U.S. Department of Transportation
Federal Highway Administration

Example Intersection Safety Implementation Plan

July 2009

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

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Executive Summary

The State Strategic Highway Safety Plan (SHSP) has an updated safety goal of reducing the number of annual fatalities within the State to no more than 850 by 2012. This is a 14.3 percent reduction from the 992 fatalities that occurred in 2008. Intersection fatalities within the State have averaged 197 annually over the 2003-2008 time period. The intersection portion of the goal is 28 fewer intersection fatalities by 2012.[1]

A workshop composed of State Department of Transportation (DOT) safety personnel (i.e., State Safety Engineer, State Traffic Engineer, Governor's Highway Safety Representative), District Office Traffic Engineering Operations personnel, Local Road Coordinator, and external representative safety partners (e.g., Metropolitan Planning Organization representative, City Traffic Engineer, Regional Planning Coordinator, State and Local Police representatives) was held on January 21-22, 2009, to identify safety initiatives in the intersection emphasis area that could help achieve the intersection safety goal. The results of that workshop indicate that the intersection goal can be achieved by 2012 with the following provisions:

- The traditional approach of relying primarily on pursuing major improvements at high-crash intersections must be complemented with a) a systematic approach that involves deploying large numbers of relatively low-cost, cost-effective countermeasures at many targeted high-crash intersections and b) a comprehensive approach that coordinates an engineering, education, and enforcement (3E) initiative on corridors and in urban areas with large numbers of severe intersection crashes.
- The systematic and comprehensive approaches will generate a much larger number of intersection improvements statewide, and District traffic personnel will have to take a more active role in identifying the appropriateness of systematic improvements within their Districts.
- To achieve the intersection safety goal, it will take an investment of approximately $50 million beyond currently programmed intersection safety projects over the 4-year period, or $12.5 million annually to achieve the goal. These funds need to be available between now and 2012 to deploy the needed cost-effective improvements. Some of the countermeasures can be implemented by State DOT personnel and by local municipalities, reducing the level of funding needed.
- To ensure success, the upper management within the State DOT should provide leadership and guidance during the implementation phase

The bottom line of a successful implementation of this plan is that once fully implemented over a 10-year period, more than 54,000 intersection crashes and 3,080 disabling injuries will be prevented along with at least 270 lives saved.

[1] The intersection portion of the goal is calculated by multiplying the average annual number of intersection fatalities (197) by the SHSP's safety goal's rate of reduction (0.143), or 197×0.143 = 28.

Background

The State SHSP has an overall goal to reduce the number of fatalities on State roads to no more than 850 by 2012. This is a 14.3 percent reduction from the 992 fatalities that occurred in 2008. One of the emphasis areas identified in the SHSP is to improve intersection safety. Intersection fatalities within the State have averaged 197 annually over the 2003-2008 time period. The SHSP provides insight on broad initiatives in the intersection safety area to support achieving the overall goal, but it lacks detail regarding countermeasures, actions, deployment characteristics, costs, impacts, and key steps that have to be taken to significantly improve intersection safety. The intersection portion of this goal is projected to be 28 fewer annual intersection fatalities by 2012.[2] The purpose of this Plan is to provide the specifics on countermeasures, actions, key steps, schedules, and investments needed to achieve that goal.

[2] The intersection portion of the goal is calculated by multiplying the average annual number of intersection fatalities (197) by the SHSP's safety goal's rate of reduction (0.143), or 197×0.143 = 28.

The Intersection Safety Goal

Over the past several years, the number of intersection fatalities within the State has had minor fluctuations as indicated in Table 1.

Table 1. State Intersection Fatalities

	2003	2004	2005	2006	2007	2008	Average
Number of Intersection Fatalities	214	184	187	210	187	200	197

The SHSP goal is to reduce the number of fatalities by 14.3 percent by 2012. Applied to intersections, this results in a decrease in intersection fatalities from an average of 197 per year to no more than 169 per year.[3]

The Approach

In the past, traditional intersection safety program efforts have been based upon identifying and analyzing individual high-crash intersections from the crash data system, defining crash patterns, determining appropriate countermeasures, and then implementing those countermeasures. While this is an important approach and needs to continue, it has limited impact in terms of reducing statewide numbers of intersection fatalities.

To help lower statewide intersection fatalities, two additional initiatives are recommended to be undertaken as follows:

- Systematic application of large numbers of cost-effective, low-cost countermeasures.
- Comprehensive application of low-cost infrastructure improvements coupled with targeted education and enforcement initiatives on an area and corridor basis.

The systematic approach is the reverse of the traditional approach in that low-cost, effective countermeasures are first identified and then the crash data system is searched to identify a large number of high-crash intersections where the countermeasure can be cost-effectively deployed. Estimates of the impacts of the deployments can be made in terms of projected statewide cost-effective deployment levels, annual lives saved, and deployment costs.

The comprehensive approach combines sets of cost-effective, low-cost infrastructure countermeasures with a coordinated set of education and enforcement initiatives targeted to intersection safety. The comprehensive approach is normally applied on a highway corridor or city-wide basis targeting the reduction of severe intersection crashes.

Distribution of the State Intersection Fatality Problem

The State intersection crash and fatality data was analyzed to gain insight on the distribution and characteristics of the intersection crash problem. Key information derived from the intersection data analysis is shown in Tables 2-4.

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[3] The decrease in intersection fatalities is calculated by decreasing the average annual number of intersection fatalities (197) by the SHSP's safety goal's rate of reduction (0.143), or 197×(1-0.143) = 169.

Table 2. Intersection Crashes, Fatalities, and Incapacitating Injuries for Signalized Intersections – 2003-2008

Locality	Total Crashes	Total Fatalities	Fatalities Per 100 Crashes	Total Incapacitating Injuries	Incapacitating Injuries Per 100 Crashes
State Roads					
Rural	4,107	17	0.41	227	5.53
Urban	73,913	124	0.17	2,482	3.36
Total	78,020	141	0.18	2,709	3.47
Local Roads					
Rural	676	5	0.74	11	1.63
Urban	73,815	159	0.22	2,160	2.93
Total	**74,491**	**164**	**0.22**	**2,171**	**2.91**

Table 3. Intersection Crashes, Fatalities, and Incapacitating Injuries, for Stop-Controlled Intersections – 2003-2008

Locality	Total Crashes	Total Fatalities	Fatalities Per 100 Crashes	Total Incapacitating Injuries	Incapacitating Injuries Per 100 Crashes
State Roads					
Rural	30,232	483	1.60	3,769	12.47
Urban	82,710	177	0.21	2,734	3.31
Total	112,942	660	0.58	6,503	5.76
Local Roads					
Rural	10,154	53	0.52	531	5.23
Urban	139,491	164	0.12	3,275	2.35
Total	149,645	217	0.15	3,806	2.54

- Over 40 percent of the fatalities occur on the State rural system at stop-controlled intersections.
- Over half of the statewide crashes and over one fourth of the fatalities occurred at local urban intersections.

Table 4. Summary of Intersection Crashes, Fatalities, and Incapacitating Injuries – 2003-2008

	State Rural Signal	State Rural Stop-Controlled	State Urban Signal	State Urban Stop-Controlled	Local Rural Signal	Local Rural Stop-Controlled	Local Urban Signal	Local Urban Stop-Controlled
All Crashes								
Crashes	4,107	30,232	73,913	82,710	676	10,154	73,815	139,491
Fatalities	17	483	124	177	5	53	159	164
Incapacitating Injuries	227	3,769	2,482	2,734	11	531	2,160	3,275
Fatalities per 100 Crashes	0.41	1.60	0.17	0.21	0.74	0.52	0.22	0.12
Incapacitating Injuries per 100 Crashes	5.53	12.47	3.36	3.31	1.63	5.23	2.93	2.35
Divided Highway Crashes								
Crashes	829	3,799	21,266	17,814	6	6	909	1,185
Fatalities	8	142	54	65	-	-	5	4
Incapacitating Injuries	76	863	856	637	-	-	32	52
Fatalities per 100 Crashes	0.97	3.74	0.25	0.36	-	-	0.55	0.34
Incapacitating Injuries per 100 Crashes	9.17	22.72	4.03	3.58	-	-	3.52	4.37
Angle Crashes								
Crashes	1,588	14,393	27,278	28,677	238	4,066	31,643	54,978
Fatalities	11	346	66	129	5	26	86	97
Incapacitating Injuries	148	2,404	1,520	1,632	5	316	1,323	1,842
Fatalities per 100 Crashes	0.69	2.40	0.24	0.45	2.10	0.64	0.27	0.18
Incapacitating Injuries per 100 Crashes	9.32	16.70	5.57	5.69	2.10	7.77	4.18	3.35
Left-Turn Crashes								
Crashes	1,266	-	21,172	-	196	-	19,742	-
Fatalities	5	-	35	-	1	-	39	-
Incapacitating Injuries	77	-	1,127	-	2	-	757	-
Fatalities per 100 Crashes	0.39	-	0.17	-	0.51	-	0.20	-
Incapacitating Injuries per 100 Crashes	6.08	-	5.32	-	1.02	-	3.83	-
Pedestrian Crashes								
Crashes	7	11	236	41	1	15	879	373
Fatalities	1	-	5	-	-	-	29	5
Incapacitating Injuries	3	2	66	4	0	4	170	56
Fatalities per 100 Crashes	-	-	2.12	-	-	-	3.30	1.34

	State Rural Signal	State Rural Stop-Controlled	State Urban Signal	State Urban Stop-Controlled	Local Rural Signal	Local Rural Stop-Controlled	Local Urban Signal	Local Urban Stop-Controlled
Incapacitating Injuries per 100 Crashes	42.86	18.18	27.97	9.76	0	26.67	19.34	15.01
Dark Crashes								
Crashes	721	5,050	17,840	13,234	110	1,618	17,814	28,118
Fatalities	7	111	54	29	3	13	81	73
Incapacitating Injuries	53	847	683	544	1	91	631	765
Fatalities per 100 Crashes	0.97	2.20	.30	0.22	-	0.80	0.47	0.28
Incapacitating Injuries per 100 Crashes	7.35	16.77	3.83	4.11	0.91	5.62	3.54	2.72
Wet Pavement Crashes								
Crashes	433	3,238	5,136	2,506	27	345	5,136	1,548
Fatalities	5	48	7	1	-	1	7	2
Incapacitating Injuries	31	428	154	246	2	46	25	28
Fatalities per 100 Crashes	-	1.48	0.14	-	-	-	0.14	-
Incapacitating Injuries per 100 Crashes	7.16	1.22	3.00	5.06	7.41	13.33	1.61	1.12

Summary of Countermeasures

A summary of the countermeasures, deployment levels, costs, and estimated lives saved using these three approaches is provided in Table 3.

Table 5. Countermeasures, Costs, Deployment Levels, and Estimated Fatality Reductions

Countermeasure	Approach	Number of Intersections to be Improved	Construction Cost ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
Basic Set of Sign and Marking Improvements –State Stop-Controlled Intersections	Systematic	1,108	8.87		1,382	117.7	13.07
Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons – State Stop-Controlled Intersections	Systematic	69	0.69		54	4.0	0.44
J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections	Systematic	56	16.80		77	17.5	2.87
Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections	Systematic	236	1.89		555	15.1	0.71
Basic Set of Signal and Sign Improvements – State Signalized Intersections	Systematic	395	1.92		789	28.1	1.52
Change of Permitted and Protected Left-Turn Phase to Protected Only – State Signalized Intersections	Systematic	536	2.67		819	44.0	1.49
Advance Detection Control Systems – State Signalized Intersections	Systematic	67	1.00		45	4.2	0.31
Basic Set of Signal and Sign Improvements – Local Signalized Intersections	Systematic	263	2.63		670	19.5	1.51
Change of Permitted and Protected Left-Turn Phase to Protected Only – Local Signalized Intersections	Systematic	387	1.94		623	23.7	1.27
New or Upgraded Lighting – State Rural Intersections	Systematic	64	3.84		49	8.4	1.08
High-Friction Surface – State Intersections	Systematic	53	2.65		86	11.3	1.27
Enforcement-Assisted Lights	Systematic	1 City	0.09	0.05	45	2.3	0.11

Countermeasure	Approach	Number of Intersections to be Improved	Construction Cost ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes	Comprehensive	3 Corridors	6.00	0.30	83	7.5	1.25
Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes	Comprehensive	1 City	1.0	0.10	383	6.6	0.57
Roundabouts	Traditional	3	2.4		32	3.0	0.36
Total			**54.39**	**0.45**	**5,692**	**312.9**	**27.83**

Key First Steps

There are several key first steps that need to be taken before actual countermeasure implementation activities begin.

1. The draft implementation plan should be presented to the Districts and other affected Headquarters organizations to share, review, provide input, and accept the content.
2. The funding level needed to fully implement the plan ($52 million over 4 years) may pose a funding problem for the State DOT when taking other safety priorities and obligation limits into consideration. A financial analysis needs to be undertaken to identify the probable level of available Highway Safety Improvement Program (HSIP) funds, 402 funding for the education and enforcement components, and other safety funds that may be available to finance this initiative considering committed safety projects currently programmed. In addition, some of the countermeasures, such as the sign and marking enhancements on State highways, may be considered for implementation by District Offices without Federal funds.
3. Upon review, acceptance, and modification of the Intersection Safety Implementation Plan by the Districts and affected Headquarters organizations and completion of the financial analysis, the final draft intersection implementation plan should be presented to State DOT upper management for acceptance, modification, or rejection. Once guidance is received, the Intersection Safety Implementation Plan and the SHSP need to be reviewed and potentially updated to reflect the guidance provided.

It is projected that items 1 through 3 can be accomplished within the next 6 months, and implementation activities can then commence. The State Safety Engineer will lead the completion of these steps.

Implementation

The successful implementation of the multiple strategies in the plan will require constant and broad management support. It is expected that as the effort is implemented, unforeseen problems will arise, new opportunities will develop, and changes in direction and emphasis will be needed to take advantage of changing conditions. As such, the following actions should be taken to ensure success.

- A Highway Safety Committee comprised of the following members should provide guidance and address issues and problems that arise during the implementation of the program. The Committee should meet on a planned quarterly basis throughout the implementation phase.
  - Office of Safety.
  - Office of Traffic Engineering Operations.
  - Governors Highway Safety Representative.
  - Federal Highway Administration (FHWA) Safety Representative.
  - District Traffic/Safety Representative.
- The State DOT Office of Safety should develop and deploy a tracking system to monitor the implementation of the various types of countermeasures being deployed. This system should include forms designed to secure before and after targeted crash histories, dates of implementation, linkages to other improvements implemented at the intersection, and other information deemed pertinent by the Highway Safety Committee.

The remainder of this section provides a detailed description of and key implementation steps for each countermeasure to be implemented. A tabulation of the countermeasures and type of approach is shown in Table 6.

Table 6. Intersection Safety Countermeasures by Approach Type

Number	Countermeasure	Approach
1	Sign and Marking Improvements – State Stop-Controlled Intersections ➢ Basic Set of Sign and Marking Improvements ➢ Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons ➢ Optional Signing and Marking Improvements Based on the Characteristics of the Intersection	Systematic
2	J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections	Systematic
3	Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections	Systematic
4	Signal and Sign Improvements – State Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Optional Signal and Sign Improvements Based on the Characteristics of the Intersection ➢ Change of Permitted and Protected Left-Turn Phase to Protected Only ➢ Advance Detection Control Systems	Systematic

Number	Countermeasure	Approach
5	Signal and Sign Improvements – Local Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Change of Permitted and Protected Left-Turn Phase to Protected Only	Systematic
6	New or Upgraded Lighting – State Rural Intersections	Systematic
7	High-Friction Surface – State Intersections	Systematic
8	Enforcement-Assisted Lights	Systematic
9	Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes	Comprehensive
10	Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes	Comprehensive
11	Roundabouts	Traditional

1. Sign and Marking Improvements – State Stop-Controlled Intersections

Description

Basic Set of Signing and Marking Improvements

This initiative involves the installation of a set of basic signing and marking improvements that are collectively low-cost, designed to lower the potential of future crashes significantly, and are to be applied predominantly on single through lane, high-crash, stop-controlled State intersections in both rural and urban areas. They may also be applied on dual through lane, high-crash, stop-controlled intersections with lower traffic volumes (less than about 25,000 average annual daily traffic (AADT)) where the use of J-treatments is not appropriate and the frequency of acceptable gaps for entering traffic is such that long waiting and higher risk taking are not present at the intersection.

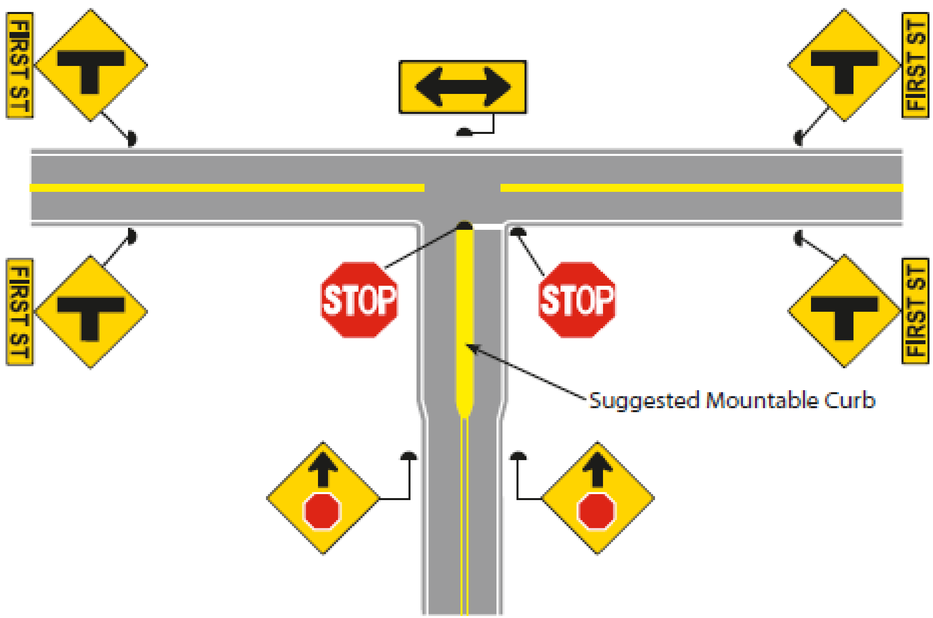

Figure 1. Examples of Basic Low-Cost Countermeasures for Stop-Controlled Intersections – Double Up Oversize Warning Signs, Double STOP Signs, Traffic Island on Stop Approach (if feasible), Street Name Signs, Stop Bars, and Double Warning Arrow at the Stem of T-Intersections

Basic enhancements considered for improvement are illustrated in Figure 1 and include the following:

- Through approach.
  - Doubled up (left and right), oversize advance intersection warning signs, with street name plaques.
- Stop approach.
  - Doubled up (left and right), oversize advance "Stop Ahead" intersection warning signs.
  - Doubled up (left and right), oversize STOP signs.

- Installation of a minimum 6 ft. wide raised splitter island on the stop approach (if no pavement widening is required).
- Properly placed stop bar.
- Removal of any foliage or parking that limits sight distance
- Double arrow warning sign at stem of T-intersections.

The high-crash intersections where the basic set of signing and marking improvements are to be considered for installation are summarized in Table 7. The State Safety Engineer has a complete listing of all intersections with numbers of crashes that meet or exceed the threshold levels in this and all remaining tables. In addition to this listing, detailed crash information for each crash that occurred at these intersections is also available.

Note to the Reader: The threshold crash levels in the following tables are selected based on the estimated maximum number of intersections that can be improved by the countermeasure within the timeframe of the implementation plan. For example, in Table 7 the threshold of 6 crashes in 6 years (i.e., an average of 1 crash per year) for basic sign and marking improvements at State rural stop-controlled intersections was selected based on a maximum of 1,000 statewide intersections that can be improved within the 5-year implementation plan period. In Table 12, the crash threshold of 6 crashes in 6 years (i.e., average of 1 crash per year) for basic sign and marking improvements at local rural stop-controlled intersections was selected for equivalency with the threshold established for State rural stop-controlled intersections in Table 7.

Table 7. Basic Set of Sign and Marking Improvements – State Stop-Controlled Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Basic Set of Sign and Marking Improvements – Rural	6	1,221	13,722	977	7.82	1.60	12.47	732	91.20	11.71
Basic Set of Sign and Marking Improvements – Urban	50	165	12,180	131	1.05	0.21	3.31	650	21.50	1.36
Total				1,108	8.87			1,382	117.7	13.07

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $8,000 per intersection.

[3] A CRF of 0.40 is used.

Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons

In addition to the basic sign and marking enhancements at State stop-controlled intersections, this initiative also involves the installation of supplemental warning notification for the traveling public at State stop-controlled intersections with a number of crashes that is well beyond the crash threshold for sign and marking enhancements. The enhanced warning notifications may be either solar-powered LED flashing beacons placed on the oversized advance warning signs for the through approach, or they could be a combination of both presence detectors on the stop approach that recognize a stopped vehicle and activated LED flashing beacons on advance warning signs on the through approach. Flashing beacons may also be placed on the STOP signs if running STOP signs is a significant problem and transverse rumble strips are not appropriate due to noise issues.

The high-crash intersections where flashing beacons are to be considered for installation are summarized in Table 8.

Table 8. Flashing Beacons – State Stop-Controlled Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons –Rural	24	66	2,261	52	0.52	1.60	12.47	24	3.0	0.38
Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons –Urban	100	21	2,842	17	0.17	0.21	3.31	30	1.00	0.06
Total				69	0.69			54	4.00	0.44

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $10,000 per intersection.

[3] A net increased CRF of 0.08 is used – 0.13×(1-0.40) =0.08.

Optional Signing and Marking Improvements Based on the Characteristics of the Intersection

The optional additional improvements listed below may be beneficial if specific intersection safety concerns are present. These improvements should be considered for each stop-controlled intersection with a number of crashes that meets or exceeds the threshold. The determination to include one or more of these improvements cannot be determined from the crash data; it must be made after a field review of the intersection to identify physical, traffic, or pedestrian characteristics that merit inclusion.

- Placing reflective strips on sign posts if sign visibility due to a competing background may be a concern.
- Installing peripheral transverse markings or narrowing the approach lane width by reconfiguring the lane lines on the through approach if entry speeds are high.
- Applying rumble strips or transverse pavement markings on the stop approach if running the STOP sign is a problem and noise is not an issue.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule to implement this activity fully are shown in Table 9.

Table 9. Key Implementation Steps for Sign and Marking Improvements – State Stop-Controlled Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for District review of stop-controlled intersections with crashes above the crash threshold including: upgraded signs and markings (using information from the workshop as a base); sight distance minor improvements (foliage obstructions and parking in urban areas); use of a splitter island on the stop approaches at high-crash rural and urban stop-controlled intersections; and flashing beacons for intersections with crashes well above the crash threshold.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Establish teams (District Office Traffic Engineering Operations and/or Safety Engineer and/or consultant) to field review intersections, determine appropriate improvements, determine means to implement (department forces, new District-wide contract) and prepare contract plans (if needed).	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	3 months
3. Train team on guidelines, field review requirements, and contract plan preparation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months
4. Commence and complete field views of top-listed intersections (one-third of intersections identified), identify intersections where improvements are appropriate, identify improvements, identify which Districts will implement using Department forces, prepare statewide or area contract plans for remaining work.	District Office Traffic Engineering Operations and/or Safety Engineer District Office Consultants	12 months
5. Let contracts (if applicable) and implement improvements.	District Offices	24 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
6. Using lessons learned, identify next set (middle third of top intersections), and repeat steps 4 and 5.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	30 months (middle third step 4) 42 months (middle third step 5)
7. Using lessons learned, re-run crash data to identify last set (lower third of intersections identified plus any new intersections that exceed the threshold), and repeat steps 4 and 5.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	48 months (lower third step 4) 60 months (lower third step 5)

2. J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections

Description

This initiative involves the installation of minor channelization on the stop approaches to multi-lane, divided, high-speed highways to make them right-turn only. This treatment is considered at those intersections which have 10 or more crashes involving a stopped vehicle in a 6-year period. Left-turn and through movements from the stop approach are eliminated by minor channelization and signing. This option is feasible where vehicles can reach their intended destination by turning right at the intersection and within a reasonable distance downstream, enter an exclusive left-turn lane, and make a U-turn. Figure 2 provides an illustration.

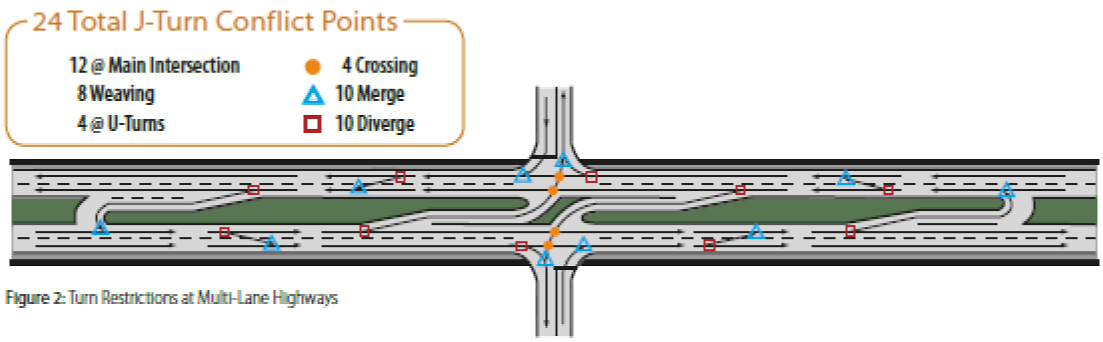

Figure 2. Turn Restrictions at Multi-Lane Highways

The J-turn treatment is considered the most effective low-cost countermeasure treatment available for reducing future crash potential at divided highway intersections. However, if left-turn lanes for the turnarounds are not available within a reasonable distance and the costs to install new lanes is prohibitive, or if significant controversy is involved with limiting movements at the intersection, less effective countermeasures can be considered as follows:

1. Install sign and marking improvements together with flashing beacons similar to those described in the sign and marking improvements countermeasure. Also, if intersection approach speeds are high, consider adding countermeasures to reduce intersection approach speeds on the through approaches (e.g., peripheral transverse pavement markings, lane narrowing techniques, or “SLOW” pavement marking legends).
2. Install presence detectors on the stop approaches that activate flashing beacons on a warning sign for the through approach, giving through motorists additional warning that a vehicle on the stop approach is present and may enter the intersection.
3. Consider adding a traffic signal if the intersection meets the Manual on Uniform Traffic Control Devices (MUTCD) signal warrants.

The high-crash intersections where J-treatments should be considered are summarized in Table 10.

Table 10. J-Turn Modifications on High-Speed Divided Arterials – State, Rural, Stop-Controlled Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
J-Turns Modifications on High-Speed Divided Arterials	10	70	1,160	56	16.80	3.74	22.72	77	17.5	2.87

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $300,000 per intersection.

[3] A CRF of 0.50 is used.

J-turn treatments also should be considered for any divided, urban, stop-controlled intersection that has a legal speed limit of 45 mph or greater and meets the rural crash thresholds indicated in Table 10.

The severity of crashes at rural stop-controlled intersections is extremely high (i.e., 3.74 fatalities per 100 crashes). As such, the three additional options listed above should be considered at all divided rural intersections and divided urban intersections with speed limits of 45mph or greater with 5 or more crashes in a 6-year period when it is not feasible to install J-turn treatments.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 11.

Table 11. Key Implementation Steps for J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for considering J-turn treatments and other options if J-treatments are not appropriate.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Establish teams (District Office Traffic Engineering Operations and/or Safety Engineer) to field review divided highway stop-controlled intersections, determine if improvements can be made, determine the type of improvements, and prepare contract plans.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	3 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
3. Develop a training package and train team on guidelines, field review requirements, and contract plan preparation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months
4. Commence and complete field reviews of intersections that meet the threshold crash levels, identify intersections where improvements are appropriate, the type of improvement, identify which Districts will implement improvements using Department forces.	District Office Traffic Engineering Operations and/or Safety Engineer	12 months
5. For those intersections in which a J-turn treatment is proposed, secure public input per DOT's processes and after determine appropriateness of implementing a J-turn treatment.	District Office Traffic Engineering Operations and/or Safety Engineer	18 months
6. Develop plans, let contract and implement J-turn treatments.	District Office Traffic Engineering Operations and/or Safety Engineer	42 months
7. For those divided intersections with optional improvements, identify improvements, identify which Districts will implement using Department forces, prepare statewide or area contract plans for these improvements.	District Office Traffic Engineering Operations and/or Safety Engineer	42 months

3. Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections

Description

This initiative involves the installation of a set of signing and marking improvements that are low-cost, designed to lower the potential of future crashes significantly, and are to be applied predominantly on single through lane, high-crash, stop-controlled local intersections in both rural and urban areas. They utilize the same basic set of sign and marking improvement countermeasure treatments and the same crash threshold levels as those described for State stop-controlled intersections in Countermeasure #1.

Since the level of effort to obtain Federal funds for multiple low-cost improvements on local roads and transfer them to local governments may exceed the costs of the low-cost improvements, the State initiative will include the following:

- An assessment of the potential for manufacturing the appropriate signs by the State Sign Shop using 100 percent Federal funds for local use at the designated intersections.
- Distribution of information on the high-crash intersection locations to appropriate local governments and guidance on low-cost sign and marking enhancements to reduce future crash potential.
- Coordination and facilitation of local government training either by the Local Technical Assistance Program (LTAP) or the FHWA Resource Center on the application of low-cost countermeasures at the high-crash intersections.

The high-crash intersections where the basic set of sign and marking should be considered are summarized in Table 12.

Table 12. Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Basic Set of Sign and Marking Improvements – Rural	6	190	1,968	152	1.22	0.21	5.23	105	5.5	0.22
Basic Set of Sign and Marking Improvements – Urban	50	105	7,683	84	0.67	0.12	2.35	410	9.6	0.49
Total				236	1.89			555	15.1	0.71

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $8,000 per intersection.

[3] A CRF of 0.40 is used.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 13.

Table 13. Key Implementation Steps for Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for local government review of stop-controlled intersections with crashes above the crash threshold, including: upgraded signs and markings (using information from the workshop as a base); sight distance minor improvements (foliage obstructions and parking in urban areas); and use of a splitter island on the stop approaches at high-crash rural and urban stop-controlled intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Perform an assessment of benefits, disadvantages, complexities, and issues associated with producing signs using 100 percent Federal safety funds to provide to locals for installation at high-crash stop-controlled local intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month (assessment completed) 2 months (decision to provide signs) 3 months (additional requirements, if any, added to guidelines).
3. Estimate the number of local governments that will need training based upon the high-crash intersection data. Determine the type of training needed for implementing the improvements. Assess the availability, capability, and capacity of LTAP, FHWA Resource Center, or other sources to provide the training.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	4 months
4. Provide crash data; guidelines for sign and marking improvements; information on availability of signs for designated intersections to municipalities (if appropriate); and training schedule and location for local governments.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months
5. Train local team on guidelines; field review requirements; improvement determination; and sign, marking, and splitter island installation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	9 months
6. Establish a monitoring and tracking system to insure that improvements at local intersections are properly identified and implemented.	District Office Traffic Engineering and/or Safety Engineer	12 months

4. Signal and Sign Improvements – State Signalized Intersections

Description

Basic Set of Signal and Sign Improvements

This initiative involves the installation of a basic set of signal, sign, and marking improvements that are low-cost, are designed to lower the potential for future crashes significantly, and are to be applied at high-crash, signalized, State intersections in both rural and urban areas.

The typical improvements considered for implementation include:

- Back plates for all signal heads (may be reflectorized).
- 12-inch LED lenses.
- At least one signal head per approach lane.
- Signal clearance timing in accordance with Institute of Transportation Engineers (ITE) clearance formula.
- Elimination of flashing operation during night conditions.

The majority of traffic signals on the State highway system already have the first three of the suggested enhancements described above installed. Consequently improvements, costs, and safety impacts for implementing the basic set of signal and sign enhancements are minimal. The two improvements expected to have the highest level of impact are signal clearance timing in accordance with the ITE clearance formula and eliminating late-night flashing operations.

The high-crash intersections where the basic set of signal and sign should be considered are summarized in Table 14.

Table 14. Basic Set of Signal and Sign Improvements – State Signalized Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Basic Set of Signal and Sign Improvements – Rural	10	123	3,012	98	0.49	0.41	5.53	75	4.1	0.31
Basic Set of Signal and Sign Improvements – Urban	50	371	28,570	297	1.48	0.17	3.36	714	24.0	1.21
Total				395	1.97			789	28.1	1.52

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $5,000 per intersection.

[3] A CRF of 0.15 is used.

Optional Signal and Sign Improvements Based on the Characteristics of the Intersection

The optional additional improvements listed below may be beneficial if specific intersection safety concerns are present. These improvements should be considered for each signalized intersection with a number of crashes that meets or exceeds the threshold. The determination to include one or more of these improvements cannot be determined from the crash data; it must be made after a field review of the intersection to identify physical, traffic, or pedestrian characteristics that merit inclusion.

- Advance intersection warning signs doubled up for isolated rural high speed intersections.
- Advance cross street name signs for high-speed approaches on arterial highways.
- Advance left and right Signal Ahead oversize warning signs for isolated traffic signals or intersections where the signal heads are not readily visible due to alignment or sight distance obstructions.
- Supplemental signal heads where normally placed signal heads may be difficult to identify due to sight distance limitations, horizontal curvature, or other obstructions; for exceptionally wide intersections where a near side signal is needed.
- Signal coordination improvements on high-volume, high-speed arterials with closely spaced traffic signals and frequent mainline stopping due to poor or no signal coordination.
- Pedestrian countdown signals at intersections with high pedestrian activity or multiple pedestrian crashes.
- Exclusive pedestrian phasing at intersections with multiple pedestrian-vehicle conflicts.
- Higher visibility crosswalks and advance pedestrian warning signs at intersections with high pedestrian activity or multiple pedestrian crashes.

Change of Permitted and Protected Left-Turn Phase to Protected Only

One major crash pattern that needs to be addressed individually is signalized intersections with a significant number or potential for left-turn, opposing-flow crashes. At these traffic signals the potential change is to modify the signal phase from permitted and protected left-turn phases to protected-only. This can be considered for intersections with high numbers of left-turn, opposing flow crashes, three or more opposing approach lanes, or high opposing volumes with few acceptable turning gaps.

The high-crash intersections where the protected only left-turn phase should be considered are summarized in Table 15.

Table 15. Change of Permitted and Protected Left-Turn Phase to Protected Only – State Signalized Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Change of Permitted and Protected Left-Turn Phase to Protected Only – Rural	5	87	841	61	0.30	0.39	6.08	47	2.9	0.18
Change of Permitted and Protected Left-Turn Phase to Protected Only Urban	10	678	13,781	475	2.37	0.17	5.32	772	41.1	1.31
Total				536	2.67			819	44.0	1.49

[1] Assumes 70% of locations can be improved.

[2] Assumes an average cost of $5,000 per intersection.

[3] A CRF of 0.48 is used.

Advance Detection Control Systems – Isolated High-Speed State, Rural, Signalized Intersections

Isolated high-speed State, rural, signalized intersections with a significant number of angle crashes is another major crash pattern that needs to be addressed individually. At these traffic signals, the proposed improvement is to install an advance detection control system capable of identifying vehicles on the mainline that will violate the yellow and red change intervals and hold the onset of green on the side approaches until the violating vehicle clears the intersection.

These systems utilize sets of advanced detectors to predict when a vehicle will be in the dilemma zone at isolated high-speed rural, signalized intersections. As the green phase begins to end, the detection control sensors identify vehicles by their position, speed, and acceleration characteristics. Taking the signal timing into account, the sensors perform automated calculations to determine if the vehicle will be in the dilemma zone as the signal would normally change to red. When such vehicles are identified, logic can be incorporated into the signal controller to hold the red phase on the side street until the vehicles on the ending green phase clear the intersection, thereby avoiding a conflict with crossing traffic.

The advance detection control system has been demonstrated at eight intersections in Texas and also is also being deployed in other parts of the nation. The evaluations from the Texas demonstrations have shown significant reductions in red-light violation and crash frequencies.

Potential candidate intersections for this improvement are State, rural, signalized intersections with five or more angle crashes. The number of intersections that potentially can be considered for the advance detection control system in this plan is 67, as shown in Table 16. Since advance detection control systems are new to the State, the State DOT will pilot the system with limited deployments between now and 2011 to gain more experience with the system. The State DOT will install the advance detection control system at 10 isolated high-speed State, rural, signalized intersections.

Table 16. Advance Detection Control Systems – Isolated High-Speed State, Rural, Signalized Intersections

Countermeasure	Threshold Crash Level (6 Years)[1]	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[2]	Construction Costs ($ Million)[3]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[4]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Advance Detection Control Systems	5	110	1,112	67	1.00	0.69	9.32	45	4.2	0.31

[1] Angle crashes.
[2] Assumes 60% of locations can be improved.
[3] Assumes an average cost of $15,000 per intersection.
[4] A CRF of 0.40 is used.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for these activities are shown in Tables 17 and 18.

Table 17. Key Implementation Steps for Signal and Sign Improvements – State Signalized Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for upgraded signal, signs, markings (using information from the workshop as a base), optional improvements; left turn safety enhancements; and advance detection control systems at isolated high-speed State, rural, signalized intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Obtain additional knowledge on advance detection control systems by visiting other States that have successfully implemented these systems.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	5 months
3. Establish teams (District Office Traffic Engineering Operations and/or Safety Engineer and/or consultant) to field review intersections, determine improvements and prepare contract plans.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	3 months
4. Develop a training package and train team on guidelines, field review requirements, and contract plan preparation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
5. Commence and complete field views of the listed signalized intersections, identify improvements, identify which Districts will implement using Department forces, prepare statewide or area contract plans for remaining work.	District Office Traffic Engineering and/or Safety Engineer and/or District Office Consultants	18 months
6. Let contract and implement improvements (including at least 10 advance detection control systems).	District Offices Headquarters Office of Traffic Engineering Operations	30 months
7. Take any lessons learned, and complete design and let contract for advance detection control systems at remaining isolated high-speed State, rural, signalized intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	54 months

Table 18. Key Implementation Steps for Advance Detection Control Systems Pilot – Isolated High-Speed State, Rural, Signalized Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Gain information and knowledge regarding the design and construction characteristics and requirements of advance detection control systems. Develop typical provisions for detection control systems for use in the State.	Headquarters Office of Traffic Engineering Operations	5 months (knowledge gained) 8 months (typical provisions developed)
2. Solicit interest from Districts that have rural signalized intersections with 10 or more angle crashes to consider incorporating an advance detection control system at approximately 10 intersections statewide.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	10 months (solicitation initiated) 12 months (solicitation finalized)
3. For those Districts interested, provide technical assistance and contacts to evaluate the appropriateness of using advance detection control systems at identified intersections within their District and provide information on developing plans and specifications for such a system.	Headquarters Office of Traffic Engineering Operations	15 months
4. Prepare and let contract plans for advance detection control systems at approved candidate intersections.	District Offices Headquarters Office of Traffic Engineering Operations	21 months
5. Complete installation. Evaluate, identify, and resolve any issues or problems.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Offices	30 months (projects completed) 36 months (projects evaluated)

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
6. Based upon the evaluation, make a decision whether to expand to remaining intersections and at what level, or terminate.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Offices	38 months
7. If decision is to expand, provide guidance to Districts on selecting appropriate intersections and finalize set of additional intersections to install advance detection control systems.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	30 months (guidance issued) 42 months (candidate intersections approved)
8. Repeat steps 4 and 5 for remaining intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Offices	60 months

5. Signal and Sign Improvements – Local Signalized Intersections

Description

Basic Set of Signal and Sign Improvements

This initiative involves the installation of a basic set of signal, sign, and marking improvements that are low-cost, are designed to lower the potential for future crashes significantly, and are to be applied predominantly on single through lane, high-crash local signalized intersections in both rural and urban areas. They utilize the same countermeasure treatments and crash threshold levels as those for State signalized intersections. In addition, low-cost pedestrian intersection treatments are to be considered, including:

- Pedestrian countdown signals.
- Crosswalks (if none exist).
- Warning signs for active pedestrian crossings.
- Potential elimination of the permissive portion of any protected/permissive turning operation phase that creates substantial conflicts with crossing pedestrians.
- Modifications to intersection approaches to reduce high approach speeds when substantive pedestrian activity is prevalent.

Since the level of effort to obtain Federal funds for multiple low-cost improvements on local roads and transfer them to local governments may exceed the costs of the low-cost improvements, the State initiative will include the following:

- An assessment of the potential for manufacturing and distributing the appropriate signs and signal materials by the State Sign Shop using 100 percent Federal funds for local use at the designated intersections.
- Distribution of information on the high-crash intersection locations to appropriate local governments and guidance on low-cost signal, sign, and marking enhancements to reduce future crash potential.
- Coordination and facilitation of local government training either by the LTAP or the FHWA Resource Center on the application of low-cost countermeasures at the high-crash intersections.

The high-crash intersections where the basic set of signal and sign improvements should be considered are summarized in Table 19.

Table 19. Basic Set of Signal and Sign Improvements – Local Signalized Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Basic Set of Signal and Sign Improvements – Rural	10	12	291	10	0.10	0.74	1.63	8	0.1	0.06
Basic Set of Signal and Sign Improvements – Urban	50	316	24,839	253	2.53	0.22	2.93	662	19.4	1.45
Total				263	2.63			670	19.5	1.51

[1] Assumes 80% of locations can be improved.

[2] Assumes an average cost of $10,000 per intersection.

[3] A CRF of 0.20 is used.

Change of Permitted and Protected Left-Turn Phase to Protected Only

One major crash pattern that needs to be addressed individually is signalized intersections with a significant number or potential for left-turn, opposing-flow crashes. At these traffic signals the potential change is to modify the signal phase from permitted and protected left-turn phases to protected-only. This can be considered for intersections with high numbers of left-turn, opposing flow crashes, three or more opposing approach lanes, or high opposing volumes with few acceptable turning gaps.

The high-crash intersections where the protected only left-turn phase should be considered are summarized in Table 20.

Table 20. Change of Permitted and Protected Left-Turn Phase to Protected Only – Local Signalized Intersections

Countermeasure	Threshold Crash Level (6 Years)	Number of Statewide Crash Intersections	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[1]	Construction Costs ($ Million)[2]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[3]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
Change of Permitted and Protected Left-Turn Phase to Protected Only – Rural	5	8	84	6	0.03	0.51	1.02	5	0.0	0.03
Change of Permitted and Protected Left-Turn Phase to Protected Only Urban	10	544	11,036	381	1.91	0.20	3.83	618	23.7	1.24
Total				387	1.94			623	23.7	1.27

[1] Assumes 70% of locations can be improved.

[2] Assumes an average cost of $5,000 per intersection.

[3] A CRF of 0.48 is used.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 21.

Table 21. Key Implementation Steps for Signal and Sign Improvements – Local Signalized Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for local government review of signalized intersections with crashes above the crash threshold which includes upgraded signal, signs, markings (using information from the workshop as a base), optional improvements; and left turn safety enhancements. Advanced detection control systems are not considered for local intersections until they have been adequately tested on the State system.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Perform an assessment of benefits, disadvantages, complexities, and issues associated with providing signs, back plates, and 12-inch LED lens using 100 percent Federal safety funds to locals for installation at high–crash local signalized intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month (assessment completed) 2 months (decision to provide materials) 3 months (additional requirements, if any, added to guidelines)

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
3. Estimate the number of local governments that will need training based upon the high-crash intersection data. Determine the type of training needed for implementing the improvements. Assess the availability, capability, and capacity of LTAP, FHWA Resource Center, or other sources to provide the training.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	4 months
4. Provide crash data; guidelines for signal, sign, and marking improvements; information on availability of signs for designated intersections to municipalities (if appropriate); and training schedule and location for local governments.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months
5. Train local team on guidelines; field review requirements; improvement determination; and signal, sign, and marking installation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	9 months
6. Establish a monitoring and tracking system to insure that improvements at local intersections are properly identified and implemented.	District Office Traffic Engineering and/or Safety Engineer	12 months

6. New or Upgraded Lighting – State Rural Intersections

Description

Crashes that occur during darkness are typically more severe than daylight crashes. Major problems associated with unlit or poorly lit intersections (e.g. only one light per intersection) include reduced ability to recognize that an intersection is approaching, reduced ability to navigate turning movements properly, and degradation of the ability to recognize other vehicles and pedestrians in or entering the intersection.

The low-cost countermeasure for unlit or poorly lit intersections with a high frequency and rate of night crashes is lighting. Typical example layouts for intersection lighting are shown in Figure 3. States should follow their design policy for intersection lighting installations.

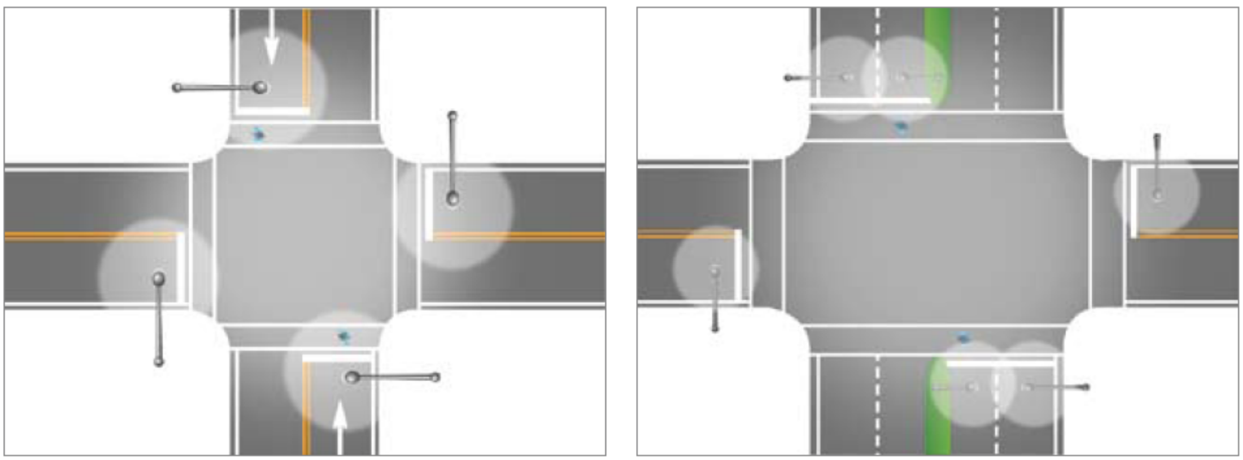

Figure 3. New Design for Intersection Lighting Layout (Single and Multi-Lane Approaches)[4]

The crash reduction factor at unlit intersections with high frequencies and rates of night crashes is 50 percent of night crashes. The crash reduction factor for improving lighting at poorly lit intersections (one existing light per intersection) is estimated by an expert safety panel as 25 percent of night crashes.

[4] Source: Federal Highway Administration, Informational Report on Lighting Design for Midblock Crosswalks, FHWA-HRT- 08-053 (Washington, DC: April 2008).

The high-crash intersections where new or upgraded should be considered are summarized in Table 22.

Table 22. New or Upgraded Lighting – State Rural Intersections

Countermeasure	Threshold Crash Level (6 Years)[1]	Number of Statewide Crash Intersections[2]	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[3]	Construction Costs ($ Million)[4]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[5]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
New or Upgraded Lighting	7	80 est.	740 est.	64	3.84	2.20	16.8	49	8.4	1.08

[1] Dark crashes.

[2] Dark crashes only and where the intersection dark/total ratio exceeds the statewide dark/total crash ratio of 0.20.

[3] Assumes 80% of locations can be improved, rural intersections are predominantly unlit, and remaining rural intersections are poorly lit.

[4] Assumes an average cost of $60,000 per intersection.

[5] A CRF of 0.50 night crashes is used for rural unlit intersections; 0.25 of night crashes for poorly lit rural intersections.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 23.

Table 23. Key Implementation Steps for New or Upgraded Lighting – State Rural Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Clarify policy regarding installation, maintenance, and energizing lighting improvement responsibilities (State or local) at high night crash, State rural intersections.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety State DOT Upper Management (Makes Policy Determination)	1 month
2. Assuming policy allows limited expansion of lighting to high night crash, State rural, unlit intersections, develop guidelines and standard for lighting typical rural intersections with two- and four-lane approaches.	Headquarters Office of Traffic Engineering Operations	2 months
3. Establish teams (District Office Traffic Engineering and/or Safety Engineer and/or consultant) to field review intersections, determine lighting improvements, and prepare contract plans.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Offices	3 months
4. Train team on lighting standards for intersections, field review requirements, and contract plan preparation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	6 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
5. Commence and complete field views of all listed State intersections, identify improvements, identify which districts will implement using Department forces, and prepare statewide or area contract plans for remaining work.	District Office Traffic Engineering and/or Safety Engineer and/or District Office Consultant	12 months
6. Execute necessary agreements with local municipalities for lighting responsibilities.	District Office Traffic Engineering and/or Safety Engineer Local Roads Coordinator	18 months
7. Let contract and implement improvements.	District Offices	42 months

7. High-Friction Surface – State Intersections

Description

Crashes that occur when the pavement is wet on approaches with speed limits of 45 mph or more may be attributed to increased stopping distances due to low skid numbers and/or severe rutting in the wheel paths that might induce hydroplaning.

The low-cost countermeasure for intersections with higher frequencies of wet pavement crashes and above average wet/total crash rates include increasing the friction characteristics on intersection approaches with low skid numbers and eliminating any severe wheel path rutting.

One way transportation officials can increase pavement friction beyond what is attainable through traditional techniques is by using new high-friction surfacing systems. These systems use a combination of resins and polymers (usually urethane, silicon, or epoxy) and a binder topped with a natural or synthetic hard aggregate.

Micro texture, macro texture, and the durability of that texture distinguish these overlays from standard asphalt and concrete pavement surfaces. High-friction surfacing systems typically use much smaller and harder aggregates, such as calcined bauxite, slag, or other synthetic aggregates. These aggregates are generally less than 6.0 mm (0.23 inch) in diameter and have high skid resistance. The small and hard aggregate makes the overlay much more resistant to wear and polishing. The resin or polymer binder combination locks the aggregate firmly in place, creating an extremely rough, hard, durable surface capable of withstanding everyday roadway demands such as heavy braking and snowplowing. The rougher texture and greater surface area increase the pavement's friction.

The length of approach to apply skid resistance surfaces is variable dependent on approach speeds, sight distance, and expected queue lengths at signalized intersections. A minimum 300 feet of approach is recommended for through high-speed approaches to stop-controlled intersections. In addition, significant wheel rutting (2 inches in depth or greater) should be eliminated before applying any skid resistant surface.

Crash reduction factors for skid-resistant surfaces on high-speed (i.e., 45 mph or greater) intersection approaches with a high frequency and rate of wet pavement crashes and either (1) a ribbed tire skid number of 30 or less, (2) wheel path rutting of at least 2 inches in depth, or (3) both is 50 percent of wet pavement crashes.[5]

The high-crash intersections where high-friction surface should be considered are summarized in Table 24.

[5] Institute of Transportation Engineers, *Toolbox of Countermeasures and Their Potential Effectiveness to Make Intersections Safer,* (Washington, DC: April 2004), http://www.ite.org/library/IntersectionSafety/toolbox.pdf.

Table 24. High-Friction Surface – State Intersections, 45 mph or Greater Speed Limit

Countermeasure	Threshold Crash Level (6 Years)[1]	Number of Statewide Crash Intersections[2]	Number of Targeted 6 Year Crashes in the Intersections	Estimated Number of Improvements[3]	Construction Costs ($ Million)[4]	Fatalities per 100 Crashes	Incapacitating Injuries per 100 Crashes	Annual Targeted Crash Reduction[5]	Annual Incapacitating Injury Reduction	Annual Estimated Fatality Reduction
High-Friction Surface	15	75 est.	1,475 est.	53	2.65	1.48	13.2	86	11.3	1.27

[1] Wet crashes at intersections with speed limits of 45 mph or greater.

[2] Assumes 70% of intersections have a skid number of 30 or less and can be overlaid.

[3] Assumes these intersections have at least 15 wet pavement crashes and a wet/total ratio of at least 0.18.

[4] Assumes an average cost of $50,000 per intersection to remove any significant rutting and apply a thin epoxy anti-skid surface.

[5] A CRF of 0.50 is used.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 25.

Table 25. Key Implementation Steps for High-Friction Surface – State Intersections

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop guidelines for friction courses; surface improvement approach lengths; severe wheel path rutting mitigation; and testing requirements for friction levels for intersection approaches.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	1 month
2. Skid test approaches on the list and determine if skid resistance needs increased.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Office Traffic Engineering Operations Engineer District Office Skid Testing Crew	5 months
3. Field review intersections on the wet pavement list that have low skid numbers and determine the appropriate skid treatment.	District Office Traffic Engineering and/or Safety Engineer	8 months
4. Develop plans and let contracts to apply skid treatments at designated intersections.	District Office Traffic Engineering and/or Safety Engineer District Office Consultants	16 months

8. Enforcement-Assisted Lights

Description

This initiative involves pursuing the use of the enforcement-assisted lights for use at signalized intersections with a significant number of angle crashes over a 5-year period. Candidate municipalities with significant numbers of angle crashes are listed in Table 26.

Table 26. Enforcement-Assisted Lights – Candidate Cities

Name	Angle Crashes	Estimated Angle Crashes at Signalized Intersections (45% of Total Angle Crashes)
City A	22,336	10,050
City B	22,335	10,050
City C	8,182	3,680
City D	4,228	1,900
City E	4,181	1,880
City F	3,415	1,540
City G	3,411	1,540

It is estimated that the total number of signals in these cities is 2,300.

A CRF of 0.15 for enforcement-assisted lights is used.

It is assumed that 1 medium size city with an estimated 2,000 angle crashes (i.e., close to average for a medium-sized city) at signalized intersections will agree to adopt the enforcement-assisted lights as a pilot or demonstration and will apply them at signalized intersections that comprise 90% of all angle crashes. The estimated angle crashes in these cities is 0.90 x 2,000 = 1,800 angle crashes at signalized intersections impacted.

The severity of angle crashes at intersections within these cities is estimated at 0.25 fatalities per 100 crashes and 5.0 incapacitating injuries per 100 crashes.

The estimated annual reduction in angle crashes over a 6-year time period is 1,800 x 0.15/6 = 45.

The estimated annual reduction in incapacitating injuries for city-wide efforts over a 6-year time period is 1,800 x 0.15 x (5.0/100)/6 = 2.25.

The estimated annual reduction in fatalities for city-wide efforts over a 6-year time period is 1,800 x 0.15 x (0.25/100)/6 =0.11.

The cost for adding the enforcement-assisted lights at 300 intersections at $300 per intersection is $0.09 million.

The State has minimal experience with the use of enforcement-assisted lights. In addition, the actual effectiveness at reducing angle crashes has not been adequately validated. As such, the State DOT will proceed cautiously with deployment, initially concentrating deployment at those intersections with high numbers of angle crashes and signal designs and timing that closely conform to current best safety practices. A pilot demonstration will be deployed at approximately 50 of these signalized intersections and evaluated to determine probable effectiveness. If effective, the effort will be expanded to the remaining candidate locations.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule for this activity are shown in Table 27.

Table 27. Key Implementation Steps for Enforcement-Assisted Lights

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1 Solicit interest from one or more of the cities listed in the above table to pilot the enforcement-assisted lights.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	2 months
2. Identify interested candidate cities. Hold meetings with candidate cities to determine interest and commitment. Obtain police and judicial agreement to enforce red-light running citations using enforcement-assisted lights.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety District Office Traffic Engineering Operations Engineer	8 months
3. Identify approximately 50-100 potential pilot intersections per city from the signalized intersections with angle crashes listed to deploy and evaluate. Prepare and issue a package of high-crash local intersections and guidelines for candidate enforcement-assisted lights and timing adjustments to municipalities that have high angle crash signalized intersections on the potential pilot intersection list.	District Office Traffic Engineering Operations and/or Safety Engineer Designated City Representative(s)	12 months
4. Initiate process to meet further with cities, including police and judiciary, either one-to-one or at a group meeting to secure local agency participation in the initiative and the commitment to enforcement. Encourage use of the guidelines provided, identify improvements, and solicit feedback to the DOT.	District Office Traffic Engineering Operations and/or Safety Engineer	15 months
5. For those municipalities desiring to pilot enforcement-assisted lights, complete preparation to install confirmation lights and install. (Ensure that the yellow and all red clearance intervals at the pilot intersections are established using the ITE formula and the 85th percentile speed.)	District Office Traffic Engineering Operations and/or Safety Engineer	30 months
6. Develop and complete an evaluation plan for initial enforcement-assisted lights.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Consultant	39 months
7. Make the decision to expand, modify, or terminate the enforcement-assisted light initiative.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	42 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
8. If decision is to expand or modify, implement the expansion or modification.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety	60 months

9. Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes

Description

The State DOT has identified 12 State route corridors with 7 or more fatal intersection crashes and a significant number of severe injury intersection crashes over the past 6 years though crash data analysis. The intent of this countermeasure is to advance a set of 3E initiatives on three of these corridors to reduce the potential for future severe intersection crashes. For each corridor, this initiative will have as its objective a reduction in corridor intersection fatalities and incapacitating injuries by a minimum of 25 percent using a combination of low-cost infrastructure improvements and targeted education and enforcement initiatives. While the selection of the corridors has been based upon high frequencies of severe intersection crashes, the approach may be broader and encompass other corridor concerns such as road departure, mid-block pedestrian problems, and driver behavioral problems, including driving while intoxicated, lack of safety belts, and speeding.

The effort begins with a thorough analysis of the crash characteristics in the corridor to understand better the problems that need to be addressed and relate crash patterns to potential countermeasures. Corridor safety studies usually are conducted on 5 to 20 mile sections of high-volume arterials that exhibit a high frequency of severe and fatal crashes.

Corridor safety studies are usually conducted using a team approach. The corridor team is normally comprised of at least the following representatives:

- District Safety Engineer.
- District Media Specialist.
- County Maintenance Manager or designee.
- Representative of State or local police responsible for enforcement on the corridor.
- Local government representative.

Additional team members may also include the District Traffic Engineer, Local Emergency Medical Services (EMS) coordinator, a Metropolitan Planning Organization (MPO) representative, and a highway design representative.

Once a corridor has been identified for a study, the Safety Engineer and the District Media Specialist should perform an analysis of the crash data along the corridor to identify crash patterns that can be addressed by low-cost countermeasures and education/enforcement actions. All cluster lists need to be reviewed to identify specific locations within the corridor that appear on one or more of the cluster lists. It is anticipated that right turn in-right turn out turn limitations at stop-controlled intersections will be a significant countermeasure to consider on the multi-lane corridors.

After the crash analysis is completed, the corridor safety team is convened to review and discuss the crash analysis, findings, and safety concerns along the corridor from each member's perspective. The team then conducts a field review of the corridor, usually in one or two vehicles, to review areas of concern defined from the crash analysis and team discussions and any other safety aspect identified during the field review. The team then reconvenes and reaches consensus on a set of countermeasures and initiatives that have strong potential to reduce future severe crashes.

The District Safety Engineer and the District Media Specialist take the results of the team field review meeting and prepare a cost estimate and an assessment of the probable safety impacts and cost-effectiveness of implementing the recommended improvements. A brief report and tentative implementation schedule are prepared and used for programming consideration of cost-effective improvements.

After the countermeasures have been identified and approved by the agencies involved, staged and coordinated implementation of the recommendations begins. The team performs oversight and monitors the implementation activities to insure that substantive safety progress along the corridor is being made.

The corridors where 3E improvements should be considered are summarized in Table 28. Since the corridor approach is new to the State DOT, a pilot effort of three corridors will be initiated. The Executive Committee will evaluate the pilot. It if considered beneficial, the pilot will be expanded to the remaining corridors, incorporating lessons learned from the pilot.

Table 28. Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes – Candidate Locations

County	On Location Street	Severity				Total Crashes
		Fatal	Incapacitating Injury	Minor Injury	Property Damage Only	
H	30	13	92	295	857	1,257
R	1	12	35	60	133	240
S	62	9	20	71	196	296
A	31	8	29	103	587	727
P	72	8	41	82	198	329
N	6	8	27	52	128	215
B	40	7	51	66	173	297
C	3	7	27	106	318	458
F	52	7	20	209	565	801
R	301	7	15	93	288	403
AA	5	7	43	377	1,068	1,495
CC	1012	7	42	423	1,310	1,782

Number of potential corridors = 12.

Estimated number of corridors that may be implemented as a pilot = 3 (H-30, R-1, and one of the following S-62, A-31, P-72, N-6, B-40, C-3).

Estimated fatalities in the 3 corridors = 33.

Estimated incapacitating injuries in the 3 corridors = 150.

Estimated annual crashes in the 3 corridors = 2,000.

Estimated crash reduction factor for applying 3E improvements = 0.25.

Estimated annual reduction in crashes over a 6-year time period = 2,000 × 0.25/6 = 83.

Estimated annual reduction in incapacitating injuries over a 6-year time period = (150/6) × 0.25 = 7.5.

Estimated annual reduction in fatalities over a 6-year time period = (33/6) × 0.25 = 1.25.

Estimated costs at $2,000,000 per corridor for infrastructure and $100,000 for education/enforcement = $6.0 million (infrastructure), $0.3 million annually (education and enforcement).

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule to fully implement this activity are shown in Table 29.

Table 29. Key Implementation Steps for Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Review 12 corridors and select 3 of the corridors to pilot and lead the implementation.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative District Offices	1 month
2. Analyze data for the corridors selected, investigating all major crash patterns (including intersections) and prepare a report of findings.	Headquarters Office of Safety	5 months
3. Select a multi-disciplinary team for each corridor to determine actions to reduce future crashes.	Engineering Operations Governor's Highway Safety Representative	6 months
4. Hold meeting of multi-disciplinary teams, complete field reviews of corridors, identify set of comprehensive 3E improvements, and prepare brief corridor reports summarizing actions and improvements proposed to reduce future fatalities. As part of the report, prepare estimated costs and schedules.	Multi-Disciplinary Team	10 months
5. Obtain agency approval on the report, including approval of their roles as defined in the report.	Affected Organizations	12 months
6. Begin implementation, including education and enforcement activities and development and letting of contract to implement infrastructure improvements.	Affected Organizations	30 month
7. Evaluate corridor approach, take any lessons learned, and make a decision to expand, expand with modifications, or terminate corridor safety approach.	Executive Committee	36 months
8. If decision is to expand or expand with modifications, proceed with steps 2 through 7 for remaining corridors.	Executive Committee	60 months

10. Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes

Description

The State DOT has identified 4 cities with the largest number of intersection fatalities over the past 6 years though crash data analysis. The purpose of this countermeasure is to identify a mid-size pilot city and initiate municipal-wide 3E approach, with an objective to reduce city intersection fatalities by a minimum of 10 percent using a combination of low-cost infrastructure improvements and targeted education and enforcement strategies beyond those that may be implemented in other systematic countermeasure deployments.

The effort begins with a preliminary meeting with city officials to determine interest in initiating a comprehensive intersection safety initiative. If interested, a thorough "cleaning up" of the crash data for intersection crashes on State and local roads within the city area is completed such that clusters of crashes at the same intersection can be accurately combined. After the data is cleaned, participants conduct a thorough analysis of the crash characteristics in the city, with the particular goal of understanding the problems that need to be addressed and relating the patterns to potential countermeasures. A city-wide multi-disciplinary team is then formed to review the crash analysis, discuss the intersection safety problems in the city, jointly field review the selected problem intersections to gain personal and group consensus of the major safety issues, and collectively develop an overall set of 3E countermeasures to improve safety in the city. After the countermeasures have been identified and approved by the agencies involved, staged and coordinated implementation of the recommendations begins. The team performs oversight and monitors the implementation activities to insure that substantive safety progress is being made.

The cities where 3E improvements should be considered are summarized in Tables 30 and 31. Since the city-wide 3E approach is relatively new to the State DOT, the pilot program will be closely monitored by the Executive Committee. The pilot will be evaluated by the Executive Committee, and, if considered beneficial, may be expanded to additional cities, incorporating lessons learned. If not beneficial, the Executive Committee can terminate or redirect the efforts.

Table 30. Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes – Candidate Cities with the Highest Intersection Fatalities and Crashes

City	Severity				Total Crashes	Pedestrian Crashes
	Fatal	Incapacitating Injury	Minor Injury	Property Damage Only		
City P	106	701	11,909	42,490	55,206	624
City R	90	1,027	10,750	40,993	52,860	240
City B	34	395	6,842	15,851	23,122	56
City D	25	256	2,717	8,383	11,381	32

Number of potential cities = 1 medium size city.

Estimated number of cities that may pursue 3E improvements – 1 (City B).

Estimated fatalities within the city = 34.

Estimated incapacitating injuries within the city = 395.

Estimated crash reduction factor for applying 3E improvements = 0.10.

Estimated annual reduction in crashes over a 6-year time period = 23,000 × 0.10/6 = 383.

Estimated annual reduction in incapacitating injuries over a 6-year time period = 395/6 × 0.10 = 6.6.

Estimated annual reduction in fatalities over a 6-year time period = 34/6 × 0.10 = 0.57.

Estimated costs at $1,000,000 per city for infrastructure and $100,000 annually for education/enforcement.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule to fully implement this activity are shown in Table 31.

Table 31. Key Implementation Steps for Area-Wide City 3E Improvements

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Review the cities and tentatively select a pilot city.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative	2 months
2. Contact selected city and determine interest. If not interested go to next candidate city. Finalize pilot city.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative	5 months
3. Analyze crash data for pilot city, investigating all major intersection crash patterns and preparing a brief report of findings.	Headquarters Office of Safety	9 months

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
4. Select a multi-disciplinary team to determine actions to reduce future crashes for the pilot city.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative City Police, Planning, and Traffic Engineering Representatives	10 months
5. Hold a meeting of the multi-disciplinary team, complete field views of problem and typical intersections, identify set of comprehensive 3E improvements, prepare a set of countermeasures and improvements proposed to reduce future intersection fatalities by at least 10 percent. As part of the set of countermeasures, prepare estimated costs and schedules.	Multi-Disciplinary Team	12 months
6. Obtain agency approval on the set of countermeasures, including approval of their roles as defined in the plan.	Affected Organizations	14 months
7. Begin implementation, including education and enforcement activities and development and letting of contract to implement infrastructure improvements.	Affected Organizations	30 months
8. Evaluate city comprehensive approach, take any lessons learned, and make a decision to expand, expand with modifications, or terminate city comprehensive safety approach.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative	36 months
9. If decision is to expand or expand with modifications, proceed with steps 2 through 9 for additional cities.	Headquarters Office of Traffic Engineering Operations Headquarters Office of Safety Governor's Highway Safety Representative	42 months and beyond, based upon schedule set

11. Roundabouts

Description

Major improvements such as the construction of roundabouts require careful individual intersection analysis and are not appropriate to consider for systematic deployment. These major physical improvements have longer-term benefits since their expected lives may be 30 years or longer (as compared to about 10 years for signs and traffic signals). In addition, the effectiveness of these improvements to potentially reduce the number of crashes at a location is greater than lower-cost improvements. For example, the installation of roundabouts is expected to reduce severe intersection crashes by 90 percent. However their high initial costs prevent them from being considered for systematic deployment. In addition, significant factors such as available right of way, environmental issues, cost differentials between alternate major improvement types, and traffic operations will have an impact on choosing them as the optimum improvement type. As a result, these improvements are best suited to consider at intersections with the highest number of crashes.

Roundabouts are usually the most effective countermeasures in terms of reducing future crash potential; however, the high cost of construction significantly reduces the attractiveness of pursuing them. The expected rate of return in terms of lived saved per dollar invested is low compared to improving large numbers of intersections with lower-cost countermeasures. This is particularly the case when funding for safety is constrained and the objective is to reduce the maximum number of fatalities and incapacitating injuries possible with the available funds.

While intersections with the highest number of state-wide crashes will be considered as candidates for implementing systematic low-cost countermeasures as described earlier in the plan, these intersections also will be considered candidates for roundabout construction (where the CRF is 0.90 for fatalities and incapacitating injuries). Candidate intersections for roundabouts are shown in Table 32.

Table 32. Roundabouts – Threshold Levels for Determining Candidate Intersections

Locality and Ownership	Traffic Control	Threshold Crash Level	Number of Intersections	Number of Crashes 2003-2008
State Rural Intersections	Signalized	> 50 Crashes	1	51
	Stop-Controlled	> 50 Crashes	7	428
State Urban Intersections	Signalized	>150 Crashes	13	2,170
	Stop-Controlled	>120 Crashes	13	1,964

It is estimated that three roundabouts will be implemented during the time frame of this initiative, two at State, rural, stop-controlled intersections and one at State, rural, signalized intersections. The estimated annual reduction in crashes from these improvements is 32 crashes, 4 incapacitating injuries, and 0.36 fatalities.

Key Implementation Steps

The key steps necessary to fully implement this initiative and realize the safety benefits of the improvements, the organizations responsible for each key step, and the schedule to fully implement this activity are shown in Table 33.

Table 33. Key Implementation Steps for Roundabouts

Step	Organization Responsible for Step	Completion Date (Months After Implementation Plan Acceptance)
1. Develop and distribute guidelines for considering roundabouts.	Headquarters Office of Safety	1 month
2. Analyze the 34 high-crash intersections (perform crash analysis and field reviews) to determine if roundabouts are appropriate solutions for the intersection. Develop project packages for each intersection where roundabouts are recommended, including cost estimates for the improvement.	Headquarters Office of Safety	7 months
3. Analyze the packages and make an assessment of the viability of the improvements and the potential impact of the project in terms of utilization of existing revenues and impact on achieving the intersection fatality goal. Select a minimum of three intersections to convert to roundabouts. Advise Safety and upper management of the assessment.	State DOT Upper Management	Within 1 month of receipt of the package
4. Develop contract plans for approved projects and let the project.	District Offices	30 months
5. Implement improvements.	District Offices	48 months

Production Performance Measures

Table 34. Production Performance Measures

Countermeasure	Measure	Target Completion Date	Actual Completion Date
Sign and Marking Improvements – State Stop-Controlled Intersections ➢ Basic Set of Sign and Marking Improvements ➢ Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons ➢ Optional Signing and Marking Improvements Based on the Characteristics of the Intersection	Issue guidelines	Issued by 8/1/09	Date issued
	Identify and implement improvements for 1st 400 intersections	320 intersection improvements implemented by 10/1/10	Actual number improved by 10/1/10
	Identify and implement improvements for 2nd 400 intersections	640 intersection improvements implemented by 10/1/11	Actual number improved by 10/1/11
	Identify and implement improvements for 3rd 400 intersections	960 intersection improvements implemented by 10/1/12	Actual number improved by 10/1/12
J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections	Issue guidelines	Issued by 8/1/09	Date issued
	Implement J-turn treatments	56 new J-turn treatments in place by 7/1/12	Actual number in place by 7/1/12
Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections	Issue guidelines to locals	Issued by 1/1/10	Date issued
	Monitor and track system	Monitor and tracking system by 7/1/10	Monitor and tracking system date in place
Signal and Sign Improvements – State Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Optional Signal and Sign Improvements Based on the Characteristics of the Intersection ➢ Change of Permitted and Protected Left-Turn Phase to Protected Only ➢ Advance Detection Control Systems	Issue guidelines	Issued by 8/1/09	Date issued
	Identify and implement improvements for 1st 170 intersections	135 intersection improvements implemented by 10/1/10	Actual number improved by 10/1/10
	Identify and implement improvements for 2nd 170 intersections	270 intersection improvements implemented by 10/1/11	Actual number improved by 10/1/11
	Identify and implement improvements for 3rd 170 intersections	395 intersection improvements implemented by 10/1/12	Actual number improved by 10/1/12
Signal and Sign Improvements – Local Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Change of Permitted and Protected Left-Turn Phase to Protected Only	Issue guidelines	Issued by 1/1/10	Date issued
	Monitor and track system	Monitor and tracking system by 7/1/10	Monitor and tracking system date in place
	Implement improvements	387 intersections improved by 7/1/12	Number of local signals improved by 7/1/12
New or Upgraded Lighting –	Issue guidelines	Issued by 8/1/09	Date issued

Countermeasure	Measure	Target Completion Date	Actual Completion Date
State Rural Intersections	Implement improvements	64 rural intersections lit by 12/1/12	Actual number lit by 12/1/12
High-Friction Surface – State Intersections	Issue guidelines	Issued by 8/1/09	Date issued
	Implement skid approach treatments	Anti-skid material applied at 53 high speed approaches to intersections by 12/1/12	Actual number lit by 12/1/12
Enforcement-Assisted Lights	Finalize selection of pilot city	4/1/10	Date finalized
	Implement red-light enforcement light demo in pilot city	1/1/11	Date implemented
Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes	Finalize selection of three corridors	8/1/09	Actual date
	Prepare corridor safety countermeasures	11/1/10	Actual date
	Implement corridor improvements	12/1/11	Actual date
Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes	Finalize selection of candidate city	12/1/09	Actual date
	Prepare set of city countermeasures	Completed by 12/1/10	Actual date
	Implement set of countermeasures	Implementation completed by 1/1/12	
Roundabouts	Finalize guidelines for roundabout consideration	Completed and issued by 9/1/09	Actual date issued
	Complete evaluations of 34 intersections	Completed by 2/1/10	Date evaluations completed
	Make decision on roundabouts	7/1/10	Date decisions made
	Approved roundabouts in place	In place by 7/1/13	Date roundabouts functional

Performance Standards – Program Effectiveness in Reducing Targeted Crashes

Table 35. Performance Measures

Countermeasure	Year Improvements Implemented	Year Evaluation Plan Developed	Year Evaluation Completed	Expected Crash Reduction	Actual Crash Reduction
Sign and Marking Improvements – State Stop-Controlled Intersections ➢ Basic Set of Sign and Marking Improvements ➢ Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons ➢ Optional Signing and Marking Improvements Based on the Characteristics of the Intersection					
J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections					
Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections					
Signal and Sign Improvements – State Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Optional Signal and Sign Improvements Based on the Characteristics of the Intersection ➢ Change of Permitted and Protected Left-Turn Phase to Protected Only ➢ Advance Detection Control Systems					
Signal and Sign Improvements – Local Signalized Intersections ➢ Basic Set of Signal and Sign Improvements ➢ Change of Permitted and Protected Left-Turn					

Countermeasure	Year Improvements Implemented	Year Evaluation Plan Developed	Year Evaluation Completed	Expected Crash Reduction	Actual Crash Reduction
Phase to Protected Only					
New or Upgraded Lighting – State Rural Intersections					
High-Friction Surface – State Intersections					
Enforcement-Assisted Lights					
Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes					
Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes					
Roundabouts					

Summary

The number of intersection fatalities and incapacitating injuries within the State can measurably decline over the next several years, but it will take a number of new and special actions, increased intersection safety emphasis, and additional funding to realize this benefit. The existing approach of emphasizing moderate- to high-cost improvements at high-crash intersections must be complemented with the deployment of a large number of low-cost, effective countermeasures and the use of coordinated 3E comprehensive solutions on high-crash corridors and in municipalities that have a high number of intersection fatalities.

For many of the countermeasures, key implementation steps include field reviews to determine the specific intersections at which improvements can be made. Appendix A provides information that can facilitate this process – listings of intersections where multiple countermeasures can be considered.

A consensus-building process must be pursued to gain the broad support and funding of Districts, MPOs, cities, and upper management of the implementation plan to better ensure effective implementation. In addition, one of the existing safety committees should guide the effective implementation of the plan. This will also improve the potential for a successful outcome.

Recapping, the countermeasures, deployment levels, costs, and estimated lives saved needed to achieve the intersection safety goal are shown in Table 36. While the level and direction of effort is well beyond that currently being pursued for intersection safety, the expected outcome – preventing over 5,400 crashes, 300 incapacitating injuries, and more than 25 fatalities at State intersections each year – is worth the investment.

Table 36. Summary of Countermeasures, Deployment Levels, Costs, and Fatality Reductions

Countermeasure	Approach	Number of Intersections to be Improved	Construction Cost ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
Basic Set of Sign and Marking Improvements –State Stop-Controlled Intersections	Systematic	1,108	8.87		1,382	117.7	13.07
Flashing Solar Powered LED Beacons on Advance Intersection Warning Signs and STOP Signs or Flashing Overhead Intersection Beacons – State Stop-Controlled Intersections	Systematic	69	0.69		54	4.0	0.44
J-Turn Modifications on High-Speed Divided Arterials – State Stop-Controlled Intersections	Systematic	56	16.80		77	17.5	2.87

Countermeasure	Approach	Number of Intersections to be Improved	Construction Cost ($ Million)	Enforcement, Education and EMS Costs (Annual $ Thousand)	Estimated Annual Crashes Reduced	Estimated Annual Incapacitating Injuries Reduced	Estimated Annual Fatalities Reduced
Basic Set of Sign and Marking Improvements – Local Stop-Controlled Intersections	Systematic	236	1.89		555	15.1	0.71
Basic Set of Signal and Sign Improvements – State Signalized Intersections	Systematic	395	1.92		789	28.1	1.52
Change of Permitted and Protected Left-Turn Phase to Protected Only – State Signalized Intersections	Systematic	536	2.67		819	44.0	1.49
Advance Detection Control Systems – State Signalized Intersections	Systematic	67	1.00		45	4.2	0.31
Basic Set of Signal and Sign Improvements – Local Signalized Intersections	Systematic	263	2.63		670	19.5	1.51
Change of Permitted and Protected Left-Turn Phase to Protected Only – Local Signalized Intersections	Systematic	387	1.94		623	23.7	1.27
New or Upgraded Lighting – State Rural Intersections	Systematic	64	3.84		49	8.4	1.08
High-Friction Surface – State Intersections	Systematic	53	2.65		86	11.3	1.27
Enforcement-Assisted Lights	Systematic	1 City	0.09	0.05	45	2.3	0.11
Corridor 3E Improvements on High-Speed Arterials with Very High Frequencies of Severe Intersection Crashes	Comprehensive	3 Corridors	6.00	0.30	83	7.5	1.25
Municipal-Wide 3E Improvements in Municipalities with High Frequencies of Severe Intersection Crashes	Comprehensive	1 City	1.0	0.10	383	6.6	0.57
Roundabouts	Traditional	3	2.4		32	3.0	0.36
Total			**54.39**	**0.45**	**5,692**	**312.9**	**27.83**

Appendix A. Intersections with Multiple Countermeasure Considerations

<u>Note to the Reader:</u> Table 37 provides a partial example of the listing of State rural stop-controlled intersections with multiple countermeasure considerations. It shows the number of crashes above the given threshold for a specific countermeasure by intersection. It is created by combining all of the distributions of crashes by intersection, using only those intersections where the number of crashes exceeds the threshold for that given countermeasure. Tables such as these should be prepared for the following types of intersections:

- State Rural Stop-Controlled Intersections.
- State Urban Stop-Controlled Intersections.
- Local Rural Stop-Controlled Intersections.
- Local Urban Stop-Controlled Intersections.
- State Rural Signalized Intersections.
- State Urban Signalized Intersections.
- Local Rural Signalized Intersections.
- Local Urban Signalized Intersections.

Table 37. Example – State Rural Stop-Controlled Intersections with Multiple Countermeasure Considerations

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