	57	28	30	13
	Angle		247	68	56	73	72	63
	Sideswipe (Same)		15	53	0	100	100	42
	Pedestrian		6	33	100	0	33	0
3 - 4	CHANGES TO EXISTING SIGNAL	20						
	All Crashes		645	9	0	3	3	13
	Angle		210	32	100	37	37	27
	Left-Turn		115	3	0	**44**	**44**	26
	Pedestrian		7	57	0	50	50	100
3 - 5	CHANGES TO EXISTING SIGNAL & GEOMETRY	19						
	All Crashes		841	40	50	33	34	43
	Angle		129	19	0	21	20	19
	Left-Turn		152	18	50	24	25	11
	Improper Turn		83	80	0	83	83	79
	Rear-End		338	48	100	45	45	50
	Sideswipe (Same)		50	48	0	18	17	52
	Pedestrian		7	**14**	100	**60**	**33**	100
3 - 6	LEFT-TURN PHASING	13						
	All Crashes		623	15	33	6	6	21
	Left-Turn		133	35	50	4	6	52

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
3 - INTERSECTIONS AND INTERCHANGES								
3 - 7	TURN LANES	24						
	All Crashes		180	6	100	**1**	3	9
	Angle		40	13	100	14	17	6
	Left-Turn		33	24	100	33	38	12
	Improper Turn		13	54	0	25	25	67
	Rear-End		53	**8**	100	**40**	**31**	3
	Sideswipe (Same)		17	59	0	75	75	54
3 - 8	ILLUMINATION	18						
	All Crashes		143	**48**	0	**14**	**14**	**73**
	Nighttime		45	18	0	29	29	8
3 - 9	SIGHT DISTANCE IMPROVEMENT	58						
	All Crashes		586	7	0	6	5	8
	Angle		165	21	75	3	7	31
	Left-Turn		115	13	0	21	21	3
	Improper Turn		54	30	0	30	30	29
	Rear-End		145	10	0	17	17	4
3 - 10	CHANNELIZATION PAVEMENT MARKING	17						
	All Crashes		127	0	100	**4**	**2**	1
	Angle		27	**33**	100	**50**	**36**	**31**
	Left-Turn		32	19	0	9	9	24
	Improper Turn		12	17	0	60	60	**14**
	Sideswipe (Same)		4	25	0	0	0	33
	Pedestrian		5	80	0	100	100	**100**
3 - 11	CHANNELIZATION SIGNING	15						
	All Crashes		110	14	**100**	**2**	**7**	27
	Angle		14	14	0	**50**	**50**	63
	Left-Turn		22	36	**100**	36	27	45
	Improper Turn		4	100	0	100	100	100
	Sideswipe (Same)		6	67	0	100	100	33

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
3 - INTERSECTIONS AND INTERCHANGES								
3 - 12	CROSSROAD/SIDEROAD SIGNING	63						
	All Crashes		82	33	100	56	59	15
	Angle		21	29	100	25	50	20
	Left-Turn		7	86	0	75	75	100
	Improper Turn		14	64	0	86	86	43
	Rear-End		26	27	0	38	38	**75**
3 - 13	STOP SIGNS	40						
	All Crashes		85	19	0	20	20	18
	Angle		26	8	0	0	0	17
	Left-Turn		18	22	0	14	14	27
	Rear-End		25	48	0	67	67	38
3 - 14	YIELD SIGNS	6						
	All Crashes		35	**37**	0	25	25	**89**
	Angle		7	43	0	33	33	50
3 - 15	SIGNAL REMOVAL	2						
	All Crashes		5	100	0	100	100	100
	Rear-End		4	100	0	100	100	100
4 - TRAFFIC CONTROL DEVICES								
4 - 1	EDGELINE MARKINGS	4						
	All Crashes		79	30	**100**	63	52	15
	Run-Off-Road		37	30	0	60	56	10
4 - 2	RAISED PAVEMENT MARKERS	43						
	All Crashes		4275	11	16	11	12	11
	Sideswipe (Same)		431	13	100	6	7	14
	Sideswipe (Opp) & Head-On		41	12	40	**15**	**4**	38
	Run-Off-Road		800	33	23	37	37	31
	Nighttime		1309	16	35	10	12	18
4 - 3	RUMBLE STRIPS	5						
	All Crashes		43	53	83	65	73	29
	Sideswipe (Opp) & Head-On		5	80	100	100	100	67
	Run-Off-Road		28	54	75	56	60	38

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.

CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
4 - TRAFFIC CONTROL DEVICES								
4 - 4	NEW CURVE SIGNING	188						
	All Crashes		558	14	55	20	24	3
	Sideswipe (Same)		20	75	100	100	100	71
	Sideswipe (Opp) & Head-On		73	29	57	47	49	3
	Run-Off-Road		328	17	57	24	27	1
4 - 5	UPGRADE CURVE SIGNING	138						
	All Crashes		439	21	6	23	22	21
	Rear-End		25	48	0	38	38	76
	Sideswipe (Same)		5	100	100	100	100	100
	Sideswipe (Opp) & Head-On		53	26	50	11	14	34
	Run-Off-Road		286	21	0	25	23	18
4 - 6	"ICY PAVEMENT" SIGNING	20						
	All Crashes		247	**15**	67	**24**	**13**	**17**
	Icy Pavement		76	**22**	100	**52**	**42**	**16**
4 - 7	"SLIPPERY WHEN WET" SIGNING	185						
	All Crashes		1819	7	**81**	10	6	8
	Wet Pavement		323	31	0	29	28	33
4 - 8	"NARROW BRIDGE" SIGNING	9						
	All Crashes		15	47	0	86	86	13
	Sideswipe (Opp) & Head-On		5	20	0	100	100	**33**
	Run-Off-Road		6	50	0	100	100	0
4 - 9	"WATCH FOR ROCKS" SIGNING	32						
	All Crashes		342	13	0	13	12	14
	Striking Rocks		33	64	0	88	88	56
4 - 10	ANIMAL WARNING SIGNING	195						
	All Crashes		2039	10	**15**	8	6	13
	Striking Animals		400	18	83	2	12	19

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CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES ALL	FATAL	INJURY	FATAL & INJURY	PDO
4 - TRAFFIC CONTROL DEVICES								
4 - 11	INTERSTATE SIGNING	20						
	All Crashes		3961	7	8	10	10	25
5 - PEDESTRIANS								
5 - 1	SIDEWALKS	4						
	All Crashes		128	**15**	100	**70**	**58**	7
	Hit Pedestrian		9	89	100	88	89	0
5 - 2	PEDESTRIAN OVERPASS	6						
	All Crashes		15	**33**	0	0	0	**62**
	Hit Pedestrian		3	67	0	50	67	0
5 - 3	PEDESTRIAN SIGNING	96						
	All Crashes		1870	4	4	8	8	1
	Hit Pedestrian		66	15	22	17	17	**33**
6 - STRUCTURES								
6 - 1	BRIDGE WIDENING	23						
	All Crashes		76	36	50	38	38	32
	Sideswipe (Same)		7	57	0	100	100	0
	Run-Off-Road		54	44	50	27	29	62
6 - 2	BRIDGE REPLACEMENT	17						
	All Crashes		52	62	100	36	40	70
	Rear-End		6	100	0	100	100	100
	Sideswipe (Same)		1	100	0	100	100	0
	Sideswipe (Opp) & Head-On		1	100	0	0	0	100
	Run-Off-Road		23	52	100	0	17	65
6 - 3	NEW BRIDGE	13						
	All Crashes		27	11	0	38	36	**15**
	Wet Pavement		4	50	0	50	50	50
6 - 4	UPGRADE BRIDGE BARRIER	45						
	All Crashes		51	25	**100**	50	41	14
	Run-Off-Road		33	42	0	46	46	40

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CRASH REDUCTION FACTORS

CRASH REDUCTION LEVELS WHICH MAY BE ATTAINABLE FROM VARIOUS SAFETY IMPROVEMENTS *(ARIZONA DATA)*

	TYPE OF IMPROVEMENT	# OF PROJECTS	# OF BEFORE CRASHES	% REDUCTION IN CRASH RATES				
				ALL	FATAL	INJURY	FATAL & INJURY	PDO
7 - RAILROAD-HIGHWAY CROSSINGS								
7 - 1	NEW FLASHING LIGHTS	3						
	All Crashes		7	43	0	0	0	60
	Hit Train		0	0	0	0	0	0
7 - 2	UPGRADE FLASHING LIGHTS	7						
	All Crashes		28	43	0	29	29	57
	Hit Train		8	38	0	0	0	60
7 - 3	NEW GATES REPLACING CROSS-BUCKS	105						
	All Crashes		107	59	90	73	76	44
	Hit Train		48	96	100	95	96	95
7 - 4	NEW GATES SUPPLEMENTING FLASHING LIGHTS	22						
	All Crashes		34	62	100	71	73	53
	Hit Train		10	80	100	100	100	60
7 - 5	CROSSING SURFACE IMPROVEMENT	16						
	All Crashes		29	7	**100**	0	**22**	20
	Run-Off-Road		8	25	0	33	33	20
	Hit Train		5	20	**100**	50	**50**	67
7 - 6	SIGNING	13						
	All Crashes		4	100	0	100	100	100
	Run-Off-Road		2	100	0	100	100	100
	Hit Train		2	100	0	100	100	0
7 - 7	PAVEMENT MARKINGS	141						
	All Crashes		169	48	**100**	43	42	51
	Run-Off-Road		32	22	0	8	8	30
	Rear-End		71	58	0	52	52	62
	Hit Train		43	56	**100**	50	43	62

Note: Underlined numbers represent statistically significant rate reductions. Numbers in **bold** represent rate increases.