Intersection Safety Implementation Plan Process

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

FHWA-SA-10-010

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Foreword

This final report has been designed to provide State Safety and Traffic Engineers with a process to use for creating an intersection safety implementation plan based upon their Strategic Highway Safety Plan (SHSP). While many SHSPs define the State's overarching safety goals, typically in terms of fatality and/or injury reduction by a specific year, they do not always define the countermeasures, deployment levels, costs, and actions needed to achieve the goal.

It is hoped that the 10-step process detailed in this report will guide and assist State Safety and Traffic Engineers in identifying the countermeasures, strategies, deployment levels, implementation steps, actions, and costs necessary to achieve the intersection safety goals of the SHSP.

This report is one in a series on the topic of Intersection Safety Implementation provided by the Federal Highway Administration's Office of Safety. Other complimentary documents include Example Data Analysis Package and Straw Man Outline, Example Intersection Safety Implementation Plan, and Intersection Safety Implementation Plan Workshop and can be found on the FHWA Office of Safety website at http://safety.fhwa.dot.gov/intersection/.

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15. Supplementary Notes George E. Rice, Jr. COTM		

16. Abstract

To achieve their safety goals, many States select intersection safety as an emphasis area as part of their Strategic Highway Safety Plan (SHSP). However, while SHSPs may identify strategies to promote intersection safety, they lack the depth of information needed to establish an action plan for implementing the strategies necessary to achieve the safety goals. This document provides a 10-step process that guides and assists State Safety and Traffic Engineers in identifying the countermeasures, strategies, deployment levels, implementation steps, actions, and costs necessary to achieve the intersection safety goals of the SHSP.

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1. OVERVIEW

All States have developed Strategic Highway Safety Plans (SHSP) and have established safety goals as part of the SHSP.

States usually express safety goals in one of two ways:

- A reduction in fatalities by a certain year.
- A reduction in a combination of fatalities and injuries by a certain year.

Either of these options can be expressed in total numbers or rates.

To achieve their safety goals, many States select intersection safety as an emphasis area. However, while SHSPs may identify strategies to promote intersection safety, they lack the depth of information needed to establish an action plan for implementing the strategies and achieving the safety goals.

This document provides States a process (outlined in Figure 1) for creating an implementation plan to guide intersection safety implementation activities. It is specifically targeted toward State Safety Engineers who have intersection safety as an emphasis area in their SHSP.

Once complete, the implementation plan will include the activities, countermeasures, strategies, deployment levels, implementation steps, and funds necessary to achieve the intersection component of an SHSP goal. The following resources are available on the FHWA Intersection Safety web page (http://safety.fhwa.dot.gov/intersection/) to assist States in developing their implementation plans:

- Example workshop presentation.
- Example data analysis package and straw man outline.
- Example intersection safety implementation plan.

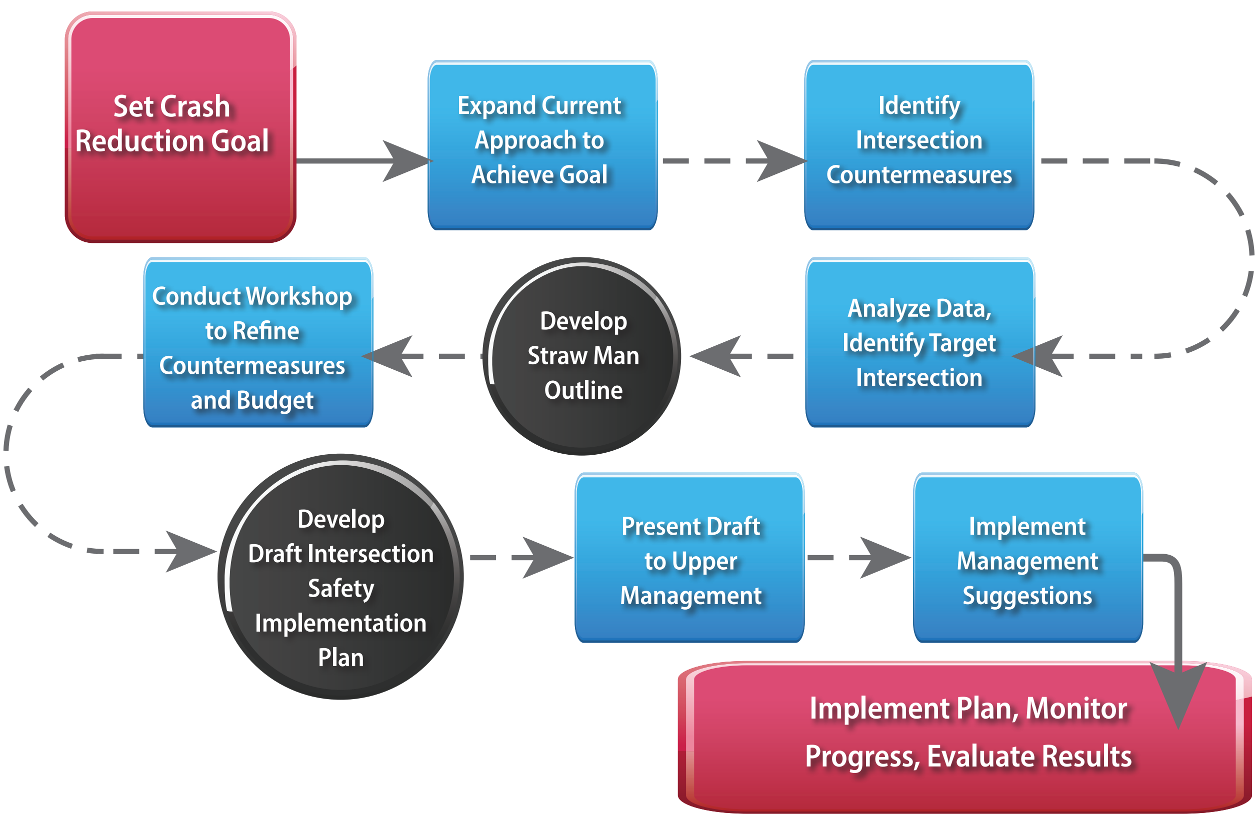

Figure 1: Process for Developing an Intersection Safety Implementation Plan

STEP 1:
Set The Intersection Crash Reduction Goal

Many State SHSPs define overall statewide safety goals. However, most SHSPs do not define the portions of the goal to be addressed by emphasis area such as improving intersection safety, reducing roadway departures, improving pedestrian safety, reducing drinking and driving, and preventing aggressive driving. Because SHSPs often do not contain this level of detail, the number and types of countermeasures within an emphasis area needed to help achieve the overall goal can not be ascertained. This can result in less focus on deployment levels, costs, and statewide fatality reductions associated with the implementation of strategies and countermeasures.

The overall SHSP goal may be expressed in terms of reductions in fatalities or some combination of fatalities and injuries by a certain time. It may also be expressed in terms of a reduction in the rate in crashes or fatalities per million vehicle miles traveled (VMT) or per 1,000 population. Two examples of setting an intersection goal that is aligned with the SHSP goal are provided.

Example 1

SHSP Goal as a Reduction in Absolute Numbers
If the SHSP goal is established in terms of a reduction in absolute numbers of fatalities and/or injuries by a given date, then information on the past trend of those fatalities and/or injuries is needed.

Assume State B had 1,000 fatalities in 2007, 200 of which were intersection or intersection-related. State B has a goal to reduce total fatalities to no more than 850 by 2013. Over the past several years the fatalities have fluctuated as shown in Table 1.

In 2013, it is expected that 940[1] fatalities will occur. Additional strategies and efforts that result in 90 fewer fatalities are needed to achieve the goal. The intersection portion of that goal is 20 percent of 90[2], or 18 fewer intersection deaths annually.

Year	Fatalities
2007	1,000
2006	923
2005	975
2004	1,021
2003	1,064

Table 1: Sample Fatalities for State B

Example 2

SHSP Goal Expressed as a Reduction in Rate
If the SHSP goal is expressed as a rate, it is important to convert the rate to an expected reduction in fatalities and/or injuries by the time the goal is to be achieved. Two pieces of information are needed to properly make this determination:

1. The fatality rate for each of the last 5 years of data.
2. The expected annual change in VMT for each year up to the year in which the goal is expected to be achieved.

Using the data from the last 5 years, the trend in the fatality rate can be estimated. The trend can predict the expected fatality rate in the year the goal is to be achieved. Then, using the predicted fatality rate and the estimated VMT in the goal year, the expected number of fatalities can be estimated.

As an example, assume that State A also had 1,000 fatalities in 2007, 200 of which were intersection or intersection-related. State A also has a goal to reduce the fatality rate from 1.30 in 2007 to 1.00 in 2013. The fatality rates over the past several years are provided in Table 2.

Table 2 shows that the fatality rate is declining at an average rate of approximately 3 percent annually. Projecting ahead, the expected fatality rate in 2013,

1 The expected number of fatalities in 2013 without additional strategies based upon past trends is the number of fatalities in 2007 (1,000) decreased by the results of existing trends and programs in place (1 percent annual decline in fatalities) for 6 years, or 1,000-(1,000x0.01x6) = 1,000-60 = 940.
2 The additional fatality reduction to meet the 2013 goal is the expected number of fatalities in 2013 (940) decreased by the State's 2013 fatality goal (850), or 940-850=90.

assuming current trends continue and no added improvements are implemented, would be 1.12.[3] However, over the next 6 years VMT is expected to grow at a rate of 2.3 percent annually, or 13.8 percent over 2007 VMT. The statewide VMT for 2007 is 76.9 billion. Growing by 13.8 percent, VMT is projected to be 87.5 billion by 2013.

With an estimated fatality rate of 1.12, the expected number of fatalities in 2013 would be 980.[4] The goal for 2013 to achieve a fatality rate of 1.0 per 100 million VMT translates into 875 fatalities.[5] Therefore, the net reduction in fatalities in 2013 from what is expected to the goal is 105.[6] Strategies and efforts that result in 105 fewer fatalities are needed to achieve the goal. Since 20 percent of the fatalities in 2007 occurred in intersection or intersection-related crashes, the intersection component of the overall goal can be estimated as 21[7] lives saved annually at intersections beginning in 2013.

Year	Fatality Rate Per 100 Million VMT
2007	1.30
2006	1.34
2005	1.37
2004	1.41
2003	1.45

Table 2: Sample Fatality Rates for State A

The economic losses that began in 2008 probably are associated with significant reductions in highway fatalities being realized in 2008. Less travel, particularly less discretionary travel, reduces the risk exposure for a serious crash. Most State SHSP goals are set approximately 5 years out (2012-2013). There is little technical basis to determine the length of the economic downturn. However, one assumption that may be made is that current economic conditions will be gone 5 years from now and should not be taken into consideration. That is, States could use 2007 as the last year of VMT and crash data in the analysis. States may also assume that VMT in 2012 will be equivalent to 2007 and expected fatalities in 2012 would be the mean of those occurring between 2002 and 2007.

Step 1 Action.

Create an intersection crash reduction goal that is aligned with and complements the SHSP goal.

3 The expected fatality rate in 2013 is the 2007 rate (1.30) decreased by 3 percent per year for 6 years, or 1.30-(6x0.03) = 1.30-0.18 = 1.12.

4 The expected number of fatalities in 2013 is the expected fatality rate in 2013 (1.12 per 100 million VMT) multiplied by the projected VMT (87.5 billion), or (1.12x10-8)x(87.5 x109) = 980.

5 The number of fatalities in 2013 if a 1.0 per 100 million VMT fatality rate is achieved is the fatality rate goal in 2013 (1.0 per 100 million VMT) multiplied by the VMT in 2013 (87.5 billion), or (1.0x10-8)x(87.5x109) = 875.

6 The net reduction in fatalities in 2013 is the expected number of fatalities in 2013 (980) decreased by the number of fatalities if the 1.0 per 100 million VMT is achieved (875), or 980-875 = 105.

7 The intersection component of the overall goal is the net reduction in fatalities in 2013 (105) multiplied by the percentage of intersection or intersection-related crashes in 2007 (20 percent), or 105x0.20 = 21.

Step 2:

Expand the Current Approach for Achieving the Crash Reduction Goal

Traditionally, States have relied on one approach to address intersection safety problems – concentrating on improving those intersections with the highest concentrations of frequent and severe intersection crashes. However, in order to meet the intersection crash reduction goal established in Step 1, States likely will have to expand their approach.

Three approaches to implementing intersection improvements probably will be needed to achieve the intersection crash reduction goal, particularly if the goal is designed to achieve a measurable statewide reduction in intersection fatalities or fatalities and incapacitating injuries. The approaches are:

1. Traditional.
2. Systematic.
3. Comprehensive.

If the intersection crash reduction goal is expressed in terms of a reduction in statewide fatalities and a substantial number of the fatalities occur on local roads and intersections, it is probable that these approaches need to be considered for application on both State- and locally-owned intersections. As a rule of thumb, based upon experience gathered from States that have developed intersection safety plans, the relative importance of considering improvements on local intersections to achieve a statewide intersection goal can be reflected in the proportion of intersection fatalities occurring at local intersections as indicated in the following ranges:

- **Less than 10 percent** of statewide intersection fatalities occur at locally-owned intersections – Minimal importance to include locally-owned intersection improvements to achieve a statewide intersection crash reduction goal.
- **Between 10 and 20-25 percent** of statewide intersection fatalities occur at locally-owned intersections – Beneficial and probably need to include some local intersection improvements to achieve a statewide intersection crash reduction goal.
- **Greater than 20-25 percent** of statewide intersection fatalities occur at locally-owned intersections – Necessary to incorporate local intersection improvements to achieve a statewide intersection crash reduction goal.

Traditional Approach

Traditionally, States identify high-crash locations using crash data associated with a highway referencing system and, in some cases, traffic volume information. A formula to rank the locations by some combination of frequency, severity, rate, and crash trend is used to establish candidate locations for improvement. For each candidate location, crash diagrams are developed and studied to determine potential countermeasures for reducing future crash occurrence. A benefit-cost (B/C) analysis usually is performed to determine if the proposed improvement(s) is cost-effective. Those candidate locations with the best benefit-cost ratios may be selected for the limited funding available. Due to the relative high cost of many of these improvements, an average State may implement fewer than 100 traditional safety improvements annually.

Road Ownership	Number of Intersections with a Fatal Crash	Intersections with One Fatal Crash	Intersections with Two Fatal Crashes	Intersections with Three Fatal Crashes
State	683	647	34	2
Local	336	328	7	1

Table 3: Typical Distribution of Fatalities within a State over a 5-Year Period

While this approach is important and needs to continue, it has minimal impact on reducing substantial numbers of future statewide fatalities and incapacitating injuries. If a State's safety goal is measured by a reduction of statewide fatalities, there is little probability that a fatality would occur at the improvement sites during the next few years, even if the improvements had not been made. The probability of a future fatality occurring is a function of a number of independent variables, many of which safety engineers have no control over, including the following:

- Speed.
- Type of crash.
- Point of impact.
- Type and mass of involved vehicle(s).
- Safety belt usage.
- Type of highway.
- Weather and surface conditions.
- Time of day.
- Type of traffic control.
- Crash location – urban or rural.
- Age and health of drivers and occupants.
- Emergency medical service (EMS) capabilities.
- Distance to nearest hospital.

In addition, statistics from States indicate very few intersections have multiple fatal crashes over a 5-year period. A typical distribution of fatal crashes within a State over a 5-year period is shown in Table 3.

If a fatal crash has occurred at an intersection, there is a relatively low probability that another one will occur within the next few years even if nothing is done to the intersection. If the statewide goal is expressed as a measured reduction of statewide fatalities (or fatalities and incapacitating injuries), then a traditional approach limited to a relatively nominal number of intersection improvements (less than approximately 100 annually) will be insufficient by itself to achieve the goal. Additional approaches to supplement the traditional approach are needed to achieve the intersection crash reduction goal.

Systematic Approach

The systematic approach is the opposite of the traditional approach in that it starts with a set of low-cost, effective countermeasures that the State is comfortable deploying and searches the crash data system to identify intersections where the countermeasures can be deployed cost-effectively. This approach is not limited to the highest crash locations. Typically, it focuses on treating the 3-6 percent of the intersections at which 25-45 percent of the statewide targeted intersection crashes exist.

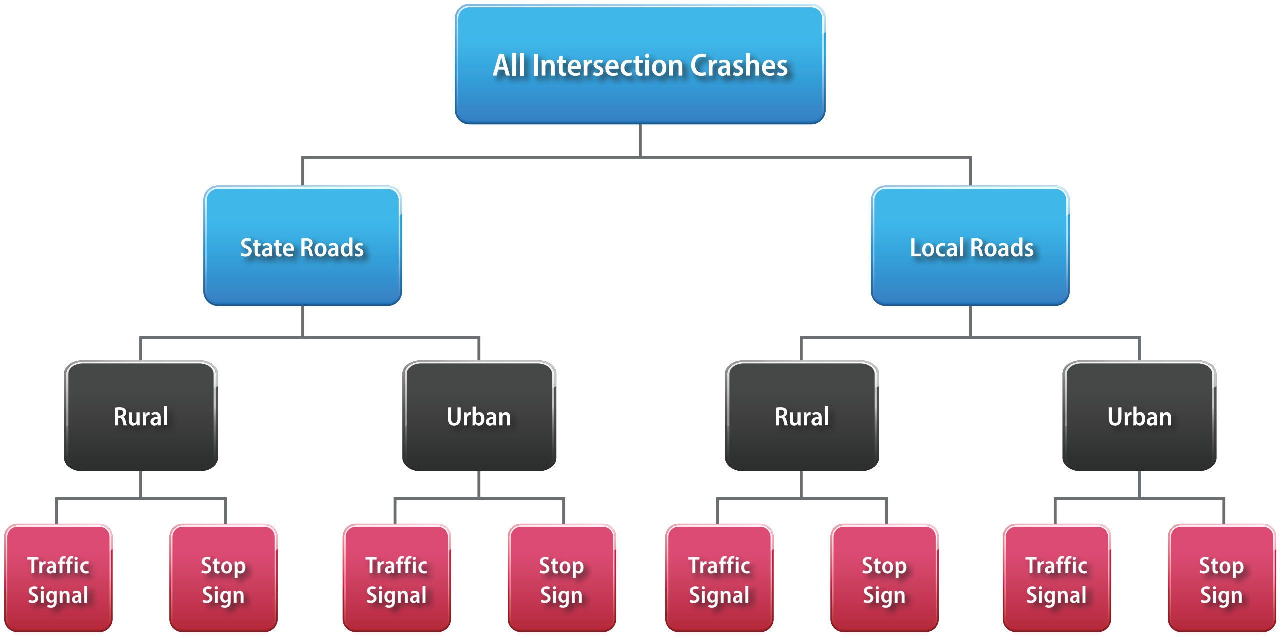

Figure 2: Levels of Information for the Systematic Approach Crash Data Analysis

In the systematic approach, intersection crash data are divided into three levels of information: State or local ownership, urban or rural location, and stop-controlled or signalized. As shown in Figure 2, all combinations of these levels (e.g., State, rural, stop-controlled, local urban signalized intersections) are used as a basis for analyzing the data. The breakdown of intersection ownership is important since State and local government implementation processes are often quite different. The separation of crashes by urban and rural area is necessary since crash severity (i.e., potential for a fatality) is much greater in rural areas for the same type of crash. The type of traffic control will dictate countermeasure treatment. In addition, the severity of similar types of crashes can differ significantly depending on the type of control (e.g., angle crashes at rural stop-controlled intersections are generally much more severe than angle crashes at rural signalized intersections).

The cost of a fatality and all injury categories should be used in performing benefit/cost (B/C) analyses to determine the target crash threshold where it is cost-effective to apply a designated low-cost countermeasure or sets of countermeasures. These costs were updated in a February 5, 2008, US Department of Transportation (USDOT) memo, Treatment of the Economic Value of a Statistical Life in Departmental Analyses, and are summarized in Table 4.

Severity	Descriptor	Cost Per Injury (2007 Dollars)
K	Fatal	5,800,000
A	Incapacitating	402,000
B	Evident	80,000
C	Possible	42,000
PDO	Property Damage Only	4,000

Table 4: USDOT Fatality and Injury Costs

Crash data analyses to determine if a countermeasure is cost-effective and can be considered for systematic deployment take crash types into consideration. Examples of crash type information needed to evaluate the potential deployment of various countermeasures are shown in Table 5.

For each of the crash types in Table 5, two key pieces of crash data are needed to perform the analyses:

- The **severity of crashes**, usually expressed in fatalities per 100 crashes for **all** of the statewide crashes over the past 5 years. The number of incapacitating injuries per 100 crashes may also be used to measure the impact of a countermeasure on incapacitating injuries.
- The **distribution of crashes per intersection** using 5 or more years of crash data for **all** intersections that had at least one crash. For example, this 5-year distribution may show that 25-45 percent of statewide crashes at State, rural, stop-controlled intersections occur in 3-6 percent of the intersections.

Traffic Control	Ownership	Area	Crash Type						
			Total	Angle	Left Turn	Dark	Wet	Pedes-trian	Speeding
Stop	State					✓	✓		✓
Stop	State	Urban	✓	✓	✓	✓	✓	✓	✓
Stop	Local	Rural	✓	✓	✓	✓	✓		✓
Stop	Local	Urban	✓	✓	✓	✓	✓	✓	✓
Signal	State	Rural	✓	✓	✓	✓	✓		✓
Signal	State	Urban	✓	✓	✓	✓	✓	✓	✓
Signal	Local	Rural	✓	✓	✓	✓	✓		✓
Signal	Local	Urban	✓	✓	✓	✓	✓	✓	✓

Table 5: Targeted Crash Types by Traffic Control, Ownership, and Area

Traffic Control	Ownership	Area	Crash Type					
			Total	Angle	Left Turn	Dark	Wet	Pedestrian
Stop	State	Rural	2.40	3.12	2.08	3.79	3.04	11.76
Stop	State	Urban	1.14	1.40	1.48	1.70	1.32	3.95
Stop	Local	Rural	1.24	1.57	1.14	1.69	1.60	2.80
Stop	Local	Urban	0.51	0.60	0.52	0.63	1.47	1.73
Signal	State	Rural	1.60	3.53	2.53	1.88	0.44	16.98
Signal	State	Urban	0.59	0.88	0.98	0.98	0.60	15.91
Signal	Local	Rural	0.72	1.03	1.00	0.96	0.65	7.49
Signal	Local	Urban	0.39	0.55	0.55	0.52	0.16	2.55

Table 6: Typical Rates for Fatalities per 100 Crashes

An example of typical rates for fatalities per 100 crashes is provided in Table 6. This table shows that rural stop-controlled intersections have the highest severity rates, and that these rates generally increase at night. Pedestrian crashes have a much higher fatality rate than other types of crashes. Crashes at local intersections have a severity similar to, but may be slightly less than, those occurring at State intersections. It is important that each State compute its own values for these severity rates using the most current 5 years of crash data.

Typical distributions for total crashes at State stop-controlled and signalized intersections are provided in Tables 7 and 8.

Number of Crashes per Intersection	Number of Intersections	Cumulative		Cumulative	
		Intersections	Percent	Crashes	Percent
50 and greater	7	7	0.07	428	1.42
30-49	26	33	0.31	1,390	4.60
20-29	91	124	1.16	3,506	11.60
10-19	389	513	4.82	8,601	28.45
5-9	1,033	1,546	14.51	15,347	50.76
4	576	2,122	19.92	17,651	58.39
3	1,008	3,130	29.38	20,675	68.39
2	2,034	5,164	48.47	24,743	81.84
1	5,489	10,653	100.00	30,232	100.00
Total	10,653	10,653	100.00	30,232	100.00

Table 7: Typical Distribution of Total Crashes at Rural State Stop-Controlled Intersections – 5 Years of Data

Number of Crashes per Intersection	Number of Intersections	Cumulative		Cumulative	
		Intersections	Percent	Crashes	Percent
50 and greater	8	8	1.44	573	13.95
30-49	23	31	5.57	1,407	34.26
20-29	36	67	12.03	2,258	54.98
10-19	56	123	22.08	3,012	73.34
5-9	73	196	35.19	3,490	84.98
4	31	227	40.75	3,614	88.00
3	43	270	48.47	3,743	91.14
2	77	347	62.30	3,897	94.89
1	210	557	100.00	4,107	100.00
Total	557	557	100.00	4,107	100.00

Table 8: Typical Distribution of Total Crashes at Rural State Signalized Intersections – 5 Years of Data

Two key observations can be made from Tables 7 and 8. In Table 7, if the 513 intersections that had 10 or more crashes were treated with low-cost countermeasures, almost 30 percent of the crashes that occur at State, rural, stop-controlled intersections could be impacted by the countermeasures. In Table 8, if the 31 intersections that had 30 or more crashes were treated with low-cost countermeasures, then over 34 percent of the crashes that occur at State, rural, signalized intersections could be impacted by the countermeasures. Conceptually, this is the essence of the systematic approach – identifying a relatively small set of intersections that comprise a substantial portion of the statewide crash problem, and treat the set with effective, low-cost countermeasures.

When performing the above analyses, it is important that a minimum of 5 full years of crash data be utilized. More years may be used if the data is available in the crash data system and factors that can change exposure (e.g., significant land use changes, traffic volume changes) have not occurred over the crash data period. Three years of data, while acceptable for identifying high-crash locations, is considered too unstable for identifying intersections with lower repetitive crash histories to be considered for systematic deployment of low-cost countermeasures. In addition, each State should define its own threshold levels based upon the data analyses, a State's ability to implement countermeasures, and the intersection crash reduction goal.

Comprehensive Approach

Since poor driving behavior contributes substantially to intersection crashes, it is important to consider initiatives which can improve safe driving through intersections. The comprehensive approach combines low-cost engineering countermeasures with targeted education and enforcement countermeasures. It is not economical to apply the education and enforcement components to a single intersection. The comprehensive approach works best on a corridor or within a specific area (usually defined by municipality boundaries) with a significant number of severe intersection crashes. The most predominant driving characteristics are speeding on approaches to intersections (both stop-controlled and signalized) and red-light running at signalized intersections. To a lesser extent, running Stop signs and pedestrian movement violations may be specific concerns for a given corridor or area.

In all cases where education and enforcement initiatives are to be considered, appropriate low-cost engineering countermeasures should supplement the initiative and be in place before the education and enforcement initiatives begin. Examples of supplemental low-cost countermeasures include appropriate speed limit sign adjustments, traffic calming measures, and traffic signal enhancements (e.g., combined yellow plus all red clearance interval timing adjustments, increasing the visibility of the signal heads).

The State crash data system may be used to identify priority corridors and municipalities with high numbers of intersection crashes. Those 5 to 10 mile sections of highway with the highest number of intersection fatalities and incapacitating injuries over a 5 year period would be candidates for corridor intersection safety improvements. Those municipalities with the highest number of 5-year intersection fatalities and incapacitating injuries (either total, on a per capita basis, or on a VMT basis) can be considered for the area-wide approach.

Step 2 Action.

Obtain support from the State Safety Engineer for the expanded approach to achieve the intersection crash reduction goal.

Step 3:

Identify Intersection Countermeasure Types to be Considered

Countermeasure Descriptions

Suggested low-cost countermeasures that can be considered and the intersection conditions where these countermeasures can be most cost-effectively deployed are identified in the tables below. The tables provide information for each countermeasure on target crash types, crash reduction factor (CRF), average expected life, and average construction costs. The CRF information was generated primarily from the August 2008 Federal Highway Administration (FHWA) *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer*,[1] other recent FHWA publications,[2] and input from intersection safety experts and practitioners.

Systematic Approach

The systematic approach countermeasures were developed by integrating available research findings and input from intersection safety experts and practitioners in the FHWA intersection focus states.[3] A more detailed description of the crash problem and deployment characteristics for each of the these countermeasures can be found in the FHWA report *Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections.*

1 http://safety.fhwa.dot.gov/tools/crf/briefs/interissuebrief.cfm
2 FHWA-HRT-07-033, Synthesis of the Median U-Turn Intersection Treatment, Safety and Operational Benefits, http://www.tfhrc.gov/safety/pubs/07033/index.htm
FHWA-HRT-08-053, Informational Report on Lighting Design for Midblock Crosswalks, http://www.tfhrc.gov/safety/pubs/08053/index.htm
FHWA-HRT-08-063, Two Low-Cost Safety Concepts for Two-Way Stop-Controlled Rural Intersections on High-Speed Two-Lane, Two-Way Roadways, http://www.tfhrc.gov/safety/pubs/08063/index.htm
FHWA-HRT-08-067, Traffic Calming on Main Roads Through Rural Communities, http://www.tfhrc.gov/safety/pubs/08067/index.htm
3 The FHWA intersection focus states are a set of States with a disproportionate percent and/or number of intersection fatalities in comparison to other States.

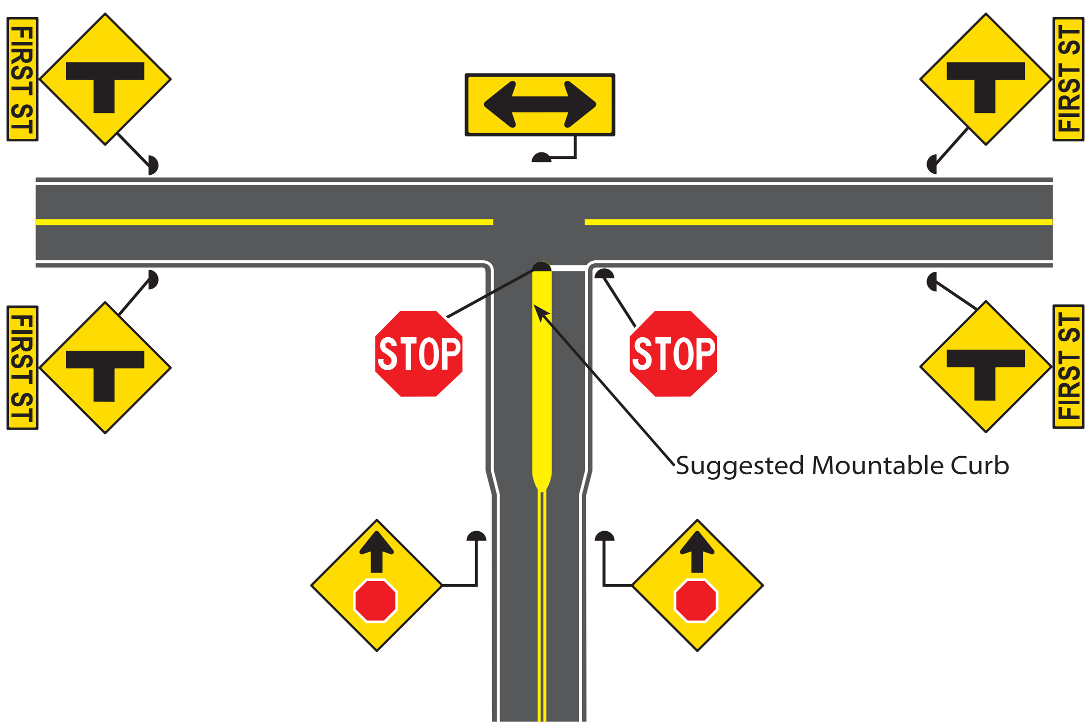

Figure 3: Examples of Basic Low-Cost Countermeasures for Stop-Controlled Intersections – Double Up Oversize Warning Signs, Double Stop Signs, Traffic Island on Stop Approach (if feasible), Street Name Signs, Stop Bars, and Double Warning Arrow at the Stem of T-Intersections

Stop-Controlled Intersections

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Implementation Factors	Typical Imple mentation Cost Range per Intersection
Basic set of sign and marking improvements	40%	10 crashes in 5 years	4-5 crashes in 5 years	None	$5,000 to $8,000
Installation of a 6 ft. or greater raised divider on stop approach (installed separately as a supplemental counter measure)	15%	20 crashes in 5 years	10 crashes in 5 years	Widening required to install island	$25,000 to $75,000 (pavement widening but no ROW required)
Either a) flashing solar powered LED beacons on advance intersection warning signs and Stop signs or b) flashing overhead intersection beacons	10% (13% for right angle crashes)	15-20 crashes in 5 years	8-10 crashes in 5 years	None	$5,000 to $15,000
Dynamic warning sign which advises through traffic that a stopped vehicle is at the intersection and may enter the intersection	Unknown	20-30 crashes in 5 years	10-20 crashes in 5 years	5 angle crashes in 5 years and inadequate sight distance from the stop approach	$10,000 to $25,000
Transverse rumble strips across the stop approach lanes in rural areas where noise is not a concern and running Stop signs is a problem ("Stop Ahead" pavement marking legend if noise is a concern)	28% (transverse rumble strips) 15% ("Stop Ahead" pavement markings)	5 running Stop sign crashes in 5 years	3 running Stop sign crashes in 5 years	Inadequate stopping sight distance on the stop approach	$3,000 to $10,000
Dynamic warning sign on the stop approach to advise high-speed approach traffic that a stopped condition is ahead	Unknown	8 running Stop sign crashes in 5 years	5 running Stop sign crashes in 5 years	Inadequate stopping sight distance on the stop approach	$10,000 to $25,000
Extension of the through edge line using short skip pattern may assist drivers to stop at the optimum point	Unknown	10 crashes in 5 years	5 crashes in 5 years	Wide throat and observed vehicles stopping too far back from the intersection	Less than $1,000
Reflective stripes on sign posts may increase attention to the sign, particularly at night	Unknown	10 crashes in 5 years	5 crashes in 5 years	Sign visibility or conspicuity significantly degraded particularly at night	Less than $1,000

Table 9: Crash Reduction Factors, Typical Crash Thresholds, Additional Applications Factors, and Estimated Implementation Cost Ranges for Countermeasures at Stop-Controlled Intersections

The basic set of sign and marking improvements for stop-controlled intersections referenced in Table 9 includes:

- Low-cost countermeasures for the through approach:
  - » Doubled-up (left and right), oversize advance intersection warning signs, with street name sign plaques.
- Low-cost countermeasures for the stop approach:
  - » Doubled-up (left and right), oversize advance "Stop Ahead" intersection warning signs.
  - » Doubled-up (left and right), oversize Stop signs.
  - » Installation of a minimum 6 ft. wide raised splitter island on the stop approach (if no pavement widening is required).
  - » Properly placed stop bar.
  - » Removal of any foliage or parking that limits sight distance.
  - » Double arrow warning sign at stem of T-intersections.

Figure 3 shows the basic set of sign and marking improvements for stop-controlled intersections, including a splitter island.

The other countermeasures in Table 9 (i.e., those not in the basic set of sign and marking improvements category) should be considered to supplement the basic set of sign and marking improvements at those stop-controlled intersections (1) with higher crash frequencies and (2) that possess the physical characteristics that the countermeasure is intended to mitigate.

Information about the J-turn treatment for stop-controlled intersections[4] is shown in Table 10. The J-turn treatment is to be considered primarily at high-speed, arterial, multi-lane highways and only permit right turn in and right turn out as illustrated in Figure 4. It also may be considered at other lower speed intersections such as those in urban areas.

4 J-turn treatments are also referred to as restricted-crossing U-turn intersection treatments.

Signalized Intersections

The basic set of sign and signal enhancements referenced in Table 11 includes:

- Twelve-inch LED lenses on all signal heads.
- Back plates on all signal heads (optional reflectorized border).
- A minimum of one traffic signal head per approach lane.
- Traffic signal yellow change interval and all-red interval timing adjusted to be in accordance with the Institute of Transportation Engineers (ITE) timing standards.
- Elimination of any late night flashing operations.

The basic set of sign and signal enhancements should be applied to all intersections with high crash frequencies. In addition, the other countermeasures listed in Table 11 should be considered at signalized intersections (1) with higher frequencies of crashes beyond the crash threshold for basic countermeasures and (2) that have specific crash types or physical limitations that the countermeasure is intended to address.

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Implementation Cost Range per Intersection
J-turn modifications on high-speed divided arterials	100% cross path, 72-84% frontal impact, 43-53% all crashes	4 angle crashes in 5 years*	4 angle crashes in 5 years*	Ability to make U-turn within about ¼ to ½ mile of intersection	$5,000 to $50,000

* If a highway section has a series of stop-controlled intersections with a high collective number of angle crashes, it is preferable to treat the problem on a system-wide basis, addressing all of the stop-controlled intersections rather than improving a few intersections that have isolated high numbers of angle crashes.

Table 10: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Countermeasures at J-Turn Stop-Controlled Intersections

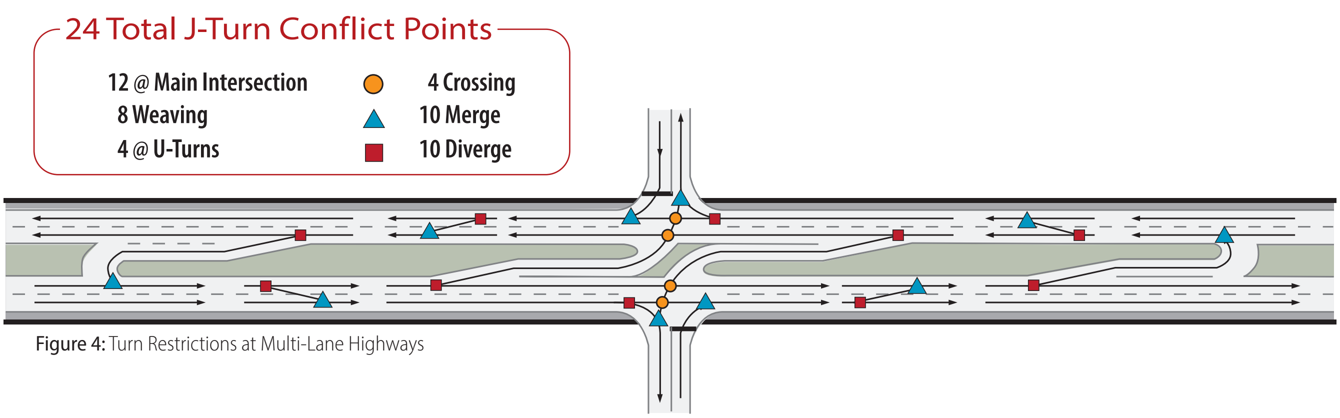

Figure 4: Turn Restrictions at Multi-Lane Highways

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Implementation Factors	Implementation Cost Range per Intersection
Basic set of signal and sign improvements	30%	20 crashes in 5 years	10 crashes in 5 years	None	$5,000 to $30,000
Change of permitted and protected left-turn phase to protected-only	41-48% of left turn crashes	5 left turn movement crashes; 3 or more opposing through lanes; minimal turning gaps available	5 left turn movement crashes; 3 or more opposing through lanes; minimal turning gaps available	None	$5,000 to $10,000
Advance cross street name signs for high-speed approaches on arterial highways	Unknown	20 crashes in 5 years	10 crashes in 5 years	High-speed approaches on four or more lane arterial highways	$1,000 to $5,000
Advance left and right "Signal Ahead" warning signs for isolated traffic signals	22%	20 crashes in 5 years	10 crashes in 5 years	Isolated traffic signal with one or more miles between signals; or traffic signals that are not readily visible due to highway alignment or obstructions	$1,000
Supplemental signal face per approach	28%	20 crashes in 5 years	10 crashes in 5 years	Signal faces obstructed by horizontal alignment; or exceptionally wide intersections (>100 ft) where a near side signal is needed	$5,000 to $15,000
Advance detection control systems	40% (injuries)	5 angle crashes in 5 years	5 angle crashes in 5 years	Isolated high-speed (45mph or greater) signalized intersections	$15,000
Signal coordination	32%	20 crashes in 5 years per intersection	10 crashes in 5 years per intersection	Arterials with closely spaced (about 1/2 mile maximum) signals	$5,000 to $50,000
Pedestrian countdown signals	25% (pedestrian crashes)	2 pedestrian crashes in 5 years	2 pedestrian crashes in 5 years	None	$5,000 to $15,000
Separate Pedestrian Phasing	34% (pedestrian crashes)	2 pedestrian crashes in 5 years involving a turning vehicle	2 pedestrian crashes in 5 years involving a turning vehicle	None	$5,000 to $15,000
Pedestrian Ladder or cross-hatched crosswalk and advanced pedestrian warning signs	15% (pedestrian crashes) for signs Unknown for crosswalk	2 pedestrian crashes in 5 years	2 pedestrian crashes in 5 years	None	$1,000 to $3,000

Table 11: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Countermeasures at Signalized Intersections

Both Stop-Controlled and Signalized Intersections

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Implementation Cost Range per Intersection
New or upgraded Lighting	50% (NEW), 25% (UPGRADED) of night crashes	10 night crashes in 5 years and a night /total crash ratio above the statewide average for urban unlit intersections	5 night crashes in 5 years and a night/total crash ratio above the statewide average for rural unlit intersections	None	$5,000 to $15,000

Table 12: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Lighting Countermeasures at Unlit or Poorly Lit Intersections

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Implementation Cost Range per Intersection
Skid resistant surface	50% (wet pavement crashes only)	8 wet pavement crashes in 5 years, a wet/total crash ratio above the statewide average wet/total crashes for intersections	8 wet pavement crashes in 5 years, a wet/total crash ratio above the statewide average wet/total crashes for intersections	High-speed approaches (45mph or greater) and a ribbed tire skid number of about 30 or less.	$20,000 to $50,000

Table 13: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Skid Resistant Countermeasures at Intersections with High Rates of Low-Friction Crashes

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Implementation Cost Range per Intersection
Lane narrowing using pavement marking and shoulder rumble strips	31%	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years	Free of noise and bicycle issues – single through lane	$20,000 to $40,000
Lane narrowing using pavement marking and raised pavement markers	Unknown but probably less than 31%	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years	Single through lane	$5,000 to $10,000
Peripheral Transverse pavement markings	Unknown	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years		$3,000 to $5,000
Dynamic speed warning sign on the through approach to reduce speed	30%	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years		$10,000
"Slow" pavement markings	Unknown	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years		$2,000 to $5,000
High-Friction Surface	25% (All crashes)	10 speed-related crashes in 5 years	5 speed-related crashes in 5 years		$20,000 to $50,000

Table 14: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Countermeasures at Stop-Controlled Intersections with High-Speed Approaches

Tables 11-14 provide crash reduction factors, the typical number of crash reductions, and estimated cost ranges for a comprehensive set of intersection countermeasures.

Comprehensive Approach

Automated red-light enforcement systems detect vehicles that enter a signalized intersection after the signal phase has turned red. The red-light camera system is connected to the traffic signal and to sensors that monitor traffic flow at the crosswalk or stop line. The system continuously monitors the traffic signal. For a specified amount of time after the signal turns red, any vehicle entering the intersection triggers the camera. One photograph will show a readable license plate. A second photograph typically shows the red light violator in the intersection. Cameras record the date, time of day, time elapsed since the beginning of the red signal, and vehicle speed. Tickets typically are sent by mail to owners of violating vehicles, based on review of photographic evidence.

Enforcement-assisted light systems activate a white light above the traffic signal as the signal turns into the red phase. Officers can be located downstream of the intersection and, using the white light activation, more easily identify and apprehend red light violators.

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Typical Imple mentation Cost Range per Intersection
Corridor engineering, education, and enforcement (3E) improvements on high-speed arterials with very high frequencies of severe intersection crashes	25% of corridor intersection fatal and incapacitating injury crashes	10 or more intersection fatalities	10 or more intersection fatalities	Length of corridor should be in the 5-10 mile range	$1,000,000 per corridor + $100,000 education and enforcement annually per corridor
Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes	10% of all intersection crashes	Top 5 or so municipalities with the most intersection fatalities		Consider density of severe crashes per capita	$500,000 to 1,000,000 + $100,000 to 200,000 (dependent on the size of the city) education and enforcement annually per municipality

Table 15: Crash Reduction Factors, Default Expected Life, and Estimated Implementation Costs for Corridor and Municipal Enforcement Countermeasures

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Typical Imple mentation Cost Range per Intersection
Automated red-light enforcement	25% of angle crashes	8 angle crashes in 5 years	4 angle crashes in 5 years	Enabling legal authority required	Normally $0 if operated by contractor
Enforcement-assisted lights	15% of angle crashes	8 angle crashes in 5 years	4 angle crashes in 5 years	Enforcement commitment required	$1,000

Table 16: Crash Reduction Factors, Typical Crash Thresholds, Additional Application Factors, and Estimated Implementation Cost Ranges for Countermeasures for Education-Enforcement Strategies at Signalized Intersections to Reduce Red-Light Running

Traditional Approach

Since the traditional approach addresses the intersections with the highest crash frequencies and/or severities, the most effective crash-reducing countermeasures should be considered for these intersections. These include roundabouts and left turn lanes. These improvements also are among the costliest countermeasures. Individual analyses are required to determine if they are the most appropriate improvements to implement.

Selecting Countermeasures

Selection of the set of countermeasures to consider for inclusion in the implementation plan will depend on a number of factors, such as:

- The size of the crash problem that the countermeasure may impact.
- The cost and CRF of the countermeasure.
- Any major deployment or policy issues associated with the countermeasure.
- Any legislative restrictions affecting the use or deployment of the countermeasure

Table 18 provides a template for States to use when considering intersection countermeasures. When completing this template, States should include any additional intersection countermeasures it is using or considering.

Intersections proposed for countermeasures listed under the first category in Table 18 – will consider for widespread deployment – eventually will need field inspection to verify that the countermeasure can be implemented and is appropriate at the intersections identified. It may be appropriate to field verify a sample set of intersections where the countermeasure may be deployed before completing the implementation plan to determine if deployment assumptions are acceptable.

Countermeasures listed under the second category in Table 18 – will limit or restrict deployment – may include countermeasures with which a State has no or little experience (e.g., dynamic intersection warning sign systems at stop-controlled intersections). It may be appropriate to consider listing these types of countermeasures in the second category until further experience is gained.

Countermeasure	Crash Reduction Factor	Typical Urban Crash Threshold	Typical Rural Crash Threshold	Additional Intersection Concern	Typical Imple mentation Cost Range per Intersection
Roundabouts	72% to 87% (injuries and fatalities)	Intersections with the most frequent severe crashes statewide	Intersections with the most frequent severe crashes statewide	Right of way restrictions; individual intersection analysis required	$500,000 to $1 million each
Left Turn Lanes	13% to 24% for left-turn crashes at signalized intersections, 37% to 60% for left-turn crashes at stop-controlled intersections	Intersections with the most frequent severe crashes statewide	Intersections with the most frequent severe crashes statewide	Right of way restrictions; individual intersection analysis required	$350,000 to $400,000 each
Other Geometric Improvements (i.e., Elimination of Skew, Vertical Curve)	Dependent upon type of countermeasure, see *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer* for specific improvements	Intersections with the most frequent severe crashes statewide	Intersections with the most frequent severe crashes statewide	Right of way restrictions; individual intersection analysis required	$250,000 to $1 million each

Table 17: Crash Reduction Factors, Additional Application Factors, and Estimated Implementation Costs for Traditional Approach Countermeasures

Those countermeasures listed in the first two categories make up the set of countermeasures to consider for achieving the intersection crash reduction goal. For countermeasures that are to be limited or restricted, States should list the specific issues that need to be addressed before wider deployment is considered. This will be helpful in developing the implementation plan. In addition, States should also identify reasons that countermeasures will not be considered (i.e., the third category in the template) for potential discussion among stakeholders during the workshop in Step 6.

Countermeasure	Will Consider for Widespread Cost-Effective Deployment	Will Limit or Restrict Cost-Effective Deployment Until Issues/Concerns are Resolved	Will not Consider Deploying at This Time
Systematic Approach – Stop-Controlled Intersections			
Basic set of sign and marking improvements			
Installation of a 6 ft. or greater raised divider on stop approach (installed separately as a supplemental countermeasure)			
Either a) flashing solar powered LED beacons on advance intersection warning signs and Stop signs or b) flashing overhead intersection beacons			
Dynamic warning sign which advises through traffic that a stopped vehicle is at the intersection and may enter the intersection			
Transverse rumble strips across the stop approach lanes in rural areas where noise is not a concern and running Stop signs is a problem ("Stop Ahead" pavement marking legend if noise is a concern)			
Dynamic warning sign on the stop approach to advise high-speed approach traffic that a stopped condition is ahead			
Extension of the through edge line using short skip pattern may assist drivers to stop at the optimum point			
Reflective stripes on sign posts may increase attention to the sign, particularly at night			
J-turn modifications on high-speed divided arterials			

Countermeasure	Will Consider for Widespread Cost-Effective Deployment	Will Limit or Restrict Cost-Effective Deployment Until Issues/Concerns are Resolved	Will not Consider Deploying at This Time
Systematic Approach – Signalized Intersections			
Basic set of signal and sign improvements			
Change of permitted and protected left-turn phase to protected-only			
Advance cross street name signs for high-speed approaches on arterial highways			
Advance left and right "Signal Ahead" warning signs for isolated traffic signals			
Supplemental signal face per approach			
Advance detection control systems			
Signal coordination			
Pedestrian countdown signals			
Separate pedestrian phasing			
Pedestrian ladder or cross-hatched crosswalk and advanced pedestrian warning signs			

Countermeasure	Will Consider for Widespread Cost-Effective Deployment	Will Limit or Restrict Cost-Effective Deployment Until Issues/Concerns are Resolved	Will not Consider Deploying at This Time
Systematic Approach – Both Stop-Controlled and Signalized Intersections			
New or upgraded lighting			
Skid resistant surface			
Lane narrowing using pavement marking and shoulder rumble strips			
Lane narrowing using pavement marking and raised pavement markers			
Peripheral transverse pavement markings			
Dynamic speed warning sign on the through approach to reduce speed			
"Slow" pavement markings			
High-friction surface			
Comprehensive Approach			
Corridor 3E improvements on high-speed arterials with very high frequencies of severe intersection crashes			
Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes			
Automated red-light enforcement			
Enforcement-assisted lights			

Countermeasure	Will Consider for Widespread Cost-Effective Deployment	Will Limit or Restrict Cost-Effective Deployment Until Issues/Concerns are Resolved	Will not Consider Deploying at This Time
Traditional Approach			
Roundabouts			
Left-turn channelization			
Other geometric improvements (i.e., elimination of skew, vertical curve)			

Table 18: Template for Documenting Countermeasure Selection

Step 3 Action.

Complete Table 18 and list all the specific issues that need to be addressed for all countermeasures identified as limited or restricted.

Step 4:

Analyze Crash and Applicable Roadway Data

The Data Analysis Process

The intersection safety implementation plan process is data-driven. The primary source of data for intersection crash analysis is a State's crash data system. The data used in the analysis helps identify candidate intersections where countermeasures can be considered for cost-effective implementation.

The most recent 5 years of crash data is recommended for use in the analysis. More years may be used if the data is available in the crash data system and factors that can change exposure (e.g., significant land use changes, traffic volume changes) have not occurred over the crash data period. Three years of data, while acceptable for identifying high-crash locations, is considered too unstable for identifying intersections with lower repetitive crash histories to be considered for systematic deployment of low-cost countermeasures.

The five levels in the data analysis process are described below.

Separate Intersection Crashes into Sub-Groups

Intersection crashes should be divided into sub-groups based on State or local ownership, urban or rural location, and traffic control type. This results in eight sub-groups for analysis:

1. State rural signalized intersection crashes.
2. State urban signalized intersection crashes.
3. State rural stop-controlled intersection crashes.
4. State urban stop-controlled intersection crashes.
5. Local rural signalized intersection crashes.
6. Local urban signalized intersection crashes.
7. Local rural stop-controlled intersection crashes.
8. Local urban stop-controlled intersection crashes.

The division of crashes into State and local ownership is helpful since the processes for implementing similar improvements on the State verses the local system are significantly different. Crashes are separated by rural and urban areas because similar types of intersection crashes are more severe in rural areas (e.g., Table 6 shows that typical values for fatalities per 100 crashes for angle crashes are 3.53 and 0.88 for State rural and State urban intersections, respectively). This is important if the State's goal is to reduce fatalities and/or incapacitating injuries instead of crashes. Finally, the types of countermeasure will be different at stop-controlled intersections compared to signalized intersections for similar crash patterns. In addition, the severity of similar crashes is greater at stop-controlled intersections than at signalized intersections.

Determine Target Crash Types

Based on the countermeasures selected in Step 3, States should identify the crash types and characteristics that the countermeasures are designed to impact. The typical types of crashes and associated countermeasures are shown in Table 19. This list provides the basis for analyzing the crash data. The combinations of crash types and sub-groups represent all of the various cuts of data that can be used in subsequent levels of the data analysis process:

Crash Type	Crash Sub Group: Traffic Control	State Rural	State Urban	Local Rural	Local Urban	Countermeasure	Approach
Total Crashes	Stop-Controlled	✓	✓	✓	✓	Basic set of sign and marking improvements	Systematic
						Installation of a 6 ft. or greater raised divider on stop approach (installed separately as a supplemental countermeasure)	Systematic
						Either a) flashing solar powered LED beacons on advance intersection warning signs and Stop signs or b) flashing overhead intersection beacons	Systematic
						Dynamic warning sign which advises through traffic that a stopped vehicle is at the intersection and may enter the intersection	Systematic
						Dynamic warning sign on the stop approach to advise high-speed approach traffic that a stopped condition is ahead	Systematic
						Roundabouts	Traditional
						Other geometric improvements (i.e., elimination of skew, vertical curve)	Traditional
Total Crashes-Divided Arterials	Stop-Controlled	✓	✓			J-turn modifications on high-speed divided arterials	Systematic
Running Stop Sign Crashes[1]	Stop-Controlled	✓	✓	✓	✓	Transverse rumble strips across the stop approach lanes in rural areas where noise is not a concern and running Stop signs is a problem ("Stop Ahead" pavement marking legend if noise is a concern)	Systematic
Total Crashes	Signalized	✓	✓	✓	✓	Basic set of signal and sign improvements	Systematic
						Signal coordination	Systematic
						Roundabouts	Traditional
						Left-turn channelization	Traditional
						Other geometric improvements (i.e., elimination of skew, vertical curve)	Traditional
Left-Turn Crashes	Stop-Controlled	✓	✓	✓	✓	Left-turn channelization	Traditional
Left-Turn Crashes	Signalized	✓	✓	✓	✓	Change of permitted and protected left-turn phase to protected-only	Systematic

Crash Type	Crash Sub Group					Countermeasure	Approach
	Traffic Control	State Rural	State Urban	Local Rural	Local Urban		
Angle Crashes - 45 mph and greater	Signalized	✓		✓		Advance detection control systems	Systematic
Angle Crashes	Signalized	✓	✓	✓	✓	Automated red-light enforcement	Comprehensive
						Enforcement-assisted lights	Comprehensive
Pedestrian Crashes	Signalized	✓	✓	✓	✓	Pedestrian countdown signals	Systematic
						Separate pedestrian phasing	Systematic
						Pedestrian ladder or cross-hatched crosswalk and advanced pedestrian warning signs	Systematic
Night Crashes	Stop-Controlled	✓	✓	✓	✓	New or upgraded lighting	Systematic
Night Crashes	Signalized	✓	✓	✓	✓	New or upgraded lighting	Systematic
Wet Crashes - 45 mph and Greater	Stop-Controlled	✓		✓		Skid resistant surface	Systematic
Wet Crashes - 45 mph and Greater	Signalized	✓		✓		Skid resistant surface	Systematic
Speed-Related Crashes	Stop-Controlled	✓	✓	✓	✓	Lane narrowing using pavement marking and shoulder rumble strips	Systematic
						Lane narrowing using pavement marking and raised pavement markers	Systematic
						Peripheral transverse pavement markings	Systematic
						Dynamic speed warning sign on the through approach to reduce speed	Systematic
						"Slow" pavement markings	Systematic
						High-friction surface	Systematic
Speed-Related Crashes	Signalized	✓	✓	✓	✓	Lane narrowing using pavement marking and shoulder rumble strips	Systematic
						Lane narrowing using pavement marking and raised pavement markers	Systematic
						Peripheral transverse pavement markings	Systematic
						Dynamic speed warning sign on the through approach to reduce speed	Systematic
						"Slow" pavement markings	Systematic
						High-friction surface	Systematic

Crash Type	Crash Sub Group					Countermeasure	Approach
	Traffic Control	State Rural	State Urban	Local Rural	Local Urban		
Fatal and Incapacitating Injury Crashes – Corridors	N/A - Crashes are grouped by county and route					Corridor 3E improvements on high-speed arterials with very high frequencies of severe intersection crashes	Comprehensive
Fatal and Incapacitating Injury Crashes – Municipalities	N/A – Crashes are grouped by city/ municipality					Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes	Comprehensive
Angle Crashes – Municipalities	Signalized	N/A – Crashes are grouped by city/ municipality				Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes	Comprehensive
Pedestrian Crashes – Municipalities	N/A – Crashes are grouped by city/ municipality					Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes	Comprehensive

1 Running Stop sign crash types may be identified from crash data systems where this specific type of crash in included in the data, usually as a causation factor.

Table 19: Typical Types of Crashes and Associated Countermeasures

There are a number of special cases or supplementary countermeasures that do not appear in Table 19 because they will be deployed only if an intersection warrants them. This determination cannot be made from the data; it requires field evaluation. These special case/ supplementary countermeasures include:

- Stop-Controlled Intersections:
  - » Extension of the through edge line using short skip pattern may assist drivers to stop at the optimum point.
  - » Reflective stripes on sign posts may increase attention to the sign, particularly at night.
- Signalized Intersections:
  - » Advance cross street name signs for high-speed approaches on arterial highways.
  - » Advance left and right "Signal Ahead" warning signs for isolated traffic signals.
  - » Supplemental signal face per approach.

Calculate Average Crash Costs and Crash Severities

Using the countermeasures selected in Step 3 and the related information in Table 19, States should calculate the average crash costs and severity of crashes for each crash type/sub-group (i.e., State and local ownership, rural and urban area, and traffic control type) combination. The formula for average crash costs uses the cost data in Table 4 and the number of injury types for each crash type/sub-group combination:

$$\text{AverageCrashCost} = \frac{(K \times 5{,}800{,}000) + (A \times 402{,}000) + (B \times 80{,}000) + (C \times 42{,}000) + (PDO \times 4{,}000)}{\text{Total Crashes}}$$

Severity usually is measured in terms of fatalities per 100 crashes and incapacitating injuries per 100 crashes using 5 years of data. Thus, if implementation of a given countermeasure is expected to prevent 200 crashes in a specified subgroup with a severity of 1 fatality per 100 crashes, it can be expected that 2 fatalities can be prevented through the implementation of the countermeasures at the identified number of intersections.[1] Table 20 shows an example of a severity and average crash cost report for angle crashes at signalized intersections.

Locality	Total Crashes	Total Fatalities	Fatalities per 100 Crashes	Total Incapacitating Injuries	Incapacitating Injuries per 100 Crashes	Average Crash Cost
State Roads						
Rural	1,588	11	0.69	148	9.32	$89,779.60
Urban	27,278	66	0.24	1,520	5.57	$56,565.07
Total	28,866	77	0.27	1,668	5.78	$58,392.30
Local Roads						
Rural	238	5	2.10	5	2.10	$121,436.97
Urban	31,643	86	0.27	1,323	4.18	$51,009.77
Total	31,881	91	0.29	1,328	4.17	$51,535.52

Table 20: Angle Crashes – Signalized Intersections – 5 Years of Data

Determine Distribution of Crash Densities

Using the same list of crash type/sub-group combinations as in the average crash cost and crash severity analysis, States need to determine the distribution of crash densities across intersections. The first step in this process creates a standard location definition for each intersection. On State roads, this definition typically is a combination of county, route, and milepost. For local roads, county, city, and the two intersecting road names are often used. The second step is to group crashes by intersection, so that the number of crashes per intersection can be obtained. Table 21 shows a sample, partial listing of crashes per intersection. It should be noted that there are over 10,000 intersections included in the complete listing of intersections associated with this sample.

1 The expected number of fatalities prevented is the expected number of crashes prevented (200) multiplied by the fatalities per 100 crashes (1), or 200x(1/100) = 200x0.01 = 2.

The final step is to create a summarized frequency distribution of intersections based on their number of crashes. Table 22 shows an example distribution for State, rural, stop-controlled intersections. This data corresponds with that shown in Table 21. This example shows that almost 5 percent[2] of the intersections (i.e., those with 10 or more crashes) account for approximately 30 percent[3] of all the crashes at State, rural, stop-controlled intersections over 5 years.

It is to be noted that only those intersections with at least one crash within the overall crash data period are listed. Therefore, there are more actual intersections in existence than those listed from the crash data.

Prepare Data Analysis Package

States should prepare a data analysis package to develop the straw man outline including a set of countermeasures, deployment level, costs, and estimated statewide annual crash reductions (Step 5), to provide relevant intersection crash information during the workshop (Step 6), and to develop the draft intersection safety implementation plan (Step 7). The package should include at least the following information:

1. **A comparison of annual intersection fatalities reported from the State crash data systems with the Fatality Analysis Reporting System (FARS) data for the State.**
2. **A universal table showing crashes and percentages of intersection crashes, incapacitating injuries, and fatalities for each of the eight sub-groups over 5 years of data.**

2 Almost 5 percent is calculated by dividing the number of intersections with 10 or more crashes (513) by the total number of intersections (10,653), or 513/10,653 = 0.482.

3 Approximately 30 percent is calculated by dividing the number of crashes at intersections with 10 or more crashes (8,601) by the total number of crashes (30,232), or 8,601/30,232 = 0.2845.

Intersection Number	Number of Crashes	Percent of Total
484482	88	0.29
308460	77	0.25
381451	58	0.19
406090	55	0.18
109723	50	0.17
352859	50	0.17
401778	50	0.17
323215	47	0.16
611052	47	0.16
378049	45	0.15
329718	42	0.14
411137	42	0.14
89587	41	0.14
176793	39	0.13
383587	39	0.13
517467	39	0.13
383490	38	0.13
494698	38	0.13
544656	38	0.13
132752	37	0.12

Table 21: Sample Listing of Crashes per Intersection – State, Rural, Stop-Controlled Intersections – 5 Years of Data

Number of Crashes per Intersection	Number of Intersections	Cumulative		Cumulative	
		Intersections	Percent	Crashes	Percent
50 and greater	7	7	0.07	428	1.42
30-49	26	33	0.31	1,390	4.60
20-29	91	124	1.16	3,506	11.60
10-19	389	513	4.82	8,601	28.45
5-9	1,033	1,546	14.51	15,347	50.76
4	576	2,122	19.92	17,651	58.39
3	1,008	3,130	29.38	20,675	68.39
2	2,034	5,164	48.47	24,743	81.84
1	5,489	10,653	100.00	30,232	100.00
Total	10,653	10,653	100.00	30,232	100.00

Table 22: Summarized Frequency Distribution – State, Rural, Stop-Controlled Intersections – 5 Years of Data

3. Other general intersection crash data, such as the distribution of crash and injury types by speed limit for stop-controlled and signalized intersections and the distribution of crash types by the eight sub-groups (total crashes and fatalities).

4. Sets of tables providing information on the average cost; number of crashes, incapacitating injuries, and fatalities; and the proportion of incapacitating injuries and fatalities per 100 crashes for each of the crash type and traffic control combinations in Table 19 that correspond to the countermeasures selected in Step 3. Table 20 provides an example.

5. Sets of tables providing information on the distribution of crash densities by intersection for each of the crash type and traffic control combinations in Table 19 that correspond to the countermeasures selected in Step 3. Table 22 provides an example.

An example data analysis package and straw man outline can be found on the FHWA Intersection Safety web page (http://safety.fhwa.dot.gov/intersection/resources/).

Data Problems and Solutions

A State may encounter at least four types of problems while analyzing its crash data to apply a systematic approach: data quality, data availability, exposure and rates, and intersections with multiple countermeasures. Approaches to addressing these problems have been found as discussed below.

Data Quality

Inconsistency of the Rural/Urban Designation at the Same Intersection. The rural/urban differential is used to define the probable severity of similar crashes. On the whole, crashes in rural areas are much more severe than similar types of crashes in urban areas. The rural/urban designation for a crash can come from two sources: directly from the police crash report or transferred from the State's roadway data file. If the information comes from the roadway data file, it is consistent for all crashes that occur at a specific intersection. If the information comes from the police crash report, the rural/urban designation may differ among crash reports for the same intersection. This becomes a problem when the data are grouped according to rural/urban designation. If an intersection has 20 crashes total, but the police crash reports show 13 of these in urban areas and 7 in rural areas, the intersection will appear on both the rural intersection reports and the urban intersection reports (i.e., an urban intersection with 13 crashes and a rural intersection with 7 crashes).

The preferred solution is to link the crash and roadway data files and use the rural/urban designation from the roadway data file for each crash. If the rural/urban information is not available from the roadway file or cannot be transferred, then the State should identify the level of data inconsistency to determine if an informed estimate of the correct urban/rural designation can be made. This can be accomplished by tabulating the distribution of crashes at high-crash intersections above the threshold level by urban and rural areas to determine if one type of area is predominant. Table 23 provides an example tabulation.

In this case, 8 of the 10 intersections are most likely rural. Two of the 10 intersections (Intersections C and D) are too close to call. The urban/rural designation for crashes at Intersections C and D should be determined by consulting designation information from the roadway data file and correcting the urban/rural data in the crash files for the appropriate crashes.

Police-reported speed limit information may be used as an alternate source of crash severity differences, as it often has more report consistency than police-reported rural/urban designation. A speed limit at and above 45 mph provides a breakpoint where the speed limit data for the same intersection is consistent. In addition, similar crashes at intersections where the speed limit is 45 mph or greater have been found to have significantly higher fatality rates (e.g., fatalities per 100 crashes) than similar crashes that occur at intersections where the speed limit is 40 mph or lower. States that do not have accurate and consistent urban/rural crash data elements can use speed limits as an indicator of intersections with higher approach speeds and more severe crashes similar to those experienced in rural areas.

Inconsistency of the Traffic Control Device Information at the Same Intersection. Most States do not have a computerized traffic control device inventory. Information on the type of traffic control at the intersection must come from police-reported traffic control device information on the crash report. Almost all intersections are controlled by a Stop sign or a traffic signal. However, the type of traffic control device reported on the police report can vary widely and include warning signs, pavement markings, or no traffic control devices

Intersection	Rural Crashes	Urban Crashes	Total Crashes
Intersection A	22	10	32
Intersection B	13	4	17
Intersection C	6	5	11
Intersection D	4	3	7
Intersection E	6	2	8
Intersection F	8	2	10
Intersection G	4	1	5
Intersection H	7	2	9
Intersection I	5	1	6
Intersection J	6	0	6

Table 23: Example Distribution of Crashes by Intersection – Rural/Urban

at all. The traffic control device information is critical to the implementation plan. It relates to the probable severity of future crashes and the type of countermeasure to apply to reduce future crashes. The traffic control device consistency problem is similar to the rural/urban designation problem.

Like the rural/urban designation problem, when the data is grouped by traffic control device, an intersection could appear on more than one data report. For example, an intersection with 20 crashes and inconsistent and/or incorrect identification of traffic control devices could appear on a stop-controlled report (assuming 10 crashes were identified as stop-controlled), a signalized report (assuming 4 crashes were identified as signalized), and an unknown report (assuming 6 crashes were identified as no, other, or unknown traffic control device).

If a State is developing a computerized traffic control device inventory, or at least a traffic signal inventory (i.e., all non-signalized intersections can be assumed to be stop-controlled), the State should complete the development of that inventory prior to the data analysis described here and use that inventory to determine if an intersection is signalized or stop-controlled.

If a traffic control device inventory is not near completion or is not readily available, the overall accuracy of the police-reported traffic control device information should determine the course of action. The thresholds for crashes at stop-controlled intersections considered for countermeasure improvement are generally 5 for rural intersections and 10 for urban intersections. If about 70 percent or more of total intersection crash reports have a correctly identified traffic control device, then those intersections with a number of crashes equaling or exceeding the thresholds noted above (which are the minimum used) should have sufficient numbers of correctly identified traffic control devices to predict the type of traffic control device for all crashes occurring at those intersections.[4] A State can proceed toward implementation plan development using the predicted traffic control device values. If the percentage of correctly identified traffic control devices is not sufficient to predict the type of traffic control devices at intersections with crashes above the threshold levels, then States should use a secondary source to determine traffic control devices at these intersections, preferably prior to the development of the straw man outline (Step 5). Video logs, photo logs, or field reviews can be used to determine or verify the type of traffic control device.

Inconsistency of Lit/Unlit Information at Intersections with Night Crashes. The data from police crash reports on the time period of the crash (e.g., day, dusk, dawn, night) is generally very good. However, in most States the data on night crashes identifying whether the intersection is lit or unlit have a significant amount of variability for crashes at the same intersection. Compounding the problem are intersections that are inadequately lit compared to current standards.

To address this problem, States can identify intersections with a high frequency and proportion (e.g., night/total crashes) of night crashes. Table 24 shows an example of the distribution of night crashes by intersection in rural areas.

States should identify the statewide mean proportion of night crashes to total crashes for both rural and urban areas. For example, with a statewide mean of 18 percent of night to total crashes in rural areas, those intersections that have both a high frequency and proportion of night crashes substantially above the mean (i.e., in this case, 25 percent or more night/total ratio) have been identified in Table 24 and should be considered for some type of lighting enhancement. A field review of these intersections is necessary to determine if lighting exists and if so, to what degree.

4 By assessing the distribution of traffic control devices for crashes at the same intersection using the same process as described for the rural/urban designation problem. For example, if there were six crashes at a rural intersection with three crashes indicating a stop-controlled traffic control device, one indicating a signalized traffic control device, and two indicating no traffic control device, it can be reasonably assumed that the intersection is stop-controlled.

Intersection Information for Crashes at Locally-Owned Intersections. Crash reports for crashes that occur at locally-owned intersections usually have reliable information on the county and municipality in which the crash occurred. However, information on the intersecting streets can be characterized in different ways depending on the reporting officer. For example, Fifth Street could be identified as Fifth St., Fifth Str, 5th Street, or 5th St, among other variations. A standard term of "Fifth St" would address this issue. Unless the information is standardized, crashes that occur at the same intersection may be spread over many intersection identifiers when an analyst tries to group crashes by intersection. This can create significant problems when trying to identify intersections with crash levels above a threshold.

To address this issue, States could establish standard nomenclature to consolidate some of the crashes for local intersections. Ideally States should do this at the time data is entered into the crash data system. However if standard nomenclature is not pre-established, it can be selectively applied to those municipalities in which intersection safety initiatives are being considered during development of the intersection safety implementation plan, thus reducing the level of effort. A sample listing of common terms, currently being used by Arizona, includes:

- Alley – AL
- Avenue – AV
- Boulevard – BLVD
- Circle – CIR
- Court – CT
- Drive – DR
- Expressway – EXWY
- Freeway – FRWY
- Highway – HWY
- Road – RD
- Street – ST

Intersection Number	Night Crashes	Total Crashes	Night/Total Ratio
4118	28	105	26.67%
3814	23	144	15.97%
4017	21	176	11.93%
3332	19	31	61.29%
5008	19	23	82.61%
3804	18	80	22.50%
6398	16	49	32.65%
8958	15	41	36.59%
1127	14	57	24.56%
3734	13	47	27.66%
1118	12	81	14.81%
3821	12	90	13.33%
5415	12	51	23.53%

Table 24: Example Distribution of Night Crashes in Rural Areas by Intersection

Data Availability

Insufficient Information to Determine if an Approach Pavement Has Both an Inordinate Number and Proportion of Wet Pavement Crashes and a Slippery Surface.

The data from police crash reports on pavement surface conditions (e.g., wet, dry, icy, snow covered) is usually very reliable. However, the physical attributes of the pavement that may be contributing to the inordinate number and proportion of wet pavement crashes often are not known.

To address this problem, States can identify intersections with a high frequency and proportion (e.g., wet pavement/total crashes) of wet pavement crashes. Table 25 shows an example of the distribution of wet pavement crashes by intersection.

States should determine the statewide mean proportion of wet to total crashes for rural and urban intersections where the speed limit is at or above 45mph. For example, if the statewide mean for rural intersections with speed limits of 45mph or above is 16 percent, those intersections that have both a high frequency and proportion of wet pavement crashes substantially above the mean (i.e., in this case, 25 percent or more wet pavement/total ratio) have been identified in Table 25 and should be considered for some type of pavement surface improvement.

The State should conduct a skid test of the approach to determine if the pavement has a low coefficient of friction. Then the State should conduct a field review of the intersection and a review of the pavement history to determine if other surface factors such as significant rutting (i.e., greater than 2 inches) exist in the wheel paths which could contribute to hydroplaning.

Intersection Number	Wet Pavement Crashes	Total Crashes	Wet Pavement/Total Ratio
492147	44	121	36.36%
310275	42	294	14.29%
314010	35	128	27.34%
239541	34	272	12.50%
135899	33	65	50.77%
352859	32	51	62.75%
131539	31	48	64.58%
175700	31	70	44.29%
132762	30	102	29.41%
636969	30	50	60.00%
654354	30	63	47.62%
310544	28	137	20.44%
189589	27	169	15.98%
245788	27	94	28.72%
538559	24	88	27.27%

Table 25: Example Distribution of Wet Pavement Crashes by Rural Intersection

Exposure and Rates

Exposure for Intersections is Different than Highway Segments. Exposure at intersections is measured in terms of the number of entering vehicles from all of the intersection legs rather than VMT. A few States have extracted volume information from their roadway data file and developed entering vehicle numbers for each of the completely State-owned intersections in the State. This information can be used to establish rates of crashes per million entering vehicles. However, most States only pull the mainline annual average daily traffic (AADT) from the roadway data file and attach it to each specific crash in the crash data file. As a result, an intersection with several crashes over a 5-year period will have different levels of AADT if the AADT is updated over the crash history period. Without complex and time-consuming programming, it can be difficult to consolidate these differences at the same intersection into single values for computing rates. Fortunately, the use of rates is not as critical in the systematic application of cost-effective, low-cost countermeasures compared to the traditional approach. There are a number of approaches to refine the number of intersections that should be considered for systematic improvement considering exposure differences. The two key questions that need to be addressed are:

1. Are there any intersections with crash frequencies slightly below the crash threshold established that have very low entering volume values? For example, if the threshold for a given countermeasure in rural areas is 5 crashes in 5 years, are there any intersections that have only 4 crashes but the mainline AADT is below 1,000?
2. Are there any intersections with crash frequencies at or slightly above the crash threshold level which have very high entering volume levels? For example, if the threshold level is 5 crashes in 5 years, are there any intersections that have 5 or 6 crashes and a mainline AADT exceeding 50,000?

If the number of through lanes or the functional classification for the mainline route in the roadway data file has been linked to the crash data file, one of these pieces of information can be used to establish different threshold levels, either based on the number of through lanes or the mainline functional classifications. For example, a higher crash threshold may be established for stop-controlled intersections with three through approach lanes as opposed to an intersection with a single through approach lane, since the volumes and exposure on the three through approach lane intersection are much greater.

Once threshold levels are established, assuming that the mainline AADT for each crash is listed in the output, the mainline AADT for intersections slightly below, at, and slightly above the crash threshold level can be scanned to determine which intersections to consider for improvement. Any very low AADT intersections slightly below the threshold may be added to the list of intersections being considered for improvement. Any very high AADT intersections either at or slightly above the threshold could be removed from improvement consideration.

Intersections with Multiple Countermeasures

Developing the Intersection Safety Implementation Plan Focuses on Identifying Separate Countermeasure Deployments at Intersections. As a result, intersections often will appear on more than one list of countermeasures. For example, a rural stop-controlled intersection may be above the crash thresholds for the basic set of sign and marking improvements, new or upgraded lighting, and skid resistance surfaces. Grouping countermeasures together for the same intersection is important since that it can reduce the number of multiple field reviews at one location.

States can create a set of matrices for each of the eight possible intersection sub-groups (i.e., State/local, rural/urban, stop-controlled/signalized) to identify intersections with multiple countermeasures. Table 26 is a sample matrix. This table shows the number of crashes above the given threshold for a specific countermeasure by intersection. It is created by combining all of the distributions of crashes by intersection, using only those intersections where the number of crashes exceeds the threshold for that given countermeasure.

Intersection Number	Countermeasure					
	Sign and Marking	Sign and Marking (Divided)	Sign and Marking-Flashing Beacons	J-Turn (Divided)	Lighting	Skid-Resistant Surface
	Threshold 6 Total Crashes	Threshold 6 Total Crashes	Threshold = 20 Total Crashes	Threshold 10 Total Crashes	Threshold = 6 Dark Crashes and Dark/Total = 0.20	Threshold 10 Wet Crashes and Wet/Total = 0.18
4482	88		88			16
0460	77	57	77	57	17	
1451	58		58			
6090	55		55			
9723	50		50			
5859	50	50	50	50		32

Table 26: Sample Matrix for State, Rural, Stop-Controlled Intersections

Step 4 Action.

Develop an intersection crash data analysis package as described in this section. Use the example data analysis package and straw man outline (found on the FHWA Intersection Safety web page, http://safety.fhwa.dot.gov/intersection/) as a guide.

Step 5:

Develop a Straw Man Outline

Once the countermeasures considered acceptable by the State to implement are identified (Step 3) and the data analysis is complete (Step 4), the State can develop a straw man outline to achieve the intersection crash reduction goal (Step 1). An example data analysis package and straw man outline can be found on the FHWA Intersection Safety web page (http://safety.fhwa.dot.gov/intersection/).

Establish Threshold Crash Levels

The first step in creating the straw man outline is establishing threshold crash levels for the intersection and crash types that each countermeasure is intended to impact. At the very least, separate thresholds should be calculated based on road ownership and location (i.e., State/local, rural/urban) such that each crash type may have up to four thresholds depending on where the crashes occur. Crash threshold levels can be established based on a number of factors including:

- The level at which a countermeasure is cost-effective (B/C ratio usually set at 2.0 or greater).
- The number of improvements, the unit cost of the countermeasure and the availability of funds per threshold level.
- The lowest number of crashes per intersection considering exposure levels that may reasonably indicate a recurrent crash problem that can be mitigated by the countermeasure (usually not less than three crashes per intersection in 5 years at very low-volume intersections).

Improvements deployed on a systematic basis have to be cost-effective, and a B/C analysis is used to make the determination. The conventional analysis uses the following formula to compute the B/C:

$$B/C = \frac{\text{NumberCrashes x CRF x AverageCrashCost}}{\text{AnnualCost}}$$

Unlike a conventional analysis, the B/C is given or set. The answer one seeks is the threshold, the minimum number of targeted crashes per intersection needed to make the countermeasure cost-effective. The threshold is represented by the number of crashes in the conventional B/C formula above.

The formula used to establish the threshold is as follows:

$$T = \frac{\text{AnnualCost x B / C}}{\text{CRFx AverageCrashCost}}$$

Where:

- T = Threshold – Minimum number of targeted crashes per intersection needed to make the countermeasure cost-effective.
- Annual Cost = Annual cost of the improvement.
  - » If the improvement involves a construction project, annual cost is the construction cost averaged over the expected life of the project.
  - » If the improvement is an education or enforcement initiative, annual cost is the annual cost of a full year of enforcement and education.
- B/C = A set B/C ratio used to determine the threshold number of intersection crashes. In this case, a B/C value of 2.0 may be used.
- CRF = Estimated crash reduction factor, or effectiveness, of the strategy to reduce targeted crashes. It is expressed in terms of the percent of targeted crashes reduced.
- Average Crash Cost = Average cost of targeted crashes using the cost data in Table 4 and the number of injury types for the targeted crashes.

As an example, consider a signal update for State urban intersections where:

- Annual Cost = $3,000 ($30,000 averaged over 10 years).
- B/C = 2.0.
- CRF = 0.30.
- Average Crash Cost = $40,000 (estimated from the distribution of fatalities, injuries, and property damage crashes for State, urban, signalized intersections).

$$T = \frac{3{,}000 \times 2.0}{0.30 \times 40{,}000} = 0.50$$

This example shows that the threshold should be 0.50 crashes annually, or between 2 and 3 crashes in 5 years. The results indicate that it does not take many crashes to apply low-cost countermeasures cost-effectively. However, when considering scarce resources, two additional factors need to be considered:

- Establishing a very low crash threshold (e.g., less than 5 crashes in 5 years) may increase the randomness of crash occurrence and not reflect intersections with persistent and repetitive crash occurrences. It is suggested that a minimum of five targeted crashes in 5 years be the base threshold used in the analyses for most intersections. Intersections with four or even possibly three crashes in 5 years may be selectively added to the list if the traffic volumes (exposure) are extremely low.
- Considering the relationship of crashes per intersection, number of intersections, and number of statewide crashes, as higher thresholds are set (crashes per intersection), the B/C will be larger and the total costs will be smaller, but the overall crash reduction also will be smaller.

As a result, scarce resources and achieving the intersection crash reduction goal have to be balanced.

Table 27 shows a sample distribution of crashes at State, urban, signalized intersections. If a State starts at the base level to achieve a B/C of 2.0 or greater (i.e., 3 or more crashes per intersection), then 2,955 intersections would be improved. This would encompass 97.5 percent of all signalized intersection crashes. However at $30,000 per intersection improvement, the costs to improve all 2,955 intersections would be close to $90 million. If the threshold is increased to 5 crashes per intersection, 2,487 intersections would be improved, encompassing 95.3 percent of all State urban signalized crashes. The costs for this level of improvement would be close to $75 million. Assuming funds are not that plentiful, if a threshold level of 50 crashes per intersection is selected, only 371 intersections would need to be improved at a cost of about $10 million. This would still encompass over 38 percent of all State, urban, signalized crashes.

Number of Crashes per Intersection	Number of Intersections	Cumulative		Cumulative	
		Intersections	Percent	Crashes	Percent
100 and greater	63	63	1.44	8,058	10.90
50-99	308	371	8.46	28,570	38.65
30-49	461	832	18.98	46,320	62.67
20-29	483	1,315	30.00	57,986	78.45
10-19	633	1,948	44.43	66,850	90.44
5-9	539	2,487	56.73	70,471	95.34
4	206	2,693	61.43	71,295	96.46
3	262	2,955	67.40	72,081	97.52
2	403	3,358	76.60	72,887	98.61
1	1,026	4,384	100.00	73,913	100.00
Total	4,384	4,384	100.00	73,913	100.00

Table 27: Sample Distribution of Crashes at State Urban Signalized Intersections

Develop Detailed Straw Man Tables for Each Countermeasure

The straw man consists of a set of countermeasures, deployment levels, costs, and safety impacts (usually defined in terms of the overall goal (i.e. annual lives saved), which collectively can achieve the overall intersection safety goal. Each countermeasure needs to be investigated in terms of its deployment levels, costs, safety impacts, and relative contribution in achieving the overall intersection safety goal using data from the data analysis. An example of the tabulation of intersections that can be considered for the basic set of sign and marking improvements for State stop-controlled intersections is shown in Table 28.[1] In this table, 1,221 intersections had 6 or more crashes within the crash history period. A 6-year crash history period was used in this evaluation because it was available and provided more stable data than 5 years of data. In addition, no significant changes in traffic or roadway features occurred during the 6 years.

1 The full example data analysis package and straw man outline can be found on the FHWA Intersection Safety web page (http://safety.fhwa.dot.gov/intersection/).

Not all of the intersections shown in Table 28 will end up as improvements. Some will have been upgraded previously; field reviews of others will show that sign and marking enhancements do not make sense. In this case, an assumption is made that only 80 percent of the intersections will remain candidates for the sign and marking enhancements after the field review. Each State can establish its own estimated retention rate for the improvement estimate. If time is available, a more accurate means of developing the estimate is to field review a random sample of the candidate intersections beforehand and use the percentage of these intersections in which enhancements are likely for the estimate.

A trial and error method can be used to develop the straw man outline with an objective to achieve the intersection crash reduction goal with the least costs. Each of the accepted countermeasures can be deployed at levels dependent on the distribution of crashes, severity of crashes (fatalities per 100 crashes), CRF, and unit construction costs. The annual lives saved per $1 million expended can be used as a gauge to determine what levels are appropriate for each countermeasure.

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Estimated Fatality Reduction[4]
Basic Set of Sign and Marking Improvements – State Rural Stop-Controlled Intersections	6	1,221	13,722	977	7.82	1.60	732	11.71
Basic Set of Sign and Marking Improvements – State Urban Stop-Controlled Intersections	30	474	23,795	379	3.03	0.21	1,269	2.67
Total				1,356	10.85			14.38

1 Estimated number of improvements assumes that 80 percent of locations can be improved. Estimated number of improvements is calculated by multiplying the number of statewide crash intersections by the percent of locations that can be improved. For the first row of the table, this calculation is 1,221x0.80 = 977.

2 Construction costs assume an average cost of $8,000 per intersection. Construction costs are calculated by multiplying the estimated number of improvements by the average cost per intersection. For the first row of the table, this calculation is 977x8,000 = $7.82 million.

3 Annual targeted crash reduction uses a CRF of 0.40. Annual targeted crash reduction is calculated by multiplying the average number of targeted crashes per year by the percent of locations that can be improved multiplied by the CRF. For the first row of the table, this calculation is (13,722/6) x0.80x0.40 = 732.

4 Annual estimated fatality reduction is calculated by multiplying the annual targeted crash reduction by the fatalities per 100 crashes and dividing by 100. For the first row of the table, this calculation is (732x1.6)/100 = 11.71.

Table 28: Sample State Stop-Controlled Intersections - Basic Set of Sign and Marking Improvements

Compile a Summary Straw Man Outline

After all of the individual countermeasure detailed straw man tables are created, the State should develop a summary straw man outline. The summary straw man outline should encompass all of the candidate countermeasures, the impact toward achieving the overall statewide intersection goal, and the costs of improvements. Specific elements include the following:

- Countermeasures – All of the countermeasures selected in Step 3.
- Approach – Systematic, comprehensive, or traditional.
- Number of Statewide Crash Intersections to be Improved – Number of intersections with the crash characteristics that can be impacted by the countermeasure. Transferred from the detailed straw man tables.
- Construction Cost – Cost for construction of infrastructure countermeasures. Transferred from the detailed straw man tables, as applicable.
- Enforcement and Education Costs – Costs for enforcement and education, countermeasures. Transferred from the detailed straw man tables, as applicable.
- Estimated Annual Crashes Reduced – Number of crashes reduced annually. Transferred from the detailed straw man tables.
- Estimated Annual Incapacitating Injuries Reduced – Number of incapacitating injuries reduced annually. Transferred from the detailed straw man tables, as applicable.
- Estimated Annual Fatalities Reduced – Number of fatalities reduced annually. Transferred from the detailed straw man tables.

Table 29 shows an example of a summary straw man outline. It is based on a State that established a goal to reduce intersection fatalities by 28 per year by 2012. In this example, the State chose to focus on reducing both fatalities and incapacitating injuries. As a result, the estimated annual incapacitating injuries reduced column is included. In addition, only the countermeasures that the State agreed to implement are included in the table (i.e., other countermeasures are not listed because the State decided not to include them in the intersection safety implementation plan).

Countermeasure	Approach	Number of Intersections to be Improved	Construction Costs ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
Basic Set of Sign and Marking Improvements – State Stop-Controlled Intersections (Rural and Urban)	Systematic	1,108	8.87		1,382	117.7	13.07
Flashing Overhead Intersection Beacons – State Stop-Controlled Intersections (Rural and Urban)	Systematic	69	0.69		54	4.0	0.44
J-Turns Modifications on High-Speed Divided Arterials – State Rural Stop-Controlled Intersections	Systematic	56	16.80		77	17.5	2.87
Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections (Rural and Urban)	Systematic	236	1.89		555	15.1	0.71
Basic Set of Signal and Sign Improvements – State Signalized Intersections (Rural and Urban)	Systematic	395	1.92		789	28.1	1.52
Basic Set of Signal and Sign Improvements – Local Signalized Intersections (Rural and Urban)	Systematic	263	2.63		670	19.5	1.51
Change of Permitted and Protected Left-Turn Phase to Protected Only – State Signalized Intersections (Rural and Urban)	Systematic	536	2.67		819	44.0	1.49
Change of Permitted and Protected Left-Turn Phase to Protected Only – Local Signalized Intersections (Rural and Urban)	Systematic	387	1.94		623	23.7	1.27
Advanced Detection Control Systems– State Signalized Intersections (Rural and Urban)	Systematic	67	1.00		45	4.2	0.31

Countermeasure	Approach	Number of Intersections to be Improved	Construction Costs ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
New or Upgraded Lighting – State Rural Intersections (Stop-Controlled and Signalized)	Systematic	64	3.84		49	8.4	1.08
High-Friction Surface – State Intersections (Stop-Controlled and Signalized, Rural and Urban)	Systematic	53	2.65		86	11.3	1.27
Enforcement-Assisted Lights	Systematic	1 City	0.09	0.05	45	2.3	0.11
Corridor 3E improvements on high-speed arterials with very high frequencies of severe intersection crashes	Compre-hensive	3 Corridors	6.00	0.30	83	7.5	1.25
Municipal-wide 3E improvements in municipalities with high frequencies of severe intersection crashes	Compre-hensive	1 City	1.00	0.10	383	6.6	0.57
Roundabouts	Traditional	3	2.40		32	3.0	0.36
Total			54.39	0.45	5,692	312.9	27.83

Table 29: Sample Summary Straw Man

Step 5 Action.

Using the intersection crash data analysis package from Step 4, establish threshold crash levels, develop detailed straw man tables for each countermeasure, and compile a summary straw man outline. Use the example data analysis package and straw man outline (found on the FHWA Intersection Safety web page, http://safety.fhwa.dot.gov/intersection/) as a guide.

Step 6:

Conduct a Workshop of Key Stakeholders and Follow-Up Implementation Planning Meeting

Two-Day Workshop

The successful reduction in statewide intersection fatalities and incapacitating injuries requires the input, support, and participation of a number of key stakeholders. They include at least the following:

- State Safety Engineer.
- State Traffic Engineer.
- State Traffic Signal and Traffic Operations Engineers.
- District or Regional Traffic/Safety Engineers.
- State Local Roads Coordinator (if one exists).
- Governor's Highway Safety Representative.
- Representatives of local governments (e.g., city, county traffic safety representatives).
- State and local police representatives.
- Metropolitan planning organization (MPO) representatives.
- FHWA Division Office Safety Engineer/Specialist.

The State should conduct a workshop with key stakeholders to achieve three goals:

1. Discuss the intersection crash reduction goal, the systematic and comprehensive approaches to achieve the goal, the crash data analysis package, and the use of potentially new intersection countermeasures.
2. Reach group consensus on a set of countermeasures, deployment characteristics, and costs to achieve the intersection crash reduction goal.
3. Establish strategic directions to successfully implement the countermeasures.

In preparation for the workshop, the following information should be prepared for discussion:

- A statewide intersection crash reduction goal.
- A set of intersection countermeasures that the State is comfortable implementing and estimated unit costs and crash reduction factors for each countermeasure.
- An intersection crash data analysis package that supports development of the straw man outline.
- A straw man outline of countermeasures; deployment levels; and characteristics, costs, and projected annual crashes, incapacitating injuries, and fatalities reduced for each countermeasure which collectively is sufficient to achieve the intersection crash reduction goal.

A typical agenda for the workshop is shown in Table 30.

Workshop Agenda	
Day 1	
8:30 AM	Welcome and Introductions • Review of Workshop Goals, Objectives, and Outcomes • Background on Reducing Intersection Fatalities
8:45 AM	Module I: Intersection Goal, Data Analysis, and Countermeasure Identification
10:00 AM	Break
10:15 AM	Module I Continued
12:00 PM	Lunch
1:00 PM	Module II: Putting It All Together
2:45 PM	Break
3:00 PM	Module II Continued • Straw Man Outline of Countermeasures, Deployment Characteristics, Costs, and Lives Saved
4:30 PM	Adjourn
Day 2	
8:30 AM	Module II Reality Check • Review Day 1 Results • Review and Fine-Tune Straw Man Outline • Check Personal Knowledge of High-Crash Intersections to Determine if Improvement Types Make Sense
9:45 AM	Break
10:00 AM	Module III: Strategic Direction and Actions • Crosscutting Barriers • Key Countermeasure Barriers
12:00 PM	Lunch
1:00 PM	Module III Continued
2:00 PM	Module IV: Action Items to Implement Components of the Plan • Key Steps to Implement Countermeasures • Performance Measures • Implementation Plan Outline
3:00 PM	Module V: Next Steps
3:15 PM	Adjourn

Table 30: Typical Agenda for Intersection Safety Implementation Plan Workshop

On the first day it is important for the group to understand the intersection crash reduction goal, the systematic and comprehensive approaches, and how these approaches work together to achieve the goal. In addition, the data analysis package assembled in Step 4 and the list of potential intersection countermeasures created from Step 3 need to be discussed. The group also should have an introduction and initial discussion of the straw man outline on Day One. The group will probably suggest changes and refinements to the straw man outline. After the Day One activities are complete, the straw man outline should be updated to reflect the changes and refinements. The refined straw man outline should be presented to the group on the morning of the second day. It is critical for the group to reach consensus on a final refined straw man outline that identifies the set of countermeasures, deployment levels, and costs required to achieve the intersection crash reduction goal. If necessary, the goal may be adjusted in terms of safety impact to be achieved (i.e., targeted annual lives saved) or time to achieve the goal.

Once the straw man outline is complete, the group identifies any key issues that may impact the successful implementation of the effort and establishes actions and strategic directions to address each issue. In working through the agenda items, several issues may arise. These issues and potential solutions gleaned from previous workshops are discussed below.

Insufficient Existing Funding to Achieve the Goal. Available Highway Safety Improvement Program (HSIP) resources may not be sufficient to fund all of the improvements in the plan. To overcome this, States can seek other available federal safety fund sources (e.g., High Risk Rural Roads program, Section 1406 – Safety Incentive Grants for Use of Seat Belts, Section 1407 – Safety Incentive to Prevent Operating of Motor Vehicles by Intoxicated Persons, Section 406 – Safety Belt Performance Grants, and Section 410 – Alcohol-Impaired Driving Countermeasure Incentive Grants), utilize regular Federal-aid funds; or use State or local funds. The time to achieve the goal also may be extended, thus lowering the annual funding needs to an affordable level.

Improvements at Local Intersections with Federal Funds. A considerable number of State and federal requirements impede the flow of funds to local governments for low-cost countermeasures. To address this issue, States may wish to use specially-trained Local Technical Assistance Program (LTAP) safety engineers and/or consultants with 100 percent federal funding to administer the program, perform the engineering, and oversee the implementation. States then can provide the materials (e.g., signs, marking material, signal appurtenances) to local governments using 100 percent federal funding as long as the localities correctly install the materials in the field. This removes any transfer of funds between State and local governments.

Education and Enforcement Initiatives Beyond the Conventional 402 Funding. States may find that the countermeasures for education and enforcement in corridors and municipalities require more 402 funds than what is available. In this case, States can investigate other federal safety funding sources available to the State (e.g., Section 1406 – Safety Incentive Grants for Use of Seat Belts, Section 1407 – Safety Incentive to Prevent Operating of Motor Vehicles by Intoxicated Persons, Section 406 – Safety Belt Performance Grants, and Section 410 – Alcohol-Impaired Driving Countermeasure Incentive Grants).

Use of Countermeasures New to or Rarely Used in the State. Any time something new is implemented, the potential for failure increases because of the increased level of unknown factors. States can minimize the potential for failure by taking the following actions:

- Identify a champion, a safety professional, responsible for overseeing the implementation of the countermeasure.
- Ensure that the champion becomes proficient in knowledge regarding the countermeasure by reviewing literature, conferring with other out-of-state professionals with extensive knowledge regarding the countermeasure, and potentially visiting out-of-state sites where the countermeasure has been deployed.
- Seek District or Regional personnel who may be interested in deploying a demonstration of the technology.
- Identify the key issues that are preventing widespread implementation of the countermeasure and establish scheduled demonstrations to address the issues and evaluate the results.[1]
- Ensure that the champion performs a rigorous assessment of the demonstrations to determine if any design, construction, or operational changes need to be made; if the countermeasure is ready for widespread deployment; and if additional demonstrations are needed.
- Upon completion of the demonstrations, make a decision on the countermeasure's readiness for widespread deployment. If so, integrate the countermeasure into normal operations. If not, make a determination on whether the countermeasure should be considered for further deployment. If the determination is to proceed, identify the remaining issues and establish a process and schedule to address them.

1 Rely on other State efforts to evaluate the countermeasure's CRF since there will be insufficient data and time to properly evaluate crash reduction effectiveness within the State.

Countermeasures Involving Policy Decisions. At least two countermeasures may involve significant policy issues– lighting on State rural intersections and installation of enforcement-assisted lights at traffic signals to reduce red-light running. Existing lighting policies may limit the use of lighting to freeways. In addition, a State may not have a policy in place for installing on the highway system devices that can enhance enforcement. Addressing these issues likely will require input from upper management.

- Lighting on State Rural Intersections – Many States have limited lighting on freeways or at interchanges and have not considered lighting at intersections because of the potential fiscal impact. To minimize fiscal impact, States can limit lighting consideration to only those intersections with a high frequency and proportion of night crashes, utilize 100 percent Federal funding for the lighting improvements, and/or consider requiring local municipalities where the intersections reside to energize and maintain the lighting.
- Installation of Enforcement-Assisted Lights – The value of enforcement-assisted lights is dependent on how aware drivers are of the function of enforcement-assisted lights, an agreement by police to use the lights for red-light running enforcement, and the commitment of the courts to process the police citations. If drivers know that police use the lights for enforcement, they easily can see the lights as they approach an intersection and slow down to stop on red. This should reduce the level of red-light running significantly. States should consider installing enforcement-assisted lights only in those municipalities with an angle crash problem at signalized intersections. Within these municipalities, States should ensure that police organizations agree to a written commitment to use the enforcement-assisted lights to enforce red-light running violations. States must also ensure that sufficient 402 funds are available to mount a limited education campaign for the residents of and surrounding the municipality about the purpose of the enforcement-assisted lights and red-light enforcement. Alternate funding such as using the flexible funding provisions of the HSIP program or State funds can also be considered.

Half-Day Follow-Up Implementation Planning Meeting

After the workshop, on the morning of the third day, a small group of key State personnel (at least the State Safety Engineer, the State Traffic Engineer, and the Governor's Highway Safety Representative) and the FHWA Division Office Safety Engineer/Specialist should meet to review the results and identify key steps needed to successfully move each countermeasure from its existing state to full implementation as defined in the tentative plan. A representative of local governments, an MPO, or the police may also participate at the discretion of the State. This small group also discusses strategic directions for implementing the plan and schedules for implementation, including identifying the upper management who must approve the initiative and the actions and schedules needed to secure that approval.

Step 6 Action.

Plan and conduct the two day workshop with key stakeholders to gain consensus on a set of countermeasures, deployment levels and characteristics, costs, and fatality reductions needed to achieve the intersection crash reduction goal. Plan and conduct the half-day follow-up implementation planning meeting to reach consensus within the State on the key steps and schedule to fully implement each countermeasure.

Step 7:

Develop a Draft Intersection Safety Implementation Plan

Upon completion of the workshop and follow-up meeting with key State personnel, the State develops a draft implementation plan. The plan should:

- Establish or re-state the intersection crash reduction goal.
- Document the problem, countermeasures, deployment characteristics, and funding needed to achieve the intersection crash reduction goal.
- Identify funding levels needed to implement plan and potential funding sources.
- Establish who has to approve the initiative and its funding and what is required for a decision.
- Document any cross-cutting or key issues (e.g., funding, local intersection countermeasure deployment, deploying new or rarely used countermeasures) and how they should be addressed.
- Document key steps and decisions needed to effectively implement the countermeasures in the plan and achieve the goal.
- Establish performance measures and tracking mechanisms to monitor implementation and fatality reductions.

A suggested outline for the plan is as follows:

- Executive Summary.
- Background.
- The Intersection Safety Goal.
  - » The Approach.
  - » Distribution of the State Intersection Fatality Problem.
  - » Summary of Countermeasures.
- Key First Steps.
- Implementation.
  - » Countermeasure Descriptions.
  - » Key Implementation Steps.
- Performance Measures
  - » Production Performance Measures.
  - » Impact Performance Measures.
- Performance Standards – Program Effectiveness in Reducing Targeted Crashes
- Summary.

An example intersection safety implementation plan is available on the FHWA Intersection Safety web page (http://safety.fhwa.dot.gov/intersection/).

The draft plan should be circulated to the key stakeholders who participated in the workshop and follow-up meeting for additions, deletions, and/or modifications. Once all comments are received, the plan should be updated into a revised draft form.

Step 7 Action.

Develop a draft intersection safety implementation plan based upon the results of the workshop and follow-up meeting. Circulate the plan among workshop and follow-up meeting participants. Revise the draft based on comments received.

Step 8:

Present the Draft Intersection Safety Implementation Plan to Upper Management

The draft plan is presented to upper management for approval, rejection, or modification. Upper management input is needed for successful implementation, since the plan probably will involve addressing a number of new issues, implementing new countermeasures, and increasing funding levels. These issues should be presented clearly to upper management for direction. Some of the key items in a briefing to upper management may include the following.

Funding. The plan may require additional funding beyond that available from the HSIP. The presentation should include an overview of the type and level of projects for which the funds will be used; the expected impact in terms of lives saved and incapacitating injuries and crashes prevented; alternative sources for securing the additional funding; and a recommended financial approach to implement the plan.

Approach. Reducing statewide intersection fatalities and incapacitating injuries likely will require supplementing the traditional approach with the systematic and comprehensive approaches.

New Countermeasures Not or Rarely Used in the State. The presentation should describe the process for implementing the new countermeasure in a way that minimizes risks of failure and/or adverse publicity while meeting the timeframes established in the plan. The presentation should include a list of the new countermeasures and how they will be introduced and implemented in the State.

Implementing Safety Improvements at Locally-Owned Intersections. The presentation should include an overview of the scope of the intersection crash problem on local intersections, the suggested course of action to make local municipalities aware of the problems, and actions the State should take to assist municipalities implement the improvements. A recommended methodology to finance local intersection improvements, including the role that the State should play, should also be included.

Policy-Related Actions. Some of the potential countermeasures (e.g., lighting rural intersections with high frequencies and proportions of night crashes) have been applied rarely or never in many States. Funding these improvements, including the maintenance and energizing responsibilities, require upper management direction. The presentation should identify portions of the plan that involve policy issues and provide recommended courses of action that meet the plan objectives while minimizing potential adverse actions on the State.

Funding Education and Enforcement Initiatives. Some of the corridor or municipal-wide initiatives may require funding beyond existing 402 funding levels. If this occurs, alternate funding sources (and recommendations on their use) need to be presented to upper management for direction. This will require special coordination with the Governor's Highway Safety Representative if that person is located outside of the State DOT.

Step 8 Action.

Prepare a presentation on the draft intersection safety implementation plan and its key issues for upper management group approval and direction.

Step 9:

Finalize the Intersection Safety Implementation Plan

The feedback received from upper management may alter some of the contents and recommendations in the plan. The final plan should incorporate these changes[1] and then be circulated to all of the key stakeholders for informational purposes.

1 In most cases, this is the responsibility of the State Safety Engineer.

Step 9 Action.

Finalize the intersection safety implementation plan based upon the guidance and direction provided by upper management. Circulate the final plan among key stakeholders for informational purposes.

Step 10:

Implement the Plan, Monitor Progress, and Evaluate Results

Once the intersection safety implementation plan is finalized, the State should take a number of key actions to ensure successful implementation and statewide reduction of intersection fatalities and incapacitating injuries. Suggested actions to improve the likelihood of success include:

1. Create an oversight committee led by the State Safety Engineer and composed of at least the Governor's Highway Safety Representative and the State Traffic Engineer (or their representatives) and the FHWA Division Office Safety Engineer/Specialist. The oversight committee should meet on a quarterly basis to monitor progress, provide direction, and make mid-course adjustments. The oversight committee also should periodically report back to upper management on progress.
2. For each countermeasure in the plan, seek or assign a staff professional as coordinator to be responsible for its successful implementation. The coordinators should provide periodic (i.e., at least twice a year) input to the oversight committee on adhering to the implementation schedules defined in the implementation plan for each countermeasure.
3. Develop and implement a system to track projects in the plan for each countermeasure for project development progress, construction, and crash history following construction.
4. On a bi-annual basis, make a comprehensive review of the plan. Update the plan as needed to reflect any substantive modifications or significant adjustments.

Step 10 Action.

Conduct implementation, monitoring, and evaluation activities.

For More Information

Jeffrey Shaw

Intersections Program Manager FHWA Office of Safety

202.738.7793

jeffreyshaw@dot.gov

U.S. Department of Transportation
Federal Highway Administration