Intersections

Intersection Safety Action Plan

Sample Plan

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A Note to the Reader – How to Use This Plan

Approximately 21 % of all traffic crash fatalities in the nation occur at intersections. If the national goal of reducing the fatality rate to no more than 1.0 death per one hundred million vehicle miles traveled is to be achieved, substantive reductions in intersection fatalities will have to occur. Traditionally, safety improvement programs have concentrated on addressing the highest crash locations in the State. Safety improvements are implemented at these locations each year, and for the most part, significant reductions of crashes have occurred. But from a statewide perspective, the number of improvements implemented is relatively small and reductions in deaths and serious injuries are almost negligible. Because traditional safety improvement programs effectively address a number of high-crash locations, they need to continue. In order to meet the national goal, states must expand their efforts, systematically applying low-cost, cost-effective improvements at a large number of locations with documented crash histories.

This Sample Intersection Safety Action Plan provides guidance, at a state level, on how to identify and systematically deploy cost-effective, publicly acceptable safety strategies that will result in a substantial statewide reduction of intersection fatalities and serious injuries. Although the Sample Plan was developed for a statewide condition, it can easily be adapted and applied for use on a regional or MPO area basis. The features of the Sample Plan are highlighted below.

- The main text of the Sample Plan is written as if it was a complete plan authored by a state. “Notes to the Reader” are included to provide additional insight on important components of the Plan and special conditions or factors that need careful consideration when developing an actual Plan.
- The Sample Plan has four major components: (1) intersection crash overview; (2) goal establishment; (3) approach to strategy selection and data analysis; and (4) strategy deployment levels and characteristics (e.g., costs, safety impacts).
- The Sample Plan uses hypothetical data for a ‘typical’ moderate size state (1,003 total fatalities in 2003 of which 240 occurred at intersections) and uses some intersection fatality crash relationships extracted from the Fatality Analysis Reporting System (FARS) data base.
- Almost every state should be capable of performing the majority of the data analyses in this Sample Plan with their own crash data and without any system upgrade or changes.
- A “stretch” goal was established in the Sample Plan, along with a number of strategies and their levels of deployment needed to achieve the goal. A large number of strategies also were incorporated to provide a “shopping list” of potential strategies for states to consider. States have the flexibility of establishing whatever goal they desire to pursue and the number and deployment levels of strategies they intend to consider to achieve the goal.
- Traditionally, a state will look at high-crash locations and determine a course of action for each location. In this plan, the strategies that will create the greatest cost-effective reductions in serious injuries and fatalities are identified first. Then the crash data system is accessed to determine at which locations strategies can be cost-effectively deployed.
- The Sample Plan provides a process, using a benefit/cost (B/C) analysis, to determine the levels of deployment, statewide impact to the number of intersection crashes, and costs of improvement strategies.
- This Sample Plan includes a discussion on the importance of statewide initiatives to improve safe driving behavior and their potential impact on intersection safety. It is important to document this tie-in if a State is also developing an overall strategic highway safety plan. The development of any intersection plan should be completely coordinated with the strategic plan. The intersection plan can be considered a subset of the strategic plan, or a detailed implementation plan for one of the key emphasis areas in the strategic plan.
- This Sample Plan highlights important decisions and issues upper management must address if the effort is to be successfully implemented. Each state will have its own set of key decisions and directions that have to be effectively dealt with in order to be successful. These issues should be thoroughly identified, evaluated, and communicated to upper management, preferably with recommended courses of action.

States are encouraged to use this Sample Intersection Safety Action Plan as a guideline as they create their intersection goals, review their data, and identify improvement strategies. The content of this plan does not represent a Federal Highway Administration standard. States have the flexibility to design their Action Plans based on their individual needs and goals.

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Executive Summary

1. **Note to the Reader:** The purpose of the Executive Summary is to provide an overview of the entire plan. It builds the case for intersection improvement strategies and describes the estimated impacts of these strategies. It also highlights important decisions and issues which upper management must address if the effort is to be successfully implemented. Each state will have its own set of key decisions and directions that have to be effectively dealt with in order to be successful. These issues should be thoroughly identified, evaluated, and communicated to upper management, preferably with recommended courses of action.

Over the five-year period from 1999-2003 nearly 5,000 people lost their lives on highways within the State and, of these, nearly 1,200 died at intersections. In past years, a gradually improving infrastructure has helped keep the number of deaths from increasing, but the growth in traffic volumes has counteracted any real reductions in fatalities. The **Hazard Elimination Program** has improved between 60 and 70 high-hazard locations each year. Approximately 50% of these high-hazard locations have been intersections.

In addition, education and enforcement initiatives to increase safety belt usage, reduce drinking and driving, and reduce aggressive driving and speeding have contributed to severe crash decreases. However, for the State to continue to have reductions in the number of statewide intersection deaths, other strategic safety efforts are needed.

This Action Plan concentrates on identifying those primarily infrastructure-related improvements that can substantively reduce intersection deaths. Two principles have been established to better ensure success of the plan:

1. Cost effectiveness in terms of crash reductions; and,
2. Substantial contribution to achieving the goal of reducing serious injuries and deaths associated with intersections.

Strategy identification and deployment information was extracted from four prime resources as follows:

- NCHRP Report 500, Volume 5 (Addressing Unsignalized Intersection Collisions)
- NCHRP Report 500, Volume 12 (Reducing Collisions at Signalized Intersections)
- Signalized Intersections: Informational Guide, FHWA http://www.tfhrc.gov/safety/pubs/04091/index.htm
- Roundabouts: An Informational Guide, FHWA http://www.tfhrc.gov/safety/00068.htm

Pedestrian safety is also a concern at intersections. Pedestrian strategies are incorporated in the plan's discussions of a corridor approach to addressing intersection safety. In addition, a separate guideline on how to develop a pedestrian action plan similar to the intersection plan is under development by FHWA. It is important that these two initiatives be coordinated during the development process so that opportunities to improve pedestrian safety at intersections can be fully realized.

A goal of decreasing intersection fatalities and serious injuries from 961 in 2003 to 850 by 2010 is established for the State. The plan demonstrates that a reduction of more than 130 intersection fatalities and serious injuries annually (which exceeds the goal) can be achieved through the strategic application of a broad array of infrastructure improvements.

1. **Note to the Reader:** This "shopping list" of strategies demonstrates that a comprehensive approach can be taken to substantially impact severe intersection crashes. The approach also can be consolidated and simplified to a few key strategies to achieve the stated goal.

Funding. This plan estimates that the following resources will be required to fund the level of cost effective improvements needed to prevent over 130 intersection deaths and serious injuries annually by 2010:

- Approximately $96 million for infrastructure intersection improvements on the State highway system.
- Approximately $7.0 million for local government infrastructure intersection safety improvements.
- $7.3 million per year for corridor and municipal-wide driver safety (behavioral) initiatives.

The plan also identifies a reduced level of effort and funding necessary to reach (rather than exceed) the State's goal of an annual reduction of 111 intersection fatalities and serious injuries by 2010.

Broad Policy Actions. There are four areas where policy actions are needed to effectively implement the Plan.

1. Traditionally the Hazard Elimination Program has concentrated on addressing the highest crash locations in the State. Because this program results in a relatively small number of improvements, the reductions in statewide numbers of deaths and serious injuries are almost negligible. However, the State should also focus on carefully administered, systematic deployment of key low-cost improvements that can produce results of such a magnitude that the statewide numbers of targeted deaths and serious injuries can be reduced.
2. Widespread use of enhanced signs and marking systems and automated red light running enforcement - two strategies which are not being applied statewide - is important in attaining the intersection goal of reduced serious injuries and fatalities. It should be the State's policy to implement these improvements as extensively and cost effectively as possible.
3. Historically, safety enhancements have been implemented by a number of agencies, each often working in isolation. Combining these independent entities into a team addressing specific corridor and area-wide intersection problems has the potential to yield synergistic results and dramatically improve safety. It would be desirable for the State DOT to take the lead to form multi-disciplinary teams and address the severe crash problems on two to three targeted corridors initially. Based on the experiences and successes of these first efforts, the concept can be expanded to remaining problem corridors and municipal-wide concerns.
4. Approximately 20% of all serious injuries and deaths at intersections occur off the State highway system. Realistically, improvements will not be extensively implemented on local roads unless Federal funds and technical assistance by the State DOT are extended to the counties and municipalities. The State should develop guidelines for when Federal funds can be made available to municipalities to fund safety improvements identified in this Plan.

In conclusion, a substantive reduction in fatalities and serious injuries at intersections can be achieved through the judicious application of select strategies. It will, however, require the DOT to: (1) invest a moderate level of funding for the strategies; and, (2) have the fortitude to initiate new directions and cost effective strategies.

Intersection Crash Overview

1. **Note to the Reader:** The purpose of this section is to provide a sense of the magnitude of intersection crashes. It lays the foundation for all other elements of the Plan and defines the characteristics of intersection crashes as much as possible so that specific conclusions regarding implementation of strategies can be made. This section orients a State's crash data so that it can be associated with the strategies to be deployed to impact intersection crashes. For each characteristic, data can be presented in tabular format and then summarized. This sample plan uses hypothetical data for a "typical" moderate size State (1,003 total fatalities in 2003 of which 240 occurred at intersections) and uses some intersection fatality crash relationships extracted from the FARS data system.

Over the five-year period 1999 to 2003 highway fatalities, serious injuries, and crashes in the State have remained relatively stable with a very slight upward trend as shown in Table 1.

Table 1. Highway Fatalities, Serious Injuries, and Crashes

	1999	2000	2001	2002	2003
Fatalities	962	982	974	998	1,003
Serious Injuries	4,561	4,432	4,619	4,481	4,596
Reportable Crashes	98,762	97,561	99,213	100,415	100,312

Table 2 shows that intersection crashes which involve multiple vehicles, a single vehicle running off the road, or a vehicle striking a pedestrian are a substantial portion of the

statewide crash problem. In 2003, these crashes accounted for approximately 17% of the statewide serious injuries and deaths and 40% of statewide crashes.

Table 2. 2003 Intersection Crash Characteristics

		Signalized Intersections			Unsignalized Intersections			Total
		Multi-Vehicle	Single Vehicle	Pedestrian	Multi-Vehicle	Single Vehicle	Pedestrian	
Urban	Fatalities	41	10	11	38	10	6	116
	Serious Injuries	120	30	34	114	30	18	346
	Reportable Crashes	17,000	1,700	300	8,000	1,000	200	28,200
Rural	Fatalities	11	6	1	100	5	1	124
	Serious Injuries	34	18	4	300	15	4	375
	Reportable Crashes	2,500	300	20	8,000	1,000	20	11,840

Over this five-year period intersection deaths and serious injuries have remained relatively constant even though vehicular miles traveled (VMT) have increased, as shown in Table 3.

Table 3. Intersection Deaths and Serious Injuries

	1999	2000	2001	2002	2003
Intersection Deaths and Serious Injuries	960	965	970	950	961
VMT (Multiplied by 100 Million)	587	608	628	647	667

There are two primary factors responsible for this stability:

1. **A Gradually Improving Infrastructure.** The Hazard Elimination Program has improved between 60 and 70 high-hazard locations each year, approximately 50% of which are intersections.
2. **Safer Drivers.** Safety belt usage has climbed from 68% in 1999 to 75% in 2003. In addition, the passage of driving under the influence (DUI) legislation in 1999, which lowered the blood alcohol concentration (BAC) level from 0.10 to 0.08, has been a deterrent to drinking and driving.

Because this Plan addresses both signalized and unsignalized intersection crashes, the crash problem needs to be analyzed from a road ownership and an urban/rural perspective. These elements have a profound influence on the application of many of the strategies available to reduce intersection crashes. The distribution of 2003 intersection crashes by these factors and severity is indicated in Table 4. The percentage of fatalities in intersection crashes by road ownership is shown in Table 5 (see the next page).

1. **Note to the Reader:** For purposes of this example, it is assumed that the crash data system is not effectively tied into the highway infrastructure data system such that those intersections with zero crashes in the five-year study period can be identified. In addition, it is assumed that the exposure, expressed in average annual daily traffic (AADT) volumes, cannot be determined on a given intersection basis and intersection crash rates per million entering vehicles cannot be ascertained. While long-range efforts may be underway in a number of States to close these gaps, this analysis will rely on data emanating solely from the current crash data system.

Table 4. Distribution of 2003 Crashes by System Ownership

	Signalized Intersections				Unsignalized Intersections			
Principal Route	Number of Intersections with Crashes	Crashes	Serious Injuries	Fatalities	Number of Intersections with Crashes	Crashes	Serious Injuries	Fatalities
Rural State/State Highways	500	2,400	40	14	3,000	6,020	210	70
Rural State/Local Highways	Unknown	400	14	4	Unknown	1,500	54	18
Rural Local/Local Highways	Unknown	20	2	0	Unknown	1,500	55	18
Urban State/State Highways	2,000	14,000	120	38	700	6,200	90	30
Urban State/Local Highways	Unknown	4,000	48	16	Unknown	1,500	30	10
Urban Local/Local Highways	Unknown	1,000	16	8	Unknown	1,500	42	14
Total		21,820	240	80		18,220	481	160

Note: The “Number of Intersections with Crashes” is shown as “Unknown” in the above table for State/Local and Local/Local intersections due to the inability of the crash data system to properly locate crashes off the State highway system (i.e. police officers may refer to the same intersection by different names on traffic crash reports).

Table 5. Percentage of 2003 Fatalities by System Ownership

	Signalized Intersections – Percentage of Total Intersection Deaths	Unsignalized Intersections – Percentage of Total Intersection Deaths	Total Percentage
Rural State/State Intersection	6	29	35
Rural State/Local Intersection	2	7	9
Rural Local/Local Intersection	0	7	7
Urban State/State Intersection	16	13	29
Urban State/Local Intersection	7	4	11
Urban Local/Local Intersection	3	6	9

Table 4 indicates that the highest number of intersection crashes occurs at urban state/state signalized intersections (14,000). However, Table 5 indicates that the highest percentages of fatalities occur at rural state/state unsignalized intersections (29%) and urban state/state signalized intersections (16%).

Multi-Vehicle Intersection Crash Characteristics

The information from Table 2 indicates that for both signalized and unsignalized intersections, the most common problem is multi-vehicle crashes. Further analysis of these crashes leads to a better understanding of the crash problem and the types of strategies that may be successful.

The distribution of multi-vehicle serious injuries and fatalities by type of intersection is shown in Table 6.

1. **Note to the Reader:** Most crash data systems capture the type of multi-vehicle crash. However, some crash data systems also capture vehicle movements. With these systems it is possible to obtain further information about the predominant angle crashes that occur at intersections. Rather than lumping all angle crashes together, a State may prefer breaking out left turn and right turn crashes separately.

Table 6. 2003 Intersection Multi-Vehicle Crash Type Fatalities and Serious Injuries by Intersection Category

	Angle (Major Road and Side Street Vehicle)	Angle (Two Opposing Major Road Vehicles)	Angle (Other)	Head-On	Rear-End	Opposing Flow Sideswipe	Same Direction Sideswipe
Signalized (Urban)	119	33	1	4	3	1	0
Signalized (Rural)	31	11	0	1	1	0	1
Unsignalized (Urban)	112	30	2	4	3	1	0
Unsignalized (Rural)	296	80	2	12	8	1	1
Total	558	154	5	21	15	3	2

The highest incidents of multi-vehicle intersection crashes involve angle crashes. The predominant angle crash type involves a major road and side street vehicle. This is followed by crashes involving two opposing major road vehicles, where for the most part, one vehicle turns left across the path of the opposing vehicle.

Pedestrian Crashes at Intersections

Pedestrian crash information can be found in Table 2 of this Plan. The data indicate that pedestrians are a primary concern at both urban signalized and unsignalized intersections. Table 2 also shows that there is a minimal pedestrian crash problem at rural intersections.

Single Vehicle Intersection Crashes

Single vehicle intersection crash information can be found in Table 2 of this Plan. Single vehicle crashes are relatively minimal in comparison to the multi-vehicle crashes that occur at intersections. These single vehicle crashes are relatively uniformly distributed in urban and rural areas, and under signalized and unsignalized conditions. While the crash data does not yield information on the underlying causes of these crashes, it is believed that many of them occur due to inattentive driving or loss of control when the driver must react to an unanticipated condition occurring in the intersection.

Speed Limits and Intersection Crash Severity

Table 7 shows that the severity of crashes increases as the speed limit on the major road increases.

Table 7. 2003 Major Road Speed Limit vs. Injury Severity

	Signalized Intersections			Unsignalized Intersections		
Major Road Speed Limit	**Total Crashes**	**Total Serious Injuries and Fatalities**	**Fatalities and Serious Injuries per 100 Crashes**	**Total Crashes**	**Total Serious Injuries and Fatalities**	**Fatalities and Serious Injuries per 100 Crashes**
30 mph and below	2,000	20	1.0	2,000	35	1.7
35 mph	6,000	70	1.2	2,000	45	2.2
40 mph	6,000	80	1.3	2,000	55	2.7
45-50 mph	6,000	100	1.6	2,000	65	3.2
55 mph and above	1,820	50	2.7	10,220	441	4.3

Note that there are fewer total crashes at high-speed signalized intersections (due to the existence of fewer such intersections on high-speed roads), but the percentage of fatalities and serious injuries at signalized intersections is 2.7 times greater for 55mph and above speed limit approach intersections compared to 30mph or less approaches.

Traffic Way Flow Type vs. Serious Injuries and Fatalities

Table 8 shows serious injuries and fatalities for undivided and divided roadways.

Table 8. 2003 Serious Injuries and Fatalities by Type of Intersection

Type of Intersection	Undivided	Divided
Signalized	130	170
Unsignalized	470	150

Note: There are 20 “unknown or other” intersection types for signalized intersections and 21 for unsignalized intersections that are not shown in the above table.

Illegal Driver Actions

Table 9 shows that illegal driver actions play a role in many severe crashes at intersections. Three concerns are as follows:

- Fatalities and serious injuries caused by drivers who violated a traffic control device or lost control due to moving violations - these include speeding, reckless driving, and failure to obey a traffic control device.
- Alcohol-related fatalities and serious injuries
- Fatalities and serious injuries where drivers and/or occupants were unbelted

Table 9. 2003 Serious Injuries and Fatalities Involving Illegal Driving Actions

		Signalized Intersections	Unsignalized Intersections
Fatalities and Serious Injuries Involving Illegal Driving	Total	160	307
	% of All Intersection Serious Injuries and Fatalities that Involved Illegal Driving Actions	50	48
Alcohol-Related Fatalities and Serious Injuries	Total	90	179
	% of All Intersection Fatalities and Serious Injuries Involving Alcohol	28	28
Unbelted Driver and Occupant	Total	200	441

Fatalities and Serious Injuries	% of All Intersection Fatalities and Serious Injuries Where Vehicular Occupants Were Unbelted (Note that these numbers do not include pedestrian fatalities and serious injuries as shown in Table 2)	74	72

In addition to illegal driving actions, drivers who are distracted, fatigued, inattentive, or who fall asleep are also considered factors in intersection crashes. However, these factors seem to be underreported in the crash data system.

Wet Pavement Conditions

Table 10 shows that 16-17% of the crashes at intersections occur on wet pavements. Intersections that have a large number and proportionately higher rate of wet pavement crashes (larger than 17%) may have a slippery pavement condition which contributes to higher crash frequencies.

Table 10. 2003 Wet Pavement Crashes

Category	Signalized Intersections	Unsignalized Intersections
Wet	3,742	3,000
Total	21,820	18,220
Wet/Total Ratio	0.17	0.16

Intersection Fatalities and Serious Injuries by Driver Age

Table 11 shows that drivers aged 16 to 18 and 75 and over have a disproportionately high number of fatal and serious injury crashes (24.1% combined compared to 15.1% of these-aged drivers in the traffic stream, as shown in the table) when they pull out from a stop sign. This same type of distribution is not shown in the table but occurs for the other angle crash type involving two opposing major road vehicles where one vehicle turns left across the path of the other vehicle. The turning driver has the higher crash distributions at the younger and older ends of the age spectrum. Younger drivers may have difficulty in determining safe gaps because of inexperience and higher risk taking. Older drivers may have problems associated with reduced vision capabilities. (It is noted that this information does not provide evidence as to which vehicle was at-fault in the crashes.)

Table 11. Driver Age Distribution in 2003 Angle Crashes at Unsignalized Intersections

Age	Drivers Pulling Out from Stopped Approach (Driver Distribution %)	Major Road Drivers (Driver Distribution %)
16	5.8	3.5
17	5.0	3.5
18	4.2	3.4
19-21	7.9	7.8
22-25	9.1	10.6
26-35	16.8	19.2
36-44	16.2	18.5
45-54	11.8	13.3
55-65	8.7	10.1
66-74	4.6	4.7
75-80	4.4	2.2
>80	4.7	2.5
Unknown	0.8	0.7
TOTAL	100.0	100.0

Daylight vs. Nighttime Conditions

When considering light conditions, only one reported crash condition is considered preventable by applying lighting – “Dark – No Street Lights”. The other crashes either occurred in the day, in dark conditions with existing street lights, or when the light condition was unknown. Table 12 shows the extent of the crashes that occurred in different lighting conditions.

Table 12. 2003 Intersection Crashes and Light Condition

	Signalized Intersections	Unsignalized Intersections
Daylight	13,800	11,620
Dark with Street Lights	3,800	2,000
Dark – No Street Lights	3,720	4,000
Unknown	500	600
TOTAL	21,820	18,220

Unlit intersections that have a high number of night crashes and a proportionally higher rate of night to total crashes than the statewide average for unlit intersections may benefit from street lighting.

The Cost of Intersection Crashes

The costs of intersection crashes may vary depending on specific factors involved. Two key measurements are needed in the upcoming analysis:

- Average cost of specific crash types expressed in dollars. This is needed to determine if an improvement may be cost effective.
- Expected deaths and serious injuries per 100 crashes that may be reduced for various crash types. This is needed to determine the extent to which an improvement helps achieve a serious injury and fatality goal.

The monetary costs of crashes are based upon FHWA cost estimates issued February 12, 2002 as noted below:

- Fatality – $ 3,000,000.
- Serious injury – $209,000.
- Non-serious injury – $42,000.
- Possible injury – $22,000.
- Property damage – $2,300.

The FHWA injury estimates are based upon the abbreviated injury scale (AIS). Since the State's definition of injury severity does not use the AIS, an interpolation of the FHWA estimates was made to coincide with the injury definitions used on the police crash report.

The average crash costs and death and serious injury rates for the major crash types were extracted from the crash data and the FHWA cost estimates were applied. The results are as follows.

Table 13. Average Crash Cost and 2003 Death/Serious Injury Rates

	Condition	Average Crash Costs ($000)	Deaths and Serious Injuries Per 100 Crashes
Signalized Rural	**Angle (Major Road and Side Street Vehicle)**	22	2.5
	Angle (Two Major Road Vehicles)	20	2.4
	Rear End	7	0.8
	All Crashes	18	2.3
	Pedestrian Crashes	Unknown	Unknown
Signalized Urban	**Angle (Major Road and Side Street Vehicle)**	18	2.2
	Angle (Two Major Road Vehicles)	16	2.1
	All Crashes	10	1.1
	Pedestrian Crashes	140	28.6
Unsignalized Rural	**Angle (Major Road and Side Street Vehicle)**	42	4.8
	Angle (Two Major Road Vehicles)	42	4.8
	Rear End (Major Road only)	10	1.1
	All Crashes	40	4.6
	Pedestrian Crashes	Unknown	Unknown
Unsignalized Urban	**Angle (Major Road and Side Street Vehicle)**	18	2.2
	Angle (Two Major Road Vehicles)	16	2.1

	All Crashes	16	2.0
	Pedestrian Crashes	130	26.6

Note: The “Unknown” shown in the rows for Pedestrian Crashes in this table is due to the relatively low number of pedestrian crashes, fatalities and serious injuries in rural areas (see Table 2).

Summary of Potential Concerns

Based on the data presented, the *potential* concerns regarding intersection fatalities and serious injuries are as follows.

- Rural unsignalized intersections primarily on State highways. (Table 4)
- Urban signalized intersections on State highways. (Table 4)
- Multi-vehicle angle crashes involving major road and entering vehicles at urban and rural intersections. (Table 6)
- Multi-vehicle angle crashes involving two major road vehicles at urban and rural intersections. (Table 6)
- Pedestrian crashes in urban areas at both signalized and unsignalized intersections. (Table 2)
- Intersections with higher speed limits on the major road (higher proportions of serious injuries and deaths). (Table 7)
- Signalized and unsignalized physically divided intersections. (Table 8)
- Intersections with a large and disproportionate number of wet pavement crashes. (Table 10)
- Unlit intersections with a large and disproportionate number of night crashes. (Table 12)
- Young and old drivers who have difficulty selecting safe gaps. (Table 11)
- Illegal driving actions relating to speed, alcohol, and/or unbelted drivers and occupants. (Table 9)

Intersection Goal

1. **Note to the Reader:** The purpose of this section of the Plan is to clearly state the intersection goal. Discussion of the goal includes at least the following information: what data will be used, the proposed reduction levels and date by which the goal should be reached, and assumptions about future conditions. The goal should be measurable and expressed in terms of a statewide reduction of intersection fatalities, serious injuries, crashes, or any combination of these by a defined date. A “stretch” goal was established in the Sample Plan along with a number of strategies and their levels of deployment needed to achieve the goal. States have the flexibility of establishing whatever goal they desire.

After careful analysis of the data and a review of the accuracy of serious injury classifications, the combination of fatalities and serious injuries will be used as the intersection performance measure in the goal. The State has also adopted an overall safety goal of achieving a fatality rate of 1.0 fatality per 100 million vehicle miles traveled by 2008, which matches the national goal. Strategies identified in this plan to reduce intersection fatalities and serious injuries will help the State make progress toward the overall goal.

Recognizing that separate initiatives will be underway to increase safety belt usage and to reduce drinking and driving and aggressive driving (which will also reduce intersection deaths and serious injuries), this initiative will concentrate on primarily infrastructure-related strategies that can reduce intersection deaths and serious injuries.

Over the period 2003 to 2010, traffic volumes are expected to continue growing at a rate of three percent per year. Intersection entering volume rates are difficult to aggregate into a single overall rate. It is anticipated that over the next few years, the State will have the computer programming capability to sum entering intersection daily traffic volumes for all State intersection approaches at State-only intersections. The State should also be able to calculate an estimated volume for local highway approaches to State intersections based on the functional class of the local road. As a result, intersection crash rates in terms of crashes per million entering vehicles will be calculated and average and abnormal intersection crash rates can be determined for various types of intersections. When completed, an intersection crash rate goal will be incorporated into the plan. However, for current conditions, only crash data will be used in the goal.

The intersection goal is as follows:

Reduce the intersection serious injuries and deaths from 961 in 2003 to no more than 850 in 2010.

Approach

1. **Note to the Reader:** This section begins with a discussion of the sources of improvement strategies and the process by which strategies were chosen for consideration to help achieve the goal. A description of the strategies is then provided. The section ends with a summary of the data and analysis procedures used to quantify the impact of improvement strategies.

Strategy Selection

Preventing 111 intersection combined deaths and serious injuries each year is a challenge, particularly since the existing safety efforts only have been able to maintain the existing level of 961 annual serious injuries and deaths. New, effective strategies have to be skillfully deployed if reductions are to be achieved.

Information from the following reports was used in identifying promising strategies:

- NCHRP Report 500, Volume 5 (Addressing Unsignalized Intersection Collisions) Strategies
    - 17.1 A—Improve management of access near unsignalized Intersections
        - 17.1 A1—Implement driveway closures/relocations (T)

- 17.1 A2—Implement driveway turn restrictions (T)

- 17.1 B—Reduce the frequency and severity of intersection conflicts through geometric design improvements
  - 17.1 B1—Provide left-turn lanes at intersections (P)
  - 17.1 B2—Provide longer left-turn lanes at intersections (T)
  - 17.1 B3—Provide offset left-turn lanes at intersections (T)
  - 17.1 B4—Provide bypass lanes on shoulders at T-intersections (T)
  - 17.1 B5—Provide left-turn acceleration lanes at divided highway intersections (T)
  - 17.1 B6—Provide right-turn lanes at intersections (P)
  - 17.1 B7—Provide longer right-turn lanes at intersections (T)
  - 17.1 B8—Provide offset right-turn lanes at intersections (T)
  - 17.1 B9—Provide right-turn acceleration lanes at intersections (T)
  - 17.1 B10—Provide full-width paved shoulders in intersection areas (T)
  - 17.1 B11—Restrict or eliminate turning maneuvers by signing (T)
  - 17.1 B12—Restrict or eliminate turning maneuvers by providing channelization or closing median openings (T)
  - 17.1 B13—Close or relocate “high-risk” intersections (T)
  - 17.1 B14—Convert four-legged intersections to two T-intersections (T)
  - 17.1 B15—Convert offset T-intersections to four-legged intersections (T)
  - 17.1 B16—Realign intersection approaches to reduce or eliminate intersection skew (P)
  - 17.1 B17—Use indirect left-turn treatments to minimize conflicts at divided highway intersections (T)
  - 17.1 B18—Improve pedestrian and bicycle facilities to reduce conflicts between motorists and nonmotorists (varies)
- 17.1 C—Improve sight distance at unsignalized intersections
  - 17.1 C1—Clear sight triangles on stop- or yield-controlled approaches to intersections (T)
  - 17.1 C2—Clear sight triangles in the medians of divided highways near intersections (T)
  - 17.1 C3—Change horizontal and/or vertical alignment of approaches to provide more sight distance (T)
  - 17.1 C4—Eliminate parking that restricts sight distance (T)
- 17.1 D—Improve availability of gaps in traffic and assist drivers in judging gap sizes at unsignalized intersections
  - 17.1 D1—Provide an automated real-time system to inform drivers of the suitability of available gaps for making turning and crossing maneuvers (E)
  - 17.1 D2—Provide roadside markers or pavement markings to assist drivers in judging the suitability of available gaps for making turning and crossing maneuvers (E)
  - 17.1 D3—Retime adjacent signals to create gaps at stop-controlled intersections (T)
- 17.1 E—Improve driver awareness of intersections as viewed from the intersection approach
  - 17.1 E1—Improve visibility of intersections by providing enhanced signing and delineation (T)
  - 17.1 E2—Improve visibility of the intersection by providing lighting (P)
  - 17.1 E3—Install splitter islands on the minor-road approach to an intersection (T)
  - 17.1 E4—Provide a stop bar (or provide a wider stop bar) on minor road approaches (T)
  - 17.1 E5—Install larger regulatory and warning signs at intersections (T)
  - 17.1 E6—Call attention to the intersection by installing rumble strips on intersection approaches (T)
  - 17.1 E7—Provide dashed markings (extended left edgelines) for major-road continuity across the median opening at divided highway intersections (T)
  - 17.1 E8—Provide supplementary stop signs mounted over the roadway (T)
  - 17.1 E9—Provide pavement markings with supplementary messages, such as STOP AHEAD (T)
  - 17.1 E10—Provide improved maintenance of stop signs (T)
  - 17.1 E11—Install flashing beacons at stop-controlled intersections (T)
- 17.1 F—Choose appropriate intersection traffic control to minimize crash frequency and severity
  - 17.1 F1—Avoid signalizing through roads (T)
  - 17.1 F2—Provide all-way stop-control at appropriate intersections (P)
  - 17.1 F3—Provide roundabouts at appropriate locations (P)
- 17.1 G—Improve driver compliance with traffic control devices and traffic laws at intersections
  - 17.1 G1—Provide targeted enforcement to reduce stop sign violations (T)
  - 17.1 G2—Provide targeted public information and education on safety problems at specific intersections (T)

- 17.1 H—Reduce operating speeds on specific intersection approaches
  - 17.1 H1—Provide targeted speed enforcement (P)
  - 17.1 H2—Provide traffic calming on intersection approaches through a combination of geometrics and traffic control devices (P)
  - 17.1 H3—Post appropriate speed limit on intersection approaches (T)
- 17.1 I—Guide motorists more effectively through complex intersections
  - 17.1 I1—Provide turn path markings (T)
  - 17.1 I2—Provide a double yellow centerline on the median opening of a divided highway at intersections (T)
  - 17.1 I3—Provide lane assignment signing or marking at complex intersections (T)

- NCHRP Report 500, Volume 12 (Reducing Collisions at Signalized Intersections) Strategies
  - 17.2 A Reduce frequency and severity of intersection conflicts through traffic control and operational improvements
    - 17.2 A1 Employ multiphase signal operation (P, T)
    - 17.2 A2 Optimize clearance intervals (P)
    - 17.2 A3 Restrict or eliminate turning maneuvers (including right turns on red) (T)
    - 17.2 A4 Employ signal coordination along a corridor or route (P)
    - 17.2 A5 Employ emergency vehicle preemption (P)
    - 17.2 A6 Improve operation of pedestrian and bicycle facilities at signalized intersections (P, T)
    - 17.2 A7 Remove unwarranted signal (P)
  - 17.2 B Reduce frequency and severity of intersection conflicts through geometric improvements
    - 17.2 B1 Provide/improve left-turn channelization (P)
    - 17.2 B2 Provide/improve right-turn channelization (P)
    - 17.2 B3 Improve geometry of pedestrian and bicycle facilities (P, T)
    - 17.2 B4 Revise geometry of complex intersections (P, T)
    - 17.2 B5 Construct special solutions (T)
  - 17.2 C Improve sight distance at signalized intersections
    - 17.2 C1 Clear sight triangles (T)
    - 17.2 C2 Redesign intersection approaches (P)
  - 17.2 D Improve driver awareness of intersections and signal control
    - 17.2 D1 Improve visibility of intersections on approach(es) (T)
    - 17.2 D2 Improve visibility of signals and signs at intersections (T)
  - 17.2 E Improve driver compliance with traffic control devices
    - 17.2 E1 Provide public information and education (T)
    - 17.2 E2 Provide targeted conventional enforcement of traffic laws (T)
    - 17.2 E3 Implement automated enforcement of red-light running (cameras) (P)
    - 17.2 E4 Implement automated enforcement of approach speeds (cameras) (T)
    - 17.2 E5 Control speed on approaches (E)
  - 17.2 F Improve access management near signalized intersections
    - 17.2 F1 Restrict access to properties using driveway closures or turn restrictions (T)
    - 17.2 F2 Restrict cross-median access near intersections (T)
  - 17.2 G Improve safety through other infrastructure treatments
    - 17.2 G1 Improve drainage in intersection and on approaches (T)
    - 17.2 G2 Provide skid resistance in intersection and on approaches (T)
    - 17.2 G3 Coordinate closely spaced signals near at-grade railroad crossings (T)
    - 17.2 G4 Relocate signal hardware out of clear zone (T)
    - 17.2 G5 Restrict or eliminate parking on intersection approaches (P)

Note: For the strategies in these two NCHRP Report 500 volumes, “P” means proven, “T” tried, and “E” experimental.

- Signalized Intersections: Informational Guide, FHWA http://www.tfhrc.gov/safety/pubs/04091/index.htm
- Roundabouts: An Informational Guide, FHWA http://www.tfhrc.gov/safety/00068.htm

The implementation of potential strategies must be cost effective and lead to a reduction of intersection serious injuries and fatalities toward meeting the goal. The following

four opportunity areas are identified as potentially the most productive toward achieving the intersection crash goal. These areas are discussed in detail in the following section of this Plan on Intersection Improvement Strategies.

1. System-wide deployment of low-cost, cost effective improvements.
2. System-wide deployment of medium and high-cost improvements at high-crash intersections.
3. Corridor and area-wide enforcement/education/engineering intersection initiative.
4. Local road intersection safety initiative.

Data Analysis

The following summarizes the data and procedures used to quantify the impacts of improvement strategies. More detailed information is provided in the improvement strategy section of this Plan.

- The crash data system is used to identify potential candidate locations with appropriate crash histories for each of the opportunity areas above. The crash data is merged with the roadway data files and the traffic volume files to provide more insight into the characteristics of the problem. However, the relationships of databases, with the exception of crash locations on State highways, have not been fully established and use of data from these systems is not feasible at this time.
- A five-year crash history (1999 to 2003) has been used in all of the calculations in the analyses.
- A benefit/cost (B/C) calculation is used to determine the threshold level of crashes to justify implementing an improvement. The effectiveness of various strategies, where available, was determined from information in the following reports: NCHRP Report 500, Volume 5 (Addressing Unsignalized Intersection Collisions); NCHRP Report 500, Volume 12 (Reducing Collisions at Signalized Intersections); FHWA's Signalized Intersections: Informational Guide; and, FHWA's Roundabouts: An Informational Guide. Other reliable sources of countermeasure effectiveness information can also be used where and when appropriate. Where ranges of effectiveness are available, the midpoint was used in the calculations.

  The NCHRP 500 Reports contain strategies that are experimental as well as tried and proven. Once the B/C threshold is set (2.0 is used here), the crash data system is searched to identify candidate locations that meet or exceed the threshold. The number of candidate locations that can ultimately be improved is estimated. (Subsequent field reviews and design developments may render some of the candidate sites inappropriate for improvements.)
- A statewide estimate of the impact (i.e. reduction in serious injuries and fatalities) of implementing each improvement type is calculated.
- The impacts of all improvement types are summed to determine if the overall effort is adequate to achieve the goal (i.e. 111 fewer annual serious injuries and fatalities at intersections by 2010).

Intersection Improvement Strategies

1. **Note to the Reader:** This portion of the Plan provides detailed information on each strategy proposed to be deployed. Traditionally, a state will look at high-crash locations and determine a course of action for each location. In this plan, the strategies that will create the greatest cost-effective reductions in serious injuries and fatalities are identified first. Then the crash data system is searched to determine locations where these strategies can be deployed cost effectively. A statewide assessment of the costs to deploy and impacts in terms of the goal (fatalities and serious injuries prevented) is made for each strategy

   A large number of strategies have been incorporated to provide a "shopping list" of potential strategies for states to consider. Strategies were selected based upon their expected potential to reduce serious injuries and fatalities and their capacity to be deployed in a cost-effective manner. States don't have to embrace the entire range of strategies.

   Information presented in this section may vary by strategy, but each strategy should attempt to contain: a detailed description of the strategy; the conditions under which the strategy will be applied; levels of deployment; estimated costs; estimated reduction levels in intersection fatalities and serious injuries; and cost-effectiveness. In this Sample Plan, strategies are grouped into categories for ease of presentation and discussion. Information is provided in both tabular and written format.

System-Wide Deployment of Low-Cost, Cost-Effective Improvements

Three types of low-cost, system-wide improvements are proposed.

1. **Enhanced Sign and Marking Systems at Unsignalized Intersections.** This set of improvements is targeted to unsignalized intersections on State highways with sufficient crash histories such that implementation of the improvement will likely be cost-effective (signalized intersections are covered in #2 below). They can be applied in both urban and rural settings, and are most appropriate in isolated conditions. These passive warning systems, sometimes in combination with active warning beacons, are designed to: (1) slow down excessive speeding on major road approaches; (2) heighten the alertness of all entering drivers to the approaching intersection; (3) encourage stopped drivers to scan the intersection properly before entering; and, (4) encourage stopped vehicles to stop at the correct approach location. A team including representatives of the State DOT, university, FHWA, and a human factors expert will analyze the crash characteristics, identify the most promising enhanced sign/marking combinations, and develop the criteria for deployment. The team also will identify a set of enhanced signs and marking improvements (compliant with the MUTCD) that have the potential to yield significant safety benefits and will propose installation at approximately five to 10 problem locations at which these improvements can be evaluated to determine safety impact prior to considering system-wide deployment.

   The estimated unit cost of this improvement is $3,000 per intersection. The actual effectiveness of this strategy is unknown, however, it is conservatively estimated that the improvement will reduce overall intersection crashes by 15%. (**Note:** States may use other effectiveness rates for this and other strategies based on existing information, such as the NCHRP Report 500 Volumes 5 and 12 or other viable sources, experience and/or judgment.) Urban and rural intersections will be evaluated separately because the severity of crashes in rural areas is much higher than in urban areas.

2. **Minor Traffic Signal Enhancements.** This set of improvements can be applied in both urban and rural areas, but are predominantly found in urban areas. The system of improvements includes signing and marking upgrades on signalized intersection approaches, signal upgrades, and application of advanced detector system technology where warranted, to: reduce high-end approach speeds and heighten driver alertness; increase the conspicuity of signal heads (e.g.,

increased size of lens, heads centered over the traffic lanes, back plates, wattage, etc.); accommodate pedestrians; and, provide safe clearance times between phases. The estimated average unit cost of these improvements is $30,000 per intersection and will vary from intersection to intersection depending on the base conditions. The actual effectiveness of these improvements is unknown, however, it is conservatively estimated that the combined improvements will reduce overall intersection crashes by 15%. (**Note**: Some signal-related strategies have effectiveness rates as high as 30-60%. States should consult available sources, such as the NCHRP Report 500 Volumes 5 and 12, for more information.) Urban and rural intersections will be evaluated separately because the severity of crashes in rural areas is much higher than in urban areas.

3. **Stop Approach Enhancements.** This set of improvements is limited to rural unsignalized intersections which have a substantial crash history associated with drivers running a stop sign (as determined from the causal factors reported in the police crash report and included in the crash data system). The improvements include:
    a. Advance intersection and traffic control warning signs, oversize signs, “doubled up” warning signs, and warning beacons;
    b. Transverse rumble strips and/or pavement markings on the stop approach designed to attract the attention of approaching motorists of the upcoming intersection (rumble strips should only be applied in those rural settings that do not have adjacent or close dwellings due to noise issues);
    c. Splitter islands to separate opposing traffic directions at the intersection and to provide for designated turning lanes;
    d. “Pork Chop” islands for placement of right-of-way control signs more central in the approaching driver’s cone of vision; and,
    e. Increasing the size or “doubling-up” of “STOP” signs and/or adding flashing beacons to “STOP” signs.

    The estimated cost of these improvements is $25,000 per intersection. The estimated effectiveness is a 50% reduction in crashes involving vehicles that run stop signs.

Application of the above criteria to the crash data system yields the results shown in Table 14 on the next page. Appendix A provides a description of the cost effectiveness data analysis performed to produce this information.

1. **Note to the Reader:** States should consider including an appendix of data analysis work as part of their plans. Appendix A provides a description of the cost effectiveness data analysis performed to produce the information in Table 14. This data analysis process should be the same for all improvements discussed in the plan.

Table 14. Cost and Impact Summary – Low-Cost, Cost-Effective Improvements (Crash Data Systems That Can Locate Crashes by Specific Location on a Route)

Category	Threshold Crash Level (Five Years)	Number of Statewide Crash Intersections	Number of Targeted Five-Year Crashes in the Intersections	Estimated Number of Improvements	Construction Costs ($ Million)	Type of Crash Reduced	Annual Targeted Crash Reduction	Annual Serious Injury and Fatality Reduction
Enhanced Sign and Marking – Unsignalized Rural Intersections	5 crashes	880	8,400	800	2.4	Intersection	230	11
Enhanced Sign and Marking –Unsignalized Urban Intersections	10 crashes	350	6,000	300	0.9	Intersection	154	3
Rural Traffic Signal Minor Enhancements	15 crashes	35	450	30	0.9	Intersection	12	<1
Urban Traffic Signal Minor Enhancements	20 crashes	450	15,000	400	12.0	Intersection	400	4
Stop Approach Improvements at Rural Unsignalized Intersections	3 running stop sign crashes	48	200	36	0.9	Intersection (running stop signs)	15	1
Total					17.1		811	20

It can be seen that collectively, these low-cost improvements are projected to reduce intersection serious injuries and deaths by 20 on an annual basis and cost $17.1 million to implement.

Calculation Example in Table 14:

Enhanced Sign and Marking - Unsignalized Rural Intersections

8,400/5 x 800/880 x 0.15 =229 annual crashes reduced (230 used in Table)

(230/100) x 4.6 (from Table 13) =10.58 annual fatalities and serious injuries reduced per year (rounded to 11 in Table)

System-Wide Deployment of Medium- and High-Cost Improvements at High-Crash Locations

1. **Note to the Reader:** For each strategy the threshold crash criteria selected takes into consideration: (1) the likelihood that future crash problems would exist if no actions are taken; and, (2) the probability that the strategy can be implemented at the intersection cost-effectively. For example, lighting unlit intersections with five or more night crashes in five years and where the proportion of night – not lighted to total crashes is greater than 0.40 at a cost of $10,000 per intersection, will yield night crash reduction benefits that are at least twice that of the construction cost of lighting over the life of the improvement. States would need to select criteria based on their crash conditions.

Strategies that are medium or high-cost also are possible for system deployment. Because of higher costs, these deployments are considered only at high-crash intersections that have crash types mitigated by the strategies. A review of the medium- to high-cost strategies in NCHRP Report 500 Volumes 5 and 12, coupled with the crash analysis, yields the following improvements and crash types for further analysis (in no particular order of importance or effectiveness).

1. **Sight distance improvements and/or dynamic warning systems** at those unsignalized intersections having a substantial number of angle crashes (for

example, five or more in five years) involving a major road vehicle and an entering vehicle from the side street. Since the crash data system does not provide information on the available sight distance at the intersection, field reviews will be necessary. A dynamic intersection warning system will be considered where it is determined that sight distance improvements will not significantly improve safety.

2. **Left turn lanes** at those unsignalized intersections having a substantial number of angle (left turning) crashes (for example, eight or more in five years) involving two major road opposing vehicles, one turning across the path of the other, or rear-end crashes (for example, eight or more in five years). Major road rear end crashes have been added to the analysis. A field review will be necessary to determine if the installation of left turn lanes is feasible and appropriate. It is desirable to offset opposing left turn lanes to increase visibility of approaching vehicles.
3. **Left turn exclusive phases and lanes** if not available at those signalized intersections having a substantive number of angle (left turning) crashes involving two opposing major road vehicles, one turning across the path of the other. Major road rear end crashes have been added to the analysis. Again, it will be necessary to verify through a field review later to determine if the installation of left turn lanes and phases is feasible and appropriate.
4. **Lighting** at those unlit intersections with a high number of crashes (for example, five or more night crashes in five years) and where the proportion of night – not lighted to total crashes is greater than 0.40. The value of 0.40 was selected because it is above the mean (0.33) night to total crash rate for all statewide intersections.
5. **Application of high-friction surfaces on high-speed approaches** (where the speed limit is equal or greater than 40 mph) having a high number of crashes (for example, five or more wet pavement crashes in five years) and a proportion of wet pavement to total crashes of 0.25 or greater. A skid test must confirm that the pavement surface friction is less than desirable.
6. **Pedestrian improvements** (e.g., pedestrian signals, cross walks, traffic calming) at intersections that have a substantial pedestrian crash problem (for example, three or more pedestrian crashes in five years).
7. **Roundabouts** or other major geometric improvements such as the elimination of skewed approaches at those unsignalized intersections with high numbers of crashes (for example, 20 or more in five years).
8. **Automated Red Light Running Traffic Signal Enforcement.** This set of improvements is limited to municipal-wide application of photo-radar enforcement at signals that exhibit higher frequencies of crashes involving running red lights. Implementation requires passage of State legislation. Municipalities having high numbers of signalized intersection crashes (100 or more signalized intersection crashes) would be candidates. The estimated average cost is $500,000 per municipality and consists of a 'floating' photo radar system that can be used at all of the intersections exhibiting high crash rates. The estimated effectiveness is a 15% reduction in municipal-wide red light running crashes. (**Note**: States may use other, higher effectiveness rates if they can be verified in NCHRP Report 500 or other reliable sources, knowledge and/or experience.)

Application of the above criteria to the crash data system yields the results shown in Table 15 (on the next page). These medium-and-high-cost improvements are projected to reduce intersection serious injuries and deaths by 40 on an annual basis and cost $63.2 million to implement.

Note: The estimated effectiveness values for each strategy are shown in parentheses in the "Annual Number of Crash Types Reduced (Estimated Effectiveness)" column of the table. Also, the determination of Annual Reduction in Serious Injuries and Fatalities in Table 15 is derived from the "Deaths and Serious Injuries per 100 Crashes" information in Table 13, except for night crashes and wet pavement crashes which were determined separately from available information in the crash data system.

Calculation example for Table 15 (on page 24)

Sight Distance Improvements or Dynamic Warning Systems

(1,200/5) x 0.20 =48 annual crashes reduced

(48/100) x 4.6 (from Table 13) =2.2 annual reduction in fatalities and serious injuries (shown as 2 in Table)

Table 15. Cost and Impact Summary – Medium- and High-Cost Improvements at High-Crash Intersections

Category	Threshold Crash Level (Five Years)	Number of Clusters at or Above Threshold	Estimated Number Improved	Estimated Number of Targeted Five-Year Crashes in Clusters Improved	Type of Crash Reduced	Annual Number of Crashes Reduced (Estimated Eff.)	Annual Reduction in Serious Injuries and Death	Construction Costs ($ Million)
Sight Distance Improvements or Dynamic Warning Systems	5 angle crashes involving a major road and entering vehicle	200	150	1,200	Angle involving a major road and entering vehicle	48 (0.20)	2	15.0
Left Turn Lanes at Unsignalized Rural Intersections	8 angle crashes involving two opposing major road vehicles	40	32	300 angle 400 rear end	Angle involving two major road vehicles	25 angle (0.42) 60 rear end (0.75)	1 (angle) 1(rear end) 2 Total	9.6
Left Turn Phases and/or Lanes at Signalized Intersections	8 angle crashes involving two opposing major road vehicles	60	50	800 angle 800 rear end	Angle involving two major road vehicles	67 angle (0.42) 120 rear end (0.75)	2 (angle) 1(rear end) 3 Total	4.0
Lighting at Unlit Intersections	5 night crashes and a night/total crash ratio >0.40	80	60	480	Night crashes	38 (0.40)	2	0.6

High Friction Surfaces for Slippery Pavements	5 wet pavement crashes on >35mph approaches and a wet/total crash ratio >0.25	100	60	800	Wet pavement crashes	80 (0.5)	3	3.0
Pedestrian Improvements (Traffic Calming, Pedestrian Phases, Crosswalks, Refuge Islands)	3 pedestrian crashes	70	60	230	Pedestrian crashes	14 (0.3)	4	1.0
Roundabouts	20 crashes	60	40	1,120	Roundabouts	202 (0.9)	9	18.0
Automated Red Light Running Enforcement	500 signalized intersection crashes per municipality	30 municipalities	24	44,000	Intersection (red light running crashes)	1,320 (0.15)	15	12.0
Total						1974	40	63.2

Local Road Intersection Safety Initiatives

Approximately one-fourth of all intersection crashes occur on local roads. The data for the local road system is not as accurate and complete as that for the State highway system but was used as an initial tool to identify potential municipalities and routes that have concentrations of targeted intersection crashes.

Since there are fewer crashes on local roads and they occur over a much larger road system, the level of concentration will be much less than that found on the State highway system. One general type of intersection strategy will be pursued on local roads as follows.

Basic and Enhanced Signing and Marking for Unsignalized Intersections. This initiative proposes to upgrade municipal-wide intersection signing and marking in those municipalities that have 25 or more local road intersection crashes at unsignalized intersections over a five-year period. The upgrade will bring the signs to the basic requirements in the 2003 MUTCD and incorporate enhanced improvements similar to what is proposed on the State highway system at select problem intersections. Signalized intersections are not included since it assumed that the local agency intersection crash problem is predominantly at rural unsignalized intersections.

The initial identification of potential municipalities and local roads with sections that meet the threshold levels (shown in Table 16) indicates that deploying municipal-wide innovative intersection sign and marking systems is projected to reduce intersection serious injuries and deaths by 9 on an annual basis and cost $2.0 million.

Table 16. Cost and Impact Summary – Local Roads Intersection Safety Initiatives

Category	Threshold Level of Crashes (Five-Years)	Number of Statewide Municipalities at or Above Threshold	Number Of Targeted Five-Year Crashes in the Clusters	Estimated Number of Municipalities Participating	Construction Cost ($ Million)	Type Of Crashes Reduced	Estimated Annual Number of Crashes Reduced (Estimated Effectiveness)	Annual Reduction of Serious Injuries and Deaths
Municipal-Wide Basic and Enhanced Intersection Sign and Marking Systems	25 or more local intersection crashes per municipality	200 municipalities	8,800	150 municipalities	2.0	Intersection crashes	198 (.15)	9

Local technical assistance program (LTAP) or State DOT engineers, along with local officials, using the municipalities identified in the list above, will manually assess major intersections. This assessment will determine if there are additional reportable crashes at the intersections. Municipal officials will also be queried to determine if they can document crash data at other intersections that meet or exceed the threshold levels. Those municipalities that have intersection(s) meeting the threshold levels for signing and marking improvements established on the State highway system (i.e. five or more in five years as noted in Table 14) will be asked if they are interested in applying signing and marking improvements at these intersections. If so, specific sign and marking improvements and cost estimates will be developed for each intersection. Federal-aid funding will be made available and the municipality must agree to assume the match.

1. **Note to the Reader:** The State will need to make a policy determination of the amount and participation rate of Federal funds to extend to municipalities.

Corridor/Area-Wide Enforcement/Education/Engineering Initiative for Intersection Improvements

Corridor Enforcement/Education/Engineering Initiative

1. **Note to the Reader:** Two approaches to identifying corridors are possible. First, intersection crashes involving serious injuries or fatalities over the past five years are plotted on statewide maps using geographic information system (GIS) technology. Corridors that have intersections with concentrations of these severe crashes become readily apparent once the maps were available. An alternative is to develop a computer-generated listing of intersection crashes involving serious injury or death that have occurred over the past five years by route and

sequential stationing. The listing will not be overwhelmingly large, and an insightful analysis and review can identify sections that have concentrations of severe intersection crashes.

Within the State, there are approximately 30 sections of highway where an inordinately high number of severe intersection crashes have occurred. These sections average about five miles in length, although a few approach 10 miles in length. A set of 30 corridors, which have between 30 and 85 intersection serious injuries and deaths over the 1999-2003 time period has been extracted from the crash data.

Corridors approximately five miles in length with high numbers of pedestrian crashes at intersections have been identified using the same procedures. Pedestrian corridors, including those pedestrian crashes that occur mid-block, were added because one of the key objectives is to promote and facilitate safe pedestrian crossings at intersections. This analysis yielded 12 corridors that have between 20 and 50 pedestrian crashes in the 1999 to 2003 time period.

Thus, a total of 42 corridors have been identified from the crash data. This number approaches the upper limit of what can be effectively addressed, given human and financial restraints. This information was shared with the State Police to obtain their input on problem corridors. While no sections were deleted, the State Police identified five additional priority sections that, from their perspective, have combinations of high frequencies of severe intersection crashes or heightened frequencies of serious traffic law violations (e.g., DUI, speeding, aggressive driving, and unbuckled drivers and occupants). These 47 sections form the basis for the initiative. The sections are predominantly high-volume, high-speed, multi-lane, free access arterials.

A state-level meeting was then held with the key partners to gain consensus on participating in the initiative and establishing a plan. Those partners included the State and local Transportation Departments, Governor's Highway Safety Representative, State Police, Chief of Police or Sheriffs Association (representing local police agencies), and Department of Health-Emergency Medical Services (EMS) Division. The 'team' agreed to the following goals for the corridors:

1. Ensure that the geometrics (e.g., left turn and right turn lanes, access management, etc.), and signs, signals, and markings are satisfactory from a safety standpoint. Provide the driver with the type of information needed to safely traverse the intersections. Coordinate this effort with those proposed in the low-cost initiative.
2. Attempt to address any overrepresentation of crashes at specific intersections within the corridor.
3. If there is an overrepresentation of these crashes involving a specific illegal action (e.g., speeding, other forms of aggressive driving, alcohol involvement), consider a targeted, corridor-specific, combined enforcement and education initiative to reduce the frequency of illegal actions.

Once consensus is reached, coordinating/participating concerns resolved, and upper management's approval to proceed is granted, a detailed crash analysis of each of the sections will be undertaken. The road safety audit process will be used as a model to identify and pursue improvements on the corridors.

Following the crash analysis, a combined team meeting and field view will be held for each of the corridors. Participants at this meeting will review the problems, identify activities to help others perform safety functions more effectively (e.g., maintenance clear-out and stabilize pull-off areas for enforcement, reference markers that EMS units can use to locate night crashes, clear areas for air evacuation, special signing to supplement enforcement, etc.), discuss potential solutions, and reach consensus on a set of corridor recommendations that significantly reduce the potential of future intersection deaths and serious injuries. Table 17 shows the expected number of corridors that can potentially be targeted for intersection improvements. Also, see Appendix B for a discussion on crash analyses for corridor improvement strategies.

Table 17. Corridors Identified for Intersection Improvement Strategies

Type of Concern	Corridors Recommended for Improvements Based on Initial Crash Analysis	Expected Number of Corridors Recommended for Improvements After Field Views
Infrastructure	47	30
Driver-Speed	22	18
Driver-Aggressive Driving	20	20
Driver-Alcohol Involvement	15	12
Driver-Occupant Unbelted	20	16
Post-Crash Survivability	13	10

The **infrastructure improvements** consist primarily of geometric improvements such as left and right turn lane additions or enhancements, access management enhancements, traffic signal safety upgrades, appropriate sign and marking enhancements, limited shoulder improvements, and fixed object removal or shielding. Thirty of the 47 corridors are recommended for infrastructure improvements. The estimated cost of these improvements on the 45 corridors is $15.0 million.

The **driver-oriented approach** consists of a set of enforcement/education/engineering initiatives on each of the identified corridors listed above. There are a combined 32 corridors that have at least one driver-oriented safe behavior initiative. Many of the 32 corridors have multiple driver concerns (speed, aggressive driving, alcohol, and safety belts) that need addressed. It is assumed that at least 30 person hours of dedicated, highly visible, and active enforcement (including checkpoints) per corridor per week is needed for each of the 32 corridors. The education component cannot be a conventional area-wide or targeted population approach because a large portion of the drivers come from and go to destinations beyond the corridor. Signs along the corridor that reach all of the affected motorists will be used. These signs will: (1) alert drivers of the specific problem (e.g., aggressive driving, high DUI crash area, etc.); (2) advise drivers of safe driving behaviors (e.g., obey traffic signals, slow down-save a life, don't tailgate, don't drink and drive, and buckle up); and, (3) advise drivers of the consequences of illegal actions (targeted enforcement zone). Follow-up radio and newspaper articles on the effort highlighting information on citations issued in the corridor and checkpoints held will also be developed and issued. The cost of the enforcement effort is 30 hours per week times an average $50 per enforcement hour times 52 weeks equals $78,000 per corridor each year. The engineering/education component, including signs, is estimated to cost $24,000 per corridor for a total individual corridor estimate of $102,000 annually. Thus the implementation of this driver safety initiative on the 32 corridors is estimated to be $3.3 million annually.

The **EMS enhancements** consist primarily of technical/infrastructure upgrades to improve the time and reliability of EMS units arriving at the scene, increased capability of servicing EMS units to sustain life, and facilitation for air evacuation of life threatening injuries. Ten of the 47 corridors are recommended for EMS enhancements. The estimated annual costs of these improvements for all 10 corridors with EMS concerns are $1.0 million.

The average effectiveness of the combined improvement is estimated to be 20%. Table 18 estimates that corridor safety improvements are projected to reduce serious deaths and injuries by 50 on an annual basis and cost $15 million for infrastructure improvements and $4.3 million annually for driver safety and EMS improvements.

Table 18. Cost and Impact Summary – Corridor Enforcement/Education/Engineering Initiative

Number of Corridors Identified	Number of Corridors Recommended for Infrastructure Improvement	Total Number of Five-Year Serious Injury and Death Crashes on Corridors to Be Improved	Annual Estimated Reduction of Serious Injuries and Deaths on Improved Corridors	Construction Cost ($ Million)	Enforcement Education Costs (Annual) ($ Million)	EMS Costs (Annual) ($ Million)
47	30	1,250	50	15.0	3.3	1.0

Two to three corridors should be initially identified and pursued to demonstrate the corridor safety concept. Based upon the experience of these first efforts, the concept can be expanded to remaining problem corridors.

Area-Wide Enforcement/Education/Engineering Initiative

A process very similar to the corridor approach will be initiated in municipalities that exhibit high numbers of severe intersection crashes. The crash data system is used to identify those municipalities that have had 100 or more intersection crashes over the past five years which resulted in a serious injury or death. Eight municipalities meet this criterion. These municipalities will be invited to participate in an initiative designed to reduce the frequency of future severe intersection crashes through a combination of engineering, enforcement, and education strategies.

1. **Note to the Reader:** The State will need to make a policy determination of the amount and participation rate of Federal funds to extend to municipalities.

For municipalities that agree to participate, Federal-aid funding will be made available and the municipality must agree to assume any necessary match. Once municipalities commit to the effort, the State and municipalities will jointly analyze the crash data to determine if there are municipal-wide intersection crash concerns involving sub-areas of the municipality, select streets, pedestrians, or specific crash characteristics such as running red lights. First, intersection crashes involving serious injuries or fatalities over the past five years will be plotted on municipal maps using either GIS technology or manually. Sections of the municipality and streets that have intersections with concentrations of these severe crashes become readily apparent once the maps are available. The listing of severe intersection crashes will not be overwhelmingly large, and an insightful analysis and review can yield key information on intersection crash characteristics that may be impacted by engineering, education, and enforcement strategies. A meeting will then held with the key partners to gain consensus in participating in the initiative and establishing a game plan. Those partners include (but are not limited to) the appropriate municipal officials, the Transportation Department, Governor's Highway Safety Representative, Chief of Police and/or Sheriff, and Department of Health-EMS Division. The team should discuss the results of the crash analysis and agree to develop a plan that considers at least the following:

1. The results of the crash analysis and the types and locations of problems to address.
2. The identification of any geometric features or characteristics (e.g. left turn and right turn lanes, reduced speed limits, traffic calming, and access management) and the consideration of potential signs, signals, and marking upgrades to reduce severe intersection crashes. This effort will be coordinated with the low-cost initiative.
3. The determination of sections of the municipality or select streets that have an overrepresentation of intersection crashes and need to be targeted.
4. Any overrepresentation of these crashes involving a specific illegal action (e.g., speeding, running red lights, other forms of aggressive driving, alcohol involvement, etc.), in which a targeted, combined enforcement and education initiative should be considered to reduce the frequency of the illegal actions identified.

If the death and serious injury rates are well above the average for all the municipalities or there are a high number of traffic deaths in the municipality, targeted EMS enhancements to the municipality to improve survivability should be identified.

Once consensus is reached on a plan and coordinating/participating concerns are resolved, a detailed crash analysis of each location is undertaken. The road safety audit process may be used as a model to identify and pursue improvements in the targeted areas. A good analysis is critical to a final successful outcome. Key questions similar to those identified in the corridor approach will be used in the analysis. Several combined team meetings and field views are then held for each location to review the specific issues, discuss potential solutions, and reach consensus on a set of recommendations.

The estimated acceptance, impact, and cost of the municipal-wide initiative are as shown in Table 19. It is anticipated that eight municipalities (with 900 intersection serious injuries and fatalities between 1999 and 2003) will be identified and six (with 700 serious injuries and fatalities between 1999 and 2003) will participate. As a starting point, the infrastructure construction costs are estimated to be slightly less than one million dollars per municipality or approximately five million for all six. The enforcement and education initiative is estimated to be $500,000 per municipality annually, with only incidental EMS costs.

Table 19. Cost and Impact Summary – Area-Wide Enforcement/Education/Engineering Initiative

Number of Municipalities Participating	Number of Five-Year Serious Injury and Death Crashes at Intersections	Estimated Effectiveness of Overall Effort	Annual Estimated Reduction of Serious Injuries and Deaths	Construction Cost ($ Million)	Enforcement Education Costs (Annual)	EMS Costs (Annual)
6	700	10%	14	5.0	3.0	0.0

Similar to the corridor approach, initial deployment should be limited to two or three municipalities to gain experience with the concept prior to full deployment. This experience can be used to refine the infrastructure and enforcement/education cost estimates for the remaining municipalities.

Safety and Cost Impacts of Intersection Improvement Strategies

1. **Note to the Reader:** This section pulls together the potential safety benefits in terms of achieving the goal of all strategies proposed together with the cost to implement those strategies.

The previous analyses indicate that a reduction in intersection deaths and serious injuries is achievable through the widespread deployment of a number of cost effective strategies. A compilation of candidate programs indicates that the intersection goal can not only be achieved but exceeded in a cost-effective manner. However, an estimated funding level well beyond the existing levels (Table 20) is needed to prevent over 130 annual intersection deaths and serious injuries.

Table 20. Tabulation of Costs and Impacts by Category

Category	Construction Cost ($ Million)	Enforcement, Education and EMS Costs (Annual $ Million)	Annual Intersection Serious Injuries and Deaths Reduced
State Highway System-Wide Deployment of Low-Cost, Cost-Effective Improvements (Table 14)	**17.1**		**20**
State Highway System-Wide Deployment of Medium- and High-Cost Improvements at High-Crash Locations (Table 15)	**63.2**		**40**
Local Road Intersection Safety Initiatives (Table 16)	**2.0**		**9**
State Highway Corridor Enforcement/Education/Engineering Initiative (Table 18)	**15.0**	**4.3**	**50**
Local Roads Area-Wide Enforcement/Education/Engineering Initiative (Table 19)	**5.0**	**3.0**	**14**
Total	**102.3**	**7.3**	**133**

Key Strategic Direction Issues

1. **Note to the Reader:** This section highlights important decisions and issues upper management must address if the effort is to be successfully implemented. Each state will have its own set of key decisions and directions that have to be effectively dealt with in order to be successful. Most of the issues identified in this section also should be issues for many states. These issues should be thoroughly identified, evaluated, and communicated to upper management, preferably with recommended courses of action.

Successful implementation of this initiative requires upper management guidance in three major areas: goal adjustment, funding and broad policy actions. A brief discussion of the issues in these areas follows.

Goal Adjustment

The previous analysis (summarized in Table 20) estimates that the initial goal of reducing intersection related serious injuries and deaths by 111 can be exceeded by 22 if all of the candidate strategies are successfully applied.

Due to the probable competition with other non-intersection safety initiatives for funding, combined with the unknown level of municipal participation and with the estimated (not specifically known) effectiveness of a number of the candidate improvement types, it has been decided, in consultation with upper management, to retain the initial goal of eliminating 111 serious injuries and fatalities at intersections annually and spread the funding over a four year period (with 2006 being the base year).

It has also been determined that all candidate initiatives will be retained and implemented. However, the implementation strategy will be applied to locations and municipalities that have slightly higher numbers of targeted crashes than those thresholds noted in Tables 14, 15 16 and 18, to reduce the number of improvement sites and costs. As an example, the threshold for the low cost innovative signing and marking improvements for rural unsignalized intersections will initially start at six rather than five as noted in Table 14. Tables 22 and 23 in Appendix A illustrate the potential impact of raising the threshold. Once more information is learned on the actual effectiveness of applied improvements and the proportion of locations that can accommodate improvements, the threshold levels can be refined.

Funding

If a substantive reduction in intersection deaths and serious injuries is to be achieved, funds above existing levels will likely be needed to deploy the cost-effective strategies defined in the plan. This plan estimates that the following resources will be needed to fund the level of improvements necessary to prevent over 130 intersection serious injuries and deaths per year:

- Approximately $96 million for infrastructure intersection improvements predominantly on the State highway system.
- Approximately $7.0 million for local government infrastructure intersection safety improvements.
- $7.3 million per year for corridor and municipal-wide driver safety initiatives.

The numbers may fluctuate somewhat after the next phase of development is completed, when the extent of municipal interest is known, site visits of the cluster locations occur, and more precise information on the site conditions is gathered to define the applicability of identified strategies, and costs are more refined. At this point in time, however, it is safe to conclude that some level of additional funding will be needed if the State is to realize a substantive reduction of intersection deaths and serious injuries. Considering the competing needs of other priorities, and recognizing the additional safety funding provided in the SAFETEA-LU legislation, a level of additional funding will need to be made available so that this important initiative can continue.

If all of the assumptions and estimates utilized in the analyses remain valid, then fewer candidate improvements and funds are needed to achieve 111 fewer serious injuries and deaths occurring at intersections annually. A proportional adjustment of funds needed (111/133) is initially applied to the above estimates to reflect an estimate of funds needed to attain the goal of 111 fewer serious injuries and deaths. This reduced estimated funding level is as follows:

- Approximately $80 million for infrastructure intersection improvements predominantly on the State highway system.

- Approximately $6.0 million for local government infrastructure intersection safety improvements.
- $6.1 million per year for corridor and municipal-wide driver safety initiatives.

To meet the goal by 2010 will require funding to be distributed over a four-year period, with approximately $21.5 million required annually, $1.5 million of which is needed for local road intersections.

Broad Policy Actions

Four areas where policy actions are needed to effectively implement the plan are as follows.

1. **Systematic Deployment of Cost-Effective Improvements** – Traditionally the highway safety improvement program has concentrated on addressing the highest crash locations in the State. Each year, between 50 and 70 safety improvements have been implemented, mainly at intersections and curves. For the most part, significant crash reductions have occurred at these sites. However, because of the relatively small number of improvements, the reductions in statewide numbers of deaths and serious injuries are almost negligible. Because this effort effectively addresses a number of high-crash locations, it needs to continue. However, in order to realize a decrease in the statewide numbers of deaths and injuries, an additional effort of systematically applying low-cost, cost-effective improvements at a large number of locations with documented crash histories needs to be pursued. Carefully administered, systematic deployment of key low-cost improvements can produce results of such a magnitude that the statewide numbers of targeted deaths and serious injuries can be reduced. Many of these low-cost improvements have not been used extensively in the State. It is proposed that systematic deployment proceed both cautiously and efficiently to expeditiously resolve design and application issues, while ensuring program cost-effectiveness.
2. **Enhanced Sign and Marking System and Automated Red Light Running Traffic Signal Enforcement** – Widespread use of these two strategies, which are rarely applied in the State, is very important in attaining the goal. Addressing the underlying causes of severe crashes at unsignalized intersections is important with enhanced signs and markings. Sign and marking enhancements that conform to the 2003 Manual on Uniform Traffic Control Devices (MUTCD) can result in significant intersection safety improvements. Careful analysis and innovative thinking will be needed to identify promising combinations that have the potential to substantively improve safety. A team including representatives of the Department, university, FHWA, and a human factors expert should analyze the crash characteristics, identify the most promising sign/marking combinations, and develop the criteria for deployment. It is proposed that these enhanced treatments be applied at approximately five to 10 intersections during the upcoming construction season to get some experience and evaluation of these improvements. The Department can then consider expansion, learning from the experiences and safety performance on these test intersections.

   Pursuit of enabling legislation is a first step for implementation of automated red light running traffic signal enforcement. A legislative strategy and package need to be developed to achieve passage of the required law. The legislative package should provide information on the level of red light running and crashes in the State, a description of the automated enforcement concept, provisions that restrict automated enforcement to intersections with red light running concerns, items that will make the legislation acceptable and fair to citizens, a summary of experience and use in other States, an assessment of the potential safety impact (i.e., lives saved and serious injuries reduced), and suggested model legislation.

3. **Formation of Multi-Disciplinary Teams to Pursue Corridor and Municipal-Wide Intersection Safety Improvements –** Historically, safety has been implemented by a number of agencies but each agency almost always performs the work in isolation. Combining these independent entities as a team addressing specific corridor and area-wide intersection problems has the potential to yield synergistic results and dramatically improve safety. It would be desirable that the Transportation Department to take the lead to form multi-disciplinary teams and address the severe crash problems on two to three targeted corridors. Based on the experiences of these first efforts, the concept can be expanded to remaining problem corridors and municipal-wide concerns.
    1. **Note to the Reader:** If the State has a statewide steering committee or developing a comprehensive highway safety plan, it is important that this initiative with each of those activities to insure consistency and reduce the potential for stove piping.
4. **Technical and Financial Assistance to Local Governments to Implement Safety Improvements at Locations with Crash Histories** – Almost 20% of all serious injuries and deaths at intersections occur off the State highway system. Realistically, safety on local roads needs to improve if statewide reductions are to occur. Past experience indicates that improvements will not be implemented extensively on local roads unless federal funds and technical assistance are extended to the municipality. It is proposed that the State policy: (1) extend funds to municipalities to implement targeted, cost-effective, safety improvements at local road locations that have a crash history; (2) adapt the Transportation Improvement Program process to provide federal funds to municipalities for this safety initiative; and, (3) extend additional resources to the LTAP program to provide the necessary technical assistance to successfully implement this component.

Next Steps

1. **Note to the Reader:** This section describes the probable next steps states will take once direction and guidance are obtained from upper management. It is left relatively open-ended so as not to second guess upper management's decisions.

Once upper management provides direction on the above funding and policy issues, implementation of the strategies in this plan will commence in accordance with the guidance received. It is envisioned that a program of projects with milestones, schedules, performance measures, and an evaluation plan will be developed for each strategy.

It is important to keep upper management apprised of any adjustments needed to attain the goal. With all of the assumptions and estimates necessary for the analyses, outcome variations due to actual verses estimated improvement effectiveness, the number of sites that can actually accommodate specified improvements verses those planned, actual verses estimated costs, and the actual verses planned number of municipalities willing to participate in the initiatives, modifications to the plan are likely going to be needed. It is suggested that a midcourse adjustment to the plan be initiated about two years into implementation that reflects actual effectiveness values, costs, municipal participation rates, and a refined estimate of the effort and adjustments needed to achieve the goal.

Appendix A – Cost Effectiveness Data Analysis for Improvement Strategies

1. **Note to the Reader:** This appendix provides a description of the cost effectiveness data analysis performed to determine the costs and impacts of each improvement strategy. The description is provided by way of an example from the system-wide, low-cost, cost-effective improvements. This data analysis process is the same for all improvements discussed in the Sample Plan. States should consider including an appendix of data analysis work as part of their Plans.

Improvements deployed on a systematic basis have to be cost-effective. A benefit/cost analysis is used to make the determination. However, unlike a conventional analysis, the B/C is given or set, and the answer one seeks is the number of targeted crashes per intersection needed to make the improvement cost-effective. The formula is as follows:

T =(Annual Cost)(B/C)/(Effectiveness)(Average Crash Cost)

Where:

- T =Threshold level of targeted crashes per intersection to consider the strategy to be cost effective. In Table 21 below, T is the threshold level of targeted crashes needed over a five-year period to achieve a B/C ratio of 2.0
- Annual (Ann.) Cost =The annual cost of the improvement. For construction improvements, Ann. Cost is the construction costs annualized over the expected life of the improvement. For an education or enforcement improvement, Ann. Cost is the annual cost of a full year of enforcement or education.
- B/C =The set benefit/cost ratio used to determine the threshold level of targeted crashes per unit. It is usually between 1.0 and 2.0. In this case a value of 2.0 is used.
- Effectiveness (Eff.) =The estimated effectiveness of the strategy in reducing targeted crashes derived from information in the guidance documents identified on page 14 of the Plan.
- Average (Avg.) Crash Cost =The average cost of targeted crashes.

A five-year crash history (1999 to 2003) is used in the analysis to provide more data on crash occurrences. Application of the above formula to the low-cost system deployments, using a B/C of 2.0, yields the minimum threshold crash level information in Table 21. Because of the low unit cost, it does not take many crashes to justify an improvement.

Table 21. Threshold Level Analysis Results for System-Wide Deployment of Low-Cost, Cost-Effective Improvements (Threshold Crash Levels)

Type of Improvement	Target Crashes	Unit	Construction Cost ($)	Expected Life (Years)	Average Crash Cost	Estimated Effectiveness	T (Five-Year Threshold Crash Level)
Enhanced Sign and Marking Systems	All crashes at rural unsignalized intersections	Unsignalized rural intersection	3,000	5	40,000	0.15	1.00
	All crashes at urban unsignalized intersections	Unsignalized urban intersection	3,000	5	16,000	0.15	2.5
Minor Traffic Signal Improvements	All crashes at rural signalized intersections	Signalized rural intersection	30,000	10	18,000	0.15	11.1
	All crashes at urban signalized intersections	Signalized urban intersection	30,000	10	10,000	0.15	20.0
Stop Approach Improvements (e.g. Rumble Strips on the Stopped Approach)	All crashes at rural unsignalized intersection crashes where the causation factor is a driver 'ran the stop sign'	Unsignalized rural intersection	25,000	10	40,000	0.50	1.25

The crash data system is searched to find intersections with crashes above the threshold and estimates of the cost and impact of the low-cost improvements are made. The five-year crash data also is sorted into separate groups reflecting the target crash categories above. Those groups are as follows:

- Unsignalized intersections in rural areas.
- Unsignalized intersections in urban areas.
- Signalized intersections in rural areas.
- Signalized intersections in urban areas.
- Unsignalized rural intersections where 'running the stop sign' is a causal factor.

As an example, for enhanced sign and marking systems at unsignalized intersections (Table 21, first improvement type), the distribution of rural unsignalized intersection crashes is shown in Table 22. (Tables for the other target crash categories should also be developed.)

Table 22. System-Wide Deployment of Low-Cost, Cost-Effective Improvements –Unsignalized Rural Intersection Five-Year Crash Array

Number of Crashes per Intersection	1	2	3	4	5	6-9	10-15	>15	Total
Number of Crashes	8,000	7,000	6,000	2,400	1,500	2,400	2,000	2,500	31,800
Number of Intersections	8,000	3,500	2,000	600	300	300	160	120	14,980
% of Crashes	25.2	22.0	18.9	7.5	4.8	7.5	6.3	7.8	100.0

1. **Note to the Reader:** Developing the above table should be relatively easy if a State locates intersection crashes to a unique location identifier within the data system. If a State does not have a unique identifier and intersection crashes are tied to a major road reference point that might vary slightly from intersection crash to intersection crash, it is still possible to accumulate intersection crashes by establishing a tight (±500 feet of the intersection) intersection cluster length on the major road.

Table 23 shows that above the three crashes per intersection level, about one-third of all the crashes occur on less than 1,500 intersections. At this point it is assumed that upon site inspection, only 90% of the eligible intersections will be eligible for enhanced sign and marking improvements. A tabulation of the incremental cost and impact of cost-effective enhanced sign and marking systems for rural unsignalized intersections is as follows.

Table 23. Enhanced Sign and Marking Impacts – Rural Unsignalized Intersections

Minimum Crash Level	Number of Five-Year Crashes	Number of Rural Unsignalized Intersections	Construction Costs ($Million)	Five-Year Crash Reduction	One-Year Crash Reduction	One-Year. Serious Injury and Fatality Reduction
3	16,800	3,480	10.4	2,520	504	23
4	10,800	1,480	4.4	1,620	324	15
5	8,400	880	2.6	1,260	250	12
6-9	6,900	580	1.7	1,035	210	10
>10	4,500	280	0.8	675	135	6

Note that the one-year serious injury and fatality reduction is calculated by multiplying the one-year crash reduction by the average unsignalized rural intersection serious injuries and fatalities per 100 crashes (4.6 serious injuries and deaths per 100 crashes) from Table 13.

In this example, a summary of costs and crash reduction impact by strategy is provided in Table 24. (Note: Table 24 is a reproduction of Table 14 in the body of the Plan.) A summary of how Table 24 was populated follows:

- A higher threshold of crashes per unit intersection is selected above that calculated in Table 21 and is shown in Column 2 of Table 24. Because of the large number of independent variables that impact when and where crashes occur, a higher threshold has been established for each category to better insure that, if no actions are taken, a crash problem may exist in the future considering regression to the mean.
- The crash data system is used to identify the statewide number of clusters of targeted crashes per unit intersection type that equal or exceed this threshold (Column 3 of Table 24).
- The total number of targeted crashes that occur at these intersections is provided in Column 4.
- An estimate of the number of intersections that can be improved is provided in Column 5 of Table 24. Not all of the intersections can be improved using low cost improvements for a variety of reasons. As an example, one of the intersections may have a stone and chip surface and not be suitable for pavement markings. This estimate will be refined in the next stage of development with site visits to determine the applicability of a designated low-cost improvement.
- The total estimated cost of Column 5 improvements is provided in Column 6 and is the product of the estimated number of improvements multiplied by the average unit cost per improvement.
- Column 8 estimates the number of annual targeted crashes reduced. This is based on the proportional estimate of targeted crashes that occur at all of the sites estimated to be improved multiplied by the estimated effectiveness of the improvement type {Column8=Column4x(Column5/Column3)(Eff.)/5}.
- The estimated number of annual serious injuries and deaths reduced (Column 9) is computed by multiplying the annual number of targeted crashes reduced (Column 8) by the appropriate “deaths and serious injuries per 100 crashes” value found in Table 13.

Table 24. Cost and Impact Summary – Low-Cost, Cost-Effective Improvements (Crash Data Systems That Can Locate Crashes by Specific Location on a Route)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Category	Threshold Crash Level (Five Years)	Number of Statewide Crash Intersections	Number of Targeted Five-Year Crashes in the Intersections	Estimated Number of Improvements	Construction Costs ($ Million)	Type of Crash Reduced	Annual Targeted Crash Reduction	Annual Serious Injury and Fatality Reduction
Enhanced Sign and Marking – Unsignalized Rural Intersections	5 crashes	880	8,400	800	2.4	Intersection	230	11
Enhanced Sign and Marking – Unsignalized Urban Intersections	10 crashes	350	6,000	300	0.9	Intersection	154	3
Rural Traffic Signal Minor Enhancements	15 crashes	35	450	30	0.9	Intersection	12	<1
Urban Traffic Signal Minor Enhancements	20 crashes	450	15,000	400	12.0	Intersection	400	4
Stop Approach Improvements at Rural Unsignalized Intersections	3 running stop sign crashes	48	200	36	0.9	Intersection (running stop sign)	15	1

Total					17.1		811	20

Appendix B – Crash Analysis for Corridor /Area-Wide Enforcement/Education/Engineering Improvement Strategies

1. **Note to the Reader:** This appendix provides key questions to ask and information to be gathered through crash analysis for corridor and area-wide enforcement/education/engineering improvement strategies.

A detailed crash analysis of each corridor/area will be conducted once consensus is reached, coordinating/participating concerns resolved, and upper management's approval to proceed is granted. Key questions to be asked in the analysis are as follows:

- Are specific types of intersection crashes overrepresented in the corridor and can they be related to geometries or access management deficiencies (e.g., left and right turn lanes, movements from specific driveways) that need to be improved?
- Are angle or pedestrian crashes a problem in portions of the corridor? If so, what are the geometries and traffic control devices in the intersection?
- Are there concentrations of crashes at select intersections or sections of the corridor? If so, where?
- Is the level of illegal driving actions reported in the crash data for a given corridor overrepresented? (i.e., Does the corridor have high levels or proportions of speed related, reckless driving, illegal passing, or alcohol involvement?) If so, what are the characteristics of these crashes in terms of time of day, day of week, driver age and sex, and type of vehicle?
- What percentage of the serious injuries and deaths involve an unbelted driver or occupant? What is the total number of unbelted serious injuries and deaths? Does the corridor have an overrepresented number of unbelted deaths and serious injuries? If so, what are the characteristics of these unbelted severe crashes in terms of time of day, day of week, and age and sex of unbelted victim?
- What are the numbers of intersection deaths that have occurred over the past five years for each corridor? Which corridors are highest?
- What is the ratio of deaths/deaths and serious injury crashes for each corridor? Which corridors have the higher ratios?

From an engineering perspective, the following information may also be gathered:

- Are there any planned roadway improvements that may impact the problem? What are they and when is it estimated they will be implemented?
- Are there opportunities to reduce excessive speeds through traffic calming measures? If so, what are they?
- What are the possibilities of adding special signing to complement corridor targeted enforcement and education initiatives on those corridors in which safer driving behavior is being pursued?
- Are there other opportunities to reduce intersection and/or pedestrian deaths and severe injuries from an engineering perspective?

From an enforcement perspective, the following information may also be gathered for corridors that exhibit a high number or proportion of severe crashes involving any one of the specific illegal actions:

- Is there firsthand knowledge of the key characteristics of specific illegal driver actions resulting in the severe crashes on identified corridors that can supplement the information gathered from the police crash reports?
- Do illegal actions reported from the police crash reports make sense in comparison with enforcement patrol experience and observations? Are there other serious concerns?
- Are there major sections within the corridor where enforcement is not practical because there are no safe pull-off areas?
- If a high rate of alcohol involvement exists in the corridor, are there drinking establishments within close proximity that may be contributing to the problem?
- Do the times and days of frequent severe crashes align with the enforcement patrols level and tactics that serve the corridor?
- Are there other opportunities to reduce the level of specific illegal actions identified on the corridor?

From an EMS perspective, for corridors that either have a high number of deaths or a high proportion of death/serious injury or death crashes, the following information may be gathered:

- Are there significant difficulties in locating severe crashes, particularly at night, which have resulted in substantive loss of time in arriving at the scene? What are the root causes of those difficulties? Can they be addressed? Are there other opportunities that can improve the arrival time?
- What is the level of EMS units training and capability that frequently serve the corridor?
- Can air evacuation be provided on the corridor? If not, are there clearance problems that could be addressed to provide air evacuation?
- Are there other opportunities to improve survivability once a severe crash occurs on the corridor?

Appendix C - Statewide Initiatives to Improve Safe Driving Behavior

1. **Note to the Reader:** This section discusses the importance of statewide initiatives and their potential impact on intersection safety. It is important to document this tie-in particularly if a State is also developing a strategic highway safety plan. In addition, the development of any intersection plan should be completely coordinated with the strategic plan. The intersection plan can be considered a subset of the strategic plan or a detailed action plan for one of the key emphasis areas in the strategic plan.

It is anticipated that statewide action plans to reduce drinking and driving (e.g., stronger DUI laws and more sobriety checkpoints), increase safety belt usage, decrease aggressive driving, promote young drivers and senior driver safety, and improve rural EMS will also help reduce the statewide number of intersection serious injuries and deaths. A short discussion of these initiatives and their impact on intersection strategies follows.

Reduced Drinking and Driving

The State currently has a 0.08 law and conducts a limited number of sobriety checkpoints. This initiative calls for much stronger penalties for BAC levels above 0.15, second and multiple DUI offenses, and drivers with suspended/revoked licenses who continue to drive. In addition, the sobriety checkpoint program will be greatly expanded from approximately 50 to 1,000 checkpoints conducted annually. These efforts will be complemented by a statewide marketing and education campaign.

Increase Safety Belt Usage

In 2003 the State safety belt use rate is 75%. The proposed action plan calls for enactment of a primary safety belt law and an expansion of the 'Click It or Ticket' campaign to four additional periods of the year.

Aggressive Driving

The primary thrust of this initiative is to reduce the levels of excessive speeding on rural interstates and major and minor rural arterials.

Young Drivers

The primary initiative in this area is to create a graduated driver licensing system through legislation for new drivers. The proposed legislation will be based upon the model law and include provisions that require parent or guardian driving supervision for the first six months of permit, an 11:00 PM curfew for provisional licensees, increased penalties for traffic violations during the provision phase, and only one peer passenger during the provisional phase.

In addition since young drivers have a disproportionate number of intersection crashes, particularly when pulling out from a stopped approach, the driver examination requirements and the driver education classes will be upgraded to provide additional guidance on selecting safe gaps when entering an intersection.

Older Drivers

This initiative will be coordinated with the older driver safety initiative. In particular, older drivers have a disproportionate number of intersection crashes and difficulties ascertaining safe gaps to enter or cross traffic. This initiative will promote education opportunities for safe entrance and crossings at intersections for older drivers and increased vision screening.

Rural Emergency Medical Services (EMS)

The rural EMS action plan will dramatically reduce the amount of time from when a crash occurs to the arrival of a patient at the hospital. A much more rapid detection system using cell phones, global positioning satellite (GPS) systems, and other technologies and a more time-efficient evacuation system to the hospital (primarily helicopter evacuations) are the primary components of the plan. This initiative is expected to save a considerable number of lives in remote rural areas. It will have no or minimal impact on the combined serious injury and fatal number since nearly all of the people who live (who would have otherwise perished without the EMS enhancements) will suffer a serious injury.