2012

District Guidance for Intersection Safety Implementation Plan

Pennsylvania Department of Transportation

Highway Safety and Traffic Operations Division

8/1/2012

The Intersection Safety Goal

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

Table 1. Pennsylvania Intersection Fatalities

	2007	2008	2009	2010	2011
Number of Intersection Fatalities	339	287	280	267	270

The Pennsylvania Strategic Highway Safety Plan (SHSP) has an updated safety goal of reducing the number of annual fatalities within Pennsylvania by half within two decades (2010-2030). In 2011, 1,286 fatalities occurred, of which 270 were intersection fatalities. In 2011, 21.0% of all fatalities occurred at intersections. That number was decreased from a 2009 value of 22.3%. The intersection portion of the updated SHSP goal is to reduce intersection fatalities by approximately 8 per year.

A workshop composed of Pennsylvania Department of Transportation (DOT) safety personnel and LTAP personnel was held on August 5-6, 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 of 30 fewer statewide intersection fatalities is achievable through the application of a diverse variety of low-cost, cost effective countermeasures. Over a projected 10 year life it is estimated that more than 54,000 intersection crashes and 3,000 disabling injuries will be prevented along with at least 300 lives saved.

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 and are 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 Pennsylvania Intersection Fatality Problem

The Pennsylvania intersection crash and fatality data was analyzed to gain insight on the distribution and characteristics of the intersection crash problem. The following table lists the Top 5 Most Effective Countermeasures, listed by category, identified from the Intersection Safety Implementation Plan (ISIP). These 5 categories of countermeasures have been singled out due to their ease of implementation and low cost to install. Almost 82 percent of the overall lives saved (38 annual lives saved for $103.68 million) can be achieved by effectively implementing the following countermeasures in Table 2. (Please note these numbers have been revised to reflect the new data and do not correspond to FHWA's initial ISIP from 2010)

Table 2. Summary of ISIP's Most Effective Countermeasures by Category (Including Deployment Levels, Costs, and Fatality Reductions)

Rank	Category	Approach	Number of Intersections	Construction Cost ($ Million)	Estimated Annual Fatalities Reduced
1	Basic Set of Sign and Marking Improvements – State Intersections – Stop-Controlled TCD	Systematic	1,934	15.48	14.67
2	Basic Set of Signal and Sign Improvements – State Intersections – Signalized TCD	Systematic	495	14.86	4.26
3	Change of Permitted and Protected Left-Turn Phase to Protected Only – State Intersections – Signalized TCD	Systematic	400	2.00	2.52
4	Pedestrian Enhancements – State Intersections	Systematic	922	27.67	4.90
5	Speed Reduction Enhancements – State Intersections	Systematic	725	21.74	3.19
Total			**4476**	**81.75**	**29.54**

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. To ensure success, the Safety Management Division will develop and deploy a tracking system (See Table 11) to monitor the implementation of the various types of countermeasures being deployed. This system will 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. Please be advised that districts will be allowed to use Section 715 and 148 Funding to implement these measures.

The following outlines each countermeasure category in detail, as well as their perspective implementation steps and a breakout of intersection locations by district. These locations include all intersections per district that meet the predetermined crash thresholds and should be addressed using a long term systematic approach starting with the highest ranked category.

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

Description

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.

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.

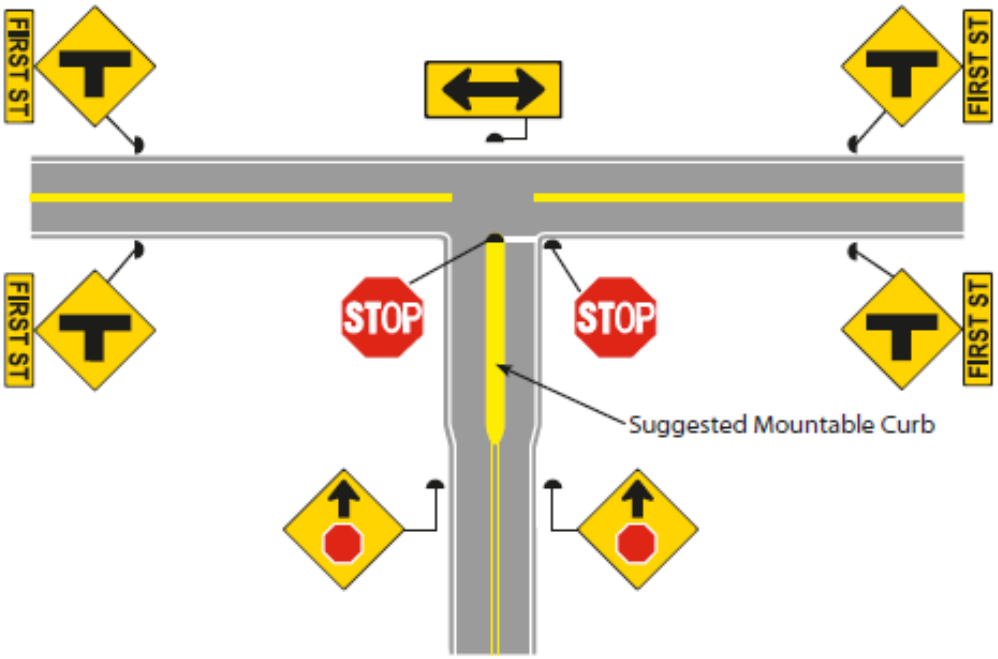

Figure 1. Examples of Basic Low-Cost Countermeasures for Stop-Controlled Intersections – Double Up Oversize Warning Signs, Double Stop Signs, Traffic Island on Stop Approach (if feasible), Street Name Signs, Stop Bars, and Double Warning Arrow at the Stem of T-Intersections

The high-crash intersections where the basic set of signing and marking improvements are to be considered for installation are summarized in Table 3:

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

Category	Number of District Intersection Locations										
	1	2	3	4	5	6	8	9	10	11	12
Basic Set of Sign and Marking Improvements – Rural ≥ 45 mph	81	45	77	55	334	260	382	40	77	33	105
Basic Set of Sign and Marking Improvements – Rural < 45 mph	18	11	32	51	167	117	263	17	8	23	33
Basic Set of Sign and Marking Improvements – Urban < 45 mph	0	0	0	0	4	13	9	0	1	3	2
Basic Set of Sign and Marking Improvements – Urban ≥ 45 mph	1	0	2	7	19	77	23	0	4	12	12
Total	**100**	**56**	**111**	**113**	**524**	**467**	**677**	**57**	**90**	**71**	**152**
Construction Cost ($ Thousand)	**800**	**448**	**888**	**904**	**4,192**	**3,736**	**5,416**	**456**	**720**	**568**	**1,126**

(1) Assumes an average cost of $8,000 per intersection.

(2) Crashes were separated by mainline Speed Limit at or above 45 MPH or below 45MPH because of significant differences in crash severities between the two groups.

Implementation

The key steps necessary to implement this initiative fully and realize the safety benefits of the improvements and the organizations responsible for each key step are shown in Table 4.

Table 4. Key Implementation Steps for Sign and Marking Improvements – State Stop-Controlled Intersections

Step	Organization Responsible for Step
1. 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).	District Traffic Engineering Operations and Safety personnel
2. Commence and complete field views of the top half of the State intersections on the list, identify intersections where improvements are appropriate, identify improvements, identify which Districts will implement using Department forces, and prepare statewide or area contract plans for remaining work.	District Traffic Engineering Operations and Safety personnel
3. Let contracts (if applicable) and implement improvements.	District Offices

2. Signal and Sign Improvements – State Signalized Intersections

Description

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.

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

The statewide high-crash intersections where the basic set of signal and sign improvements should be considered are summarized in Table 5:

Table 5. Basic Set of Signal and Sign Improvements – State Signalized Intersections

Category	Number of District Intersection Locations										
	1	2	3	4	5	6	8	9	10	11	12
Basic Set of Signal and Sign Improvements – Urban ≥ 45 mph	4	1	0	1	15	86	7	1	4	11	1
Basic Set of Signal and Sign Improvements – Urban <45mph	1	1	0	7	16	54	16	3	1	20	0
Basic Set of Signal and Sign Improvements – Rural ≥ 45 mph	16	7	17	8	86	96	47	9	19	6	26
Basic Set of Signal and Sign Improvements – Rural-<45 mph	0	0	0	3	14	3	10	1	1	0	0
Total	**21**	**9**	**17**	**19**	**131**	**239**	**80**	**14**	**25**	**37**	**27**
Construction Cost ($ Thousand)	**630**	**270**	**510**	**570**	**3,930**	**7,170**	**2,400**	**420**	**750**	**1,110**	**810**

(1) Assumes an average cost of $30,000 per intersection.

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; appropriate 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.

Implementation

The key steps necessary to implement this initiative fully and realize the safety benefits of the improvements and the organizations responsible for each key step are shown in Table 6.

Table 6. Key Implementation Steps for Signal and Sign Improvements – State Signalized Intersections

Step	Organization Responsible for Step
1. Establish teams (District Office Traffic Engineering Operations and/or Safety Engineer and/or consultant) to field review intersections, determine improvements and prepare contract plans.	District Traffic Engineering Operations and Safety personnel
2. Develop a training package and train team on guidelines, field review requirements, and contract plan preparation.	BOMO Office of Traffic Engineering Operations and Office of Safety Management
3. Commence and complete field views of the top half of the listed signalized intersections, identify improvements, identify which Municipalities will implement using Department forces, prepare District wide or area contract plans for remaining work.	District Traffic Engineering Operations and Safety personnel
4. Let contract and implement improvements.	Districts
5. Evaluate initial deployments and update guidelines for the remaining set of intersections.	Office of Safety Management

Step	Organization Responsible for Step
6. Repeat steps 4 and 5 for the remaining g signals plus any additional intersections identified above the threshold using newer crash data.	District Offices

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

Description

One major crash pattern that needs to be addressed individually is signalized intersections with a significant number of or potential for left-turn, opposing-flow crashes. At these traffic signals the potential change is likely to involve modification of 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. A capacity analysis including an assessment of the adequacy of the left turn lane storage capacity with the phasing modification should also be performed.

In addition, many of these signals use five signal heads placed between the left-turn lane and inside travel lane to provide signal information for both the left turn and inside through movement.

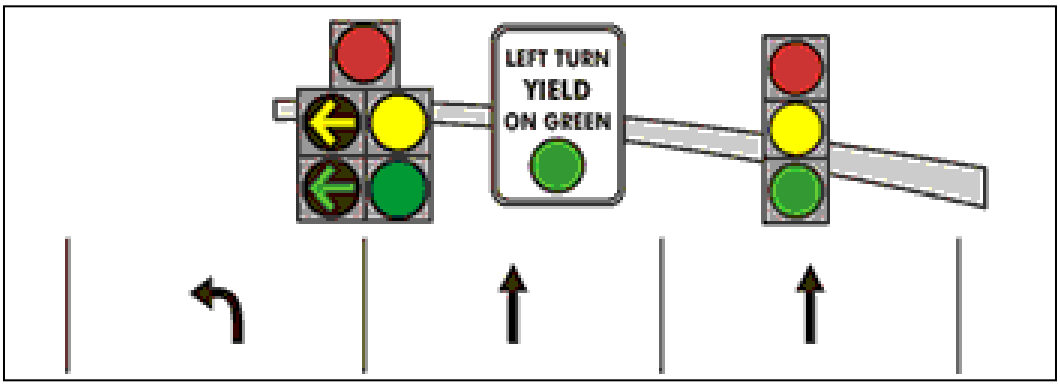

Figure 2 - Permitted and Protected Left Turn Phases

Modifying these signals to provide the protected only left-turn will probably mean replacement of the five section head with a separate set of heads for the left-turn movement placed close to the middle of the left-turn lane (extension of the mast arm will be needed for many of these installations) and another set of heads for the through movement.

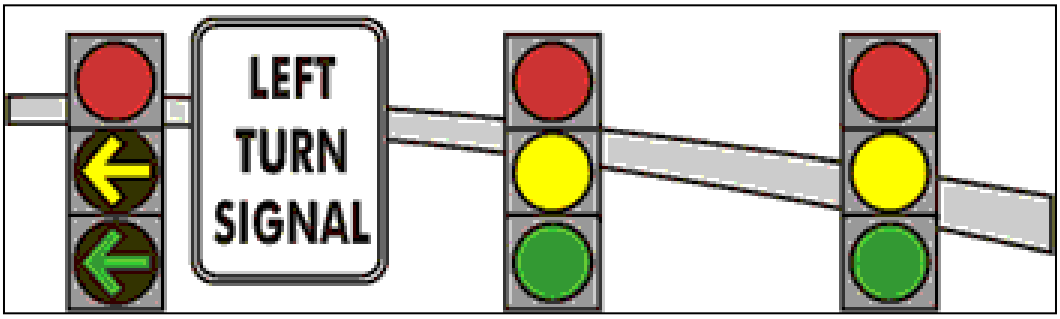

Figure 3 - Protected Left Turn Phase

The high-crash intersections where the protected only left-turn phase should be considered are summarized in Table 7:

Table 7. Change of Permitted and Protected Left-Turn Phase to Protected Only – State Signalized Intersections

Category	Number of District Intersection Locations										
	1	2	3	4	5	6	8	9	10	11	12
Change of Permitted and Protected Left-Turn Phase to Protected Only – Urban	5	3	0	12	56	193	45	4	5	35	2
Change of Permitted and Protected Left-Turn Phase to Protected Only – Rural	20	13	24	22	103	100	89	23	17	3	27
Total	**25**	**16**	**24**	**34**	**159**	**293**	**134**	**27**	**22**	**38**	**29**
Construction Cost ($ Thousand)	**125**	**80**	**120**	**170**	**795**	**1,465**	**670**	**135**	**110**	**190**	**145**

(1) Assumes an average cost of $5,000 per intersection.

Implementation

The key steps necessary to implement this initiative fully and realize the safety benefits of the improvements and the organizations responsible for each key step are shown in Table 8.

Table 8. Key Implementation Steps for Signal and Sign Improvements – State Signalized Intersections

Step	Organization Responsible for Step
1. Establish teams (District Office Traffic Engineering Operations and/or Safety Engineer and/or consultant) to field review intersections, determine improvements and prepare contract plans.	District Traffic Engineering Operations and Safety personnel
3. Commence and complete field views of the top half of the listed signalized intersections, identify improvements, identify which Municipalities will implement using Department forces, prepare District wide or area contract plans for remaining work.	District Traffic Engineering Operations and Safety personnel
4. Let contract and implement improvements.	Districts
5. Evaluate initial deployments and update guidelines for the remaining set of intersections.	Office of Safety Management
6. Repeat steps 4 and 5 for the remaining g signals plus any additional intersections identified above the threshold using newer crash data.	District Offices

4. Pedestrian Safety Enhancements at State and Local Intersections

Description

Pedestrian safety, particularly at intersections that have two or more pedestrian crashes within the past 5 years, need to be addressed. Most of these multiple pedestrian crashes occur at signalized intersections, but a few occur at stop-controlled intersections. The predominant pedestrian safety enhancements are as follows:

- Pedestrian countdown signals at intersections with high pedestrian activity or multiple pedestrian crashes. (Signalized Intersections)
- Exclusive pedestrian phasing at intersections with multiple pedestrian-turning vehicle conflicts and crashes. (Signalized Intersections)
- Higher visibility crosswalks and advance pedestrian warning signs at intersections with high pedestrian activity or multiple pedestrian crashes. (Stop-Controlled and Signalized Intersections)
- Speed reduction measures on approaches to stop-controlled intersections with multiple pedestrian crashes.

The high-crash intersections where the pedestrian enhancements should be considered are summarized in Table 9:

Table 9. Pedestrian Enhancements (Pedestrian Countdown Signals, Crosswalks, Potential Separate Pedestrian Phases) – State Intersections

Category	Number of District Intersection Locations										
	1	2	3	4	5	6	8	9	10	11	12
Pedestrian Enhancements – Urban Signalized	14	16	3	26	72	699	54	6	6	60	4
Pedestrian Enhancements – Urban Stop-Controlled	2	6	2	11	22	89	14	2	3	10	0
Pedestrian Enhancements – Rural (All TCD)	1	1	2	2	12	4	5	1	1	0	3
Total	**17**	**23**	**7**	**39**	**106**	**792**	**73**	**9**	**10**	**70**	**7**
Construction Cost ($ Thousand)	**510**	**690**	**210**	**1,170**	**3,180**	**23,760**	**2,190**	**270**	**300**	**2,100**	**210**

(1) Assumes an average cost of $30,000 per intersection.

Implementation

The key steps necessary to implement this initiative fully and realize the safety benefits of the improvements are incorporated into the processes for stop-controlled and signalized intersections above. That is, if an intersection meets the pedestrian crash thresholds identified above, in addition to the basic signal, sign, and marking enhancements to consider, the pedestrian enhancements listed above are also to be considered.

5. Speed Reduction Safety Enhancements at State Intersections

Description

Speed reduction, particularly at intersections that have multiple crashes in which the crash report has identified speeding or too fast for conditions as a causative factor should consider infrastructure improvements to reduce high-end intersection approach speeds. The predominant speed reduction enhancements are as follows:

Intersection approaches where drivers commonly enter the intersection at excessive speeds can potentially increase the severity of crashes. In addition, higher approach speeds may make it more difficult for some stopped drivers at stop-controlled intersections to identify safe gaps to enter the intersection. Another concern is intersections with high speeds on the through approaches and limited sight distance on the stop approach.

Countermeasures

The countermeasures are primarily intended for consideration on the through approaches at stop-controlled intersections; however, they may also be considered, after careful analyses, for high-speed approaches at signalized intersections. Minimal information is available concerning the crash reduction factors for speed reduction improvements. A number of countermeasures have performed well under limited levels of deployment. However, additional deployments may yield different results. These countermeasures may be cautiously deployed and complemented with evaluations to determine if the desired results have or have not been obtained.

The low-cost countermeasures for intersections with a high frequency of high-speed vehicle crashes on approaches include a number of options, as follows:

- Lane narrowing using rumble strips parallel to the edge lines. (See HRT-08-063, 'Two Low-Cost Safety Concepts for Two-Way Intersections on High-Speed Two-Lane, Two-Way Roadways' for further design and performance information.)
- Lane narrowing using raised pavement markers in lieu of rumble strips on approaches where noise issues or bicycle safety concerns associated with rumble strips cannot be addressed.
- Dynamic warning signs on the through approach warning drivers traveling at speeds above a set threshold to slow down.
- Peripheral transverse pavement markings at a spacing of 4 markings per second. (See "Peripheral Transverse Pavement Markings for Speed Control," by Bryan Katz, at http://scholar.lib.vt.edu/theses/available/etd-05172007-135959/unrestricted/KatzPhDDissertation.pdf)
- Slow or speed limit pavement marking legends highlighted within a gray or black box on the pavement and supplemented with advance intersection warning signs with advisory speed plates. (See HRT-08-063 for further performance information.)
- High friction surface applied to the approaches (approximately 300 feet in advance) and through the intersection.

The high-crash intersections where the speed reduction enhancements should be considered are summarized in Table 10:

Table 10. Speed Reduction Enhancements – State Intersections

Category	Number of District Intersection Locations										
	1	2	3	4	5	6	8	9	10	11	12
Speed Reduction Enhancements – Urban	4	2	0	5	51	160	49	3	16	28	4
Speed Reduction Enhancements – Rural	24	14	24	16	179	113	133	30	18	6	27
Total	**28**	**16**	**24**	**21**	**230**	**273**	**182**	**33**	**34**	**34**	**31**
Construction Cost ($ Thousand)	**840**	**480**	**720**	**630**	**6,900**	**8,190**	**5,460**	**990**	**1,020**	**1,020**	**930**

(1) Assumes an average cost of $30,000 per intersection.

Implementation

The key steps necessary to implement this initiative fully and realize the safety benefits of the improvements are incorporated into the processes for stop-controlled and signalized intersections above (See Section 1). That is, if an intersection meets the speed reduction crash thresholds identified above, in addition to the basic signal, sign, and marking enhancements to consider, the speed reduction enhancements listed above are also to be considered.

Tracking:

To ensure successful implementation of the multiple strategies in the plan, the Safety Management Division (SMD) will track (See Table 11) the implementation of the various types of countermeasures being deployed at the recommended locations.

The following outlines each countermeasure category in detail, a breakout of intersection locations by district and how many of those locations were addressed. These locations include all intersections per district that meet the predetermined crash thresholds and should be addressed using a long term systematic approach.

Table 11. Intersection Improvement Implementation Tracking

Category		District										
		1	2	3	4	5	6	8	9	10	11	12
Basic Set of Sign and Marking Improvements – State Intersections – Stop-Controlled TCD	Locations	100	56	111	113	524	467	677	57	90	71	152
	Addressed											
Basic Set of Signal and Sign Improvements – State Intersections – Signalized TCD	Locations	21	9	17	19	131	239	80	14	25	37	27
	Addressed											
Change of Permitted and Protected Left-Turn Phase to Protected Only – State Intersections – Signalized TCD	Locations	25	15	24	34	159	293	134	27	22	38	29
	Addressed											
Pedestrian Enhancements – State Intersections	Locations	17	23	7	39	106	792	73	9	10	70	7
	Addressed											
Speed Reduction Enhancements – State Intersections	Locations	28	16	24	21	230	273	182	33	34	34	31
	Addressed											
Total	Locations	191	119	183	226	1,150	2,064	1,146	140	181	250	246
	Addressed											

To assist SMD in determining the effectiveness of this effort, Districts will complete the ISIP Tracking Form (See Form 1) to secure before and after targeted crash histories, dates of implementation, linkages to other improvements implemented at the intersection, and other information deemed pertinent.

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DEPARTMENT OF TRANSPORTATION
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INTERSECTION SAFETY IMPLEMENTATION PLAN (ISIP) TRACKING FORM (5-10)

A - CONTACT INFORMATION

Name	Date

B - LOCATION INFORMATION

District	County	MPMS#	Project Title
SR	Section	Beginning Seg/Off	Ending Seg/Off

C – PROJECT INFORMATION

Project Cost	Funding Type	ISIP Category (From Tbl. 11)

D - PROJECT DESCRIPTION

Please provide the reason for the safety deficiency, how the project will address it and the cost associated with each safety countermeasure.

E – CRASH HISTORY

Please provide the crash summary report (CDART) for the above mentioned location for three years prior to project commencement.

Please be advised that districts will be allowed to use Section 715 and 148 Funding to implement these measures.

In Summary:

The number of intersection fatalities and incapacitating injuries within Pennsylvania 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 for intersection improvements 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.

To recap, the countermeasures, deployment levels, costs, and the estimated number of lives saved needed to assist in achieving the intersection safety goal are shown in Table 2. 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 30 fatalities at intersections each year – is worth the investment.