Pennsylvania Roadway Departure Safety Implementation Plan

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

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Executive Summary

In 2011, Pennsylvania experienced 1,285 highway fatalities, 58 percent (or 746) of which were roadway departure fatalities. Safety initiatives currently underway – along with other vehicle safety enhancements gradually being introduced into the vehicle fleet – have resulted in significant safety advances, and reduced fatalities in the 2007-2011 period. Further analysis indicates that an additional 60 lives can be saved annually over the next several years through the investment of cost-effective, low cost roadway departure countermeasures strategically deployed on the highway system.

Roadway departure fatalities accounted for slightly over 58 percent of all highway fatalities in Pennsylvania in 2011. A data analysis package and a set of roadway departure countermeasures were merged to identify a set of low cost countermeasures, deployment levels, and funds needed to achieve a substantial and cost effective annual reduction in roadway departure fatalities.

The data analysis indicates that over 60 lives can be saved annually for the next 10 years with the following enhancements to the existing safety program:

- The traditional approach of relying primarily on implementing major improvements at high-crash roadway departure locations must be complemented with a) a systematic approach that involves deploying large numbers of relatively low-cost, cost-effective countermeasures at many targeted roadway departure sites with moderate crash levels, and b) a comprehensive approach that coordinates an engineering, education, and enforcement (3-E) initiative on corridors with large numbers of severe roadway departure crashes where driver behavioral issues (alcohol, speed, non-use of safety belts) are a major crash concern..
- The systematic improvement categories to be deployed include the following: sign and marking enhancements on curves with crash histories; centerline rumble strips on rural two-lane highways; edge line rumble stripes and widened four feet paved shoulders, predominantly on rural two-lane highways; and rural tree removal or protection mitigation programs.
- The safety program needs to be expanded to incorporate low-cost, cost-effective countermeasures on other types of projects – such as resurfacing and surface transportation projects – when a crash history exists within the project area and the appropriate countermeasures can reduce future crash potential.
- The safety program must encompass cost-effective treatments on local roads since approximately 35 percent of the statewide roadway departure crash problem and 20 percent of roadway departure fatalities occur on local roads.
- Additional countermeasures rarely or never used in Pennsylvania need to be carefully and judiciously deployed on highway sections that have specific crash problems that these countermeasures can address. These countermeasures include the following: florescent yellow warning signs in advance of curves; lateral transverse grooves on poorly drained concrete pavements; and traffic calming to achieve substantive high-end speed reductions in advance of populated areas and sharp curves.
- A substantial education and highly visible enforcement program should be initiated and coordinated with the 402 Safety Program to improve safe driver behavior on selected corridors that have significant numbers of severe total and roadway departure crashes with concentrations of unsafe driver behavior characteristics.

- Saving over 60 additional lives per year will take an investment of approximately $85 million over the next 5 to 7 years to implement the infrastructure improvements, or about $14 million per year for six years. In addition, an annual cost of $ 3.2 million is needed to implement the education and enforcement initiatives. The costs can be broken into the following categories: state systematic infrastructure improvements – approximately $61 million; local systematic infrastructure improvements – approximately $6 million; engineering and inspection costs – approximately $15 million State, $2 million local; education and enforcement initiatives – approximately $3 million annually.

This plan provides specific information on how these additions to the current safety program can be implemented effectively.

The bottom line is that when the plan is fully implemented, it is projected that over 25,000 roadway departure crashes will be prevented and over 600 lives will be saved over the next 10-year period.

The Roadway Departure Safety Goal

Background

Roadway departure fatalities within the State accounted for approximately 58 percent of all highway fatalities in 2011. Over the past several years, Pennsylvania has had consistent reductions in total and road departure highway fatalities as indicated in Table 1.

Table 1: Highway Fatalities

Year	Crashes		Fatalities		
	Roadway Departure	Total	Roadway Departure	Percent of Total	Total
2007	49,903	131,691	800	53.87%	1,485
2008	49,396	125,813	825	56.43%	1,462
2009	46,251	121,518	673	53.67%	1,254
2010	43,660	121,310	764	57.70%	1,324
2011	46,120	125,060	746	58.05%	1,285
Total	235,330	625,392	3,808	55.92%	6,810

The roadway departure goal is to continue the general declining trend of roadway departure fatalities. This aligns with the overall fatality reduction goal.

Beginning with the entire crash database for 2007-2011, a subset of crashes has been defined as roadway departure-related using the following filters:

1. Include all single vehicle non-pedestrian, non-bicycle crashes.
2. Include all head-on and sideswipe, opposite direction crashes.
3. Include any remaining multi-vehicle crashes in which a fixed object was the first harmful event.
4. Remove all intersection and intersection-related crashes.
5. Remove any remaining pedestrian or bicycle-related crashes.

Approach

To help lower statewide roadway departure fatalities, two additional approaches are recommended to complement the traditional approach of improving safety at specific high-crash locations:

- Systematic application of large numbers of cost-effective, low-cost countermeasures at locations that have specific, moderate crash types above a specified crash frequency level.
- Education and enforcement initiatives targeted to corridors that exhibit a very high severe roadway departure crash history associated with unsafe driving characteristics (alcohol, speed, non-use of safety belts).

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 find highway sections that have targeted crashes at or above a crash threshold that would ensure cost-effective deployment of these countermeasures. Estimates of the impacts of the deployments can be made in terms of projected statewide roadway departure crashes prevented, annual lives saved, and overall costs to deploy the countermeasures.

The education and enforcement initiative is directed to reduce unsafe driving characteristics on corridors that have a severe roadway departure crash history associated with unsafe driving characteristics.

Both of these approaches are driven by roadway departure crash data. The systematic approach identifies crash types that specific countermeasures are designed to impact and selects clusters of locations that have targeted crashes at or above a designated threshold level. The total number of targeted crashes in these clusters is then coupled with a predicted Crash Modification Factor[1] to estimate the total number of targeted crashes that could be reduced should the countermeasure be implemented at each of the clusters. The impact of these improvements in terms of crash severity reduction is determined by multiplying these targeted crash reductions by incapacitating injuries per 100 crashes and fatalities per 100 crashes for targeted crashes in the environment of the clusters identified. Statewide ratios are used rather than the previous history at each site to produce a more reliable estimate of severity impact.

Three other features need to be added to the current approach to improve the likelihood of achieving an additional 60 lives saved annually:

1. The safety program needs to be expanded to incorporate low-cost, cost-effective countermeasures on other types of projects – such as resurfacing and surface transportation projects – when a crash history exists within the project area and the countermeasure can reduce future crash potential.
2. The safety program must encompass cost-effective treatments on local roads since almost 20 percent of the statewide roadway departure fatality problem occurs on local roads.
3. Additional countermeasures rarely or never used in Pennsylvania need to be carefully and judiciously deployed on highway sections that have specific crash problems to determine if these additional countermeasures are effective in reducing targeted crashes and, if so, to expand them in use.

Distribution of the State Roadway Departure Fatality Problem

The roadway departure crash and fatality data for Pennsylvania was analyzed to gain insight into the distribution and characteristics of the roadway departure crash problem. Key information derived from the roadway departure data analysis is shown in Tables 2 through 6.

[1] Crash Modification Factors (CMF) were identified primarily from information contained in the Crash Modification Factor clearinghouse- www.**cmfclearinghouse.org**

Table 2: Total and Roadway Departure (RD) Crashes, and Fatalities by Year (2007-2011)

Year	RD Crashes	Total Crashes	RD Fatalities	Total Fatalities	Total RD Fatalities/100 Crashes	Total Fatalities/100 Crashes
2007	49,903	131,691	800	1485	1.60	1.13
2008	49,396	125,813	825	1462	1.67	1.16
2009	46,251	121,518	673	1254	1.46	1.03
2010	43,660	121,310	764	1324	1.75	1.09
2011	46,120	125,060	746	1285	1.62	1.03
Total	235,330	625,392	3808	6810	1.62	1.09

Table 3: Roadway Departure Crashes and Fatalities by Locality (2007-2011)

Locality	Crashes		Fatalities	
	Total	Percentage	Total	Percentage
State	**172,982**	**73.51%**	**3,082**	**80.93%**
Rural	118,238	50.24%	2,340	61.45%
Urban	53,736	22.83%	716	18.80%
Unknown	1,008	0.43%	26	0.68%
Local	**62,138**	**26.40%**	**724**	**19.01%**
Rural	33,693	14.32%	458	12.03%
Urban	28,101	11.94%	261	6.85%
Unknown	344	0.15%	5	0.13%
Unknown	**210**	**0.09%**	**2**	**0.05%**
Rural	119	0.05%	2	0.05%
Urban	90	0.04%	-	0.00%
Unknown	1	0.00%	-	0.00%
Grand Total	**235,330**	**100.00%**	**3,808**	**100.00%**

Table 4: Speed Related Total and Roadway Departure Crashes and Fatalities (2007-2011)

State Local	Rural Urban	Total Speed Crashes	Total Speed RD Crashes	Total Speed Fatalities	Total Speed RD Fatalities	% Speed Fatalities that are RD
State	Rural	71,173	47,862	1,903	1,304	68%
	Urban	49,314	19,317	727	403	55%
Local	Rural	20,291	16,507	400	352	88%
	Urban	18,527	8,874	227	139	61%
	Total	159,305	92,560	3,257	2,198	67%

Table 5: Alcohol Related Total and Roadway Departure Crashes and Fatalities (2007-2011)

State Local	Rural Urban	Total Alcohol Crashes	Total Alcohol RD Crashes	Total Alcohol Fatalities	Total Alcohol RD Fatalities	% Alcohol Fatalities that are RD
State	Rural	21,840	15,342	1,361	1,003	74%
	Urban	18,694	7,523	625	315	50%
Local	Rural	7,579	6,015	291	262	89%
	Urban	12,684	5,179	208	126	60%
	Total	60,797	34,059	2,485	1,706	69%

Table 6: Unbelted Related Total and Roadway Departure Crashes and Fatalities

State Local	Rural Urban	Total Unbelted Crashes	Total Unbelted RD Crashes	Total Unbelted Fatalities	Total Unbelted RD Fatalities	% Unbelted Fatalities that are RD
State	Rural	29,569	16,405	1,913	1,334	70%
	Urban	26,803	6,935	648	385	59%
Local	Rural	7,928	5,719	294	268	91%
	Urban	15,445	4,320	213	139	65%
	Total	79,745	33,379	3,068	2,126	69%

Summary of Roadway Departure Crash Concerns

- Crashes, fatalities, and fatalities per 100 crashes have been declining for both total and roadway departure crashes. Roadway departure fatalities are declining at a slower rate than all other fatality types combined.
- Over 35% of the roadway departure crashes and nearly 20 percent of the roadway fatalities occur on local roads.
- Driving violations (speeding, alcohol, and unbelted driving) are major factors in roadway departure crashes. Many of these crashes involve multiple driving violation factors.

Summary of Roadway Departure Countermeasure Deployments

A summary of the countermeasures, deployment levels, costs, and estimated lives saved using these three approaches is provided in Table 7 and Figure 1.

Table 7: Strategy Matrix – Summary of Roadway Departure Countermeasures: Deployment Levels; Costs; Crash, Incapacitating Injury Crash, and Fatality Reductions

Countermeasure	Approach	Estimated Number of Improvements [1]	Associated Costs ($ Million) [2]	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Reduction	Annual Estimated Fatality Reduction	$ (Million) Required to Save One Annual Life
State Roads							
Enhanced Curve Sign and Marking Countermeasures - Total State Rural	Systematic	2,375	$11.88	683	28.83	18.27	0.65
Enhanced Curve Sign and Marking Countermeasures Plus High Friction Surfaces - Total State Rural	Systematic	31	$1.85	40	1.69	1.12	1.66
Enhanced Curve Sign and Marking Countermeasures - Total State Urban	Systematic	271	$1.35	174	5.10	2.65	0.51
Centerline Rumble Stripes - Total State Rural	Systematic	162	$2.91	54	16.85	3.53	0.82
Edge Line Rumble Stripes or Shoulder Rumble Strips - Total State Rural	Systematic	1,656	$4.97	400	12.92	7.79	0.64
Alignment Delineation - Total State	Systematic	150	$0.75	30	1.10	0.65	1.16
High Friction Surfaces - Total State	Systematic	24	$2.35	49	0.95	0.50	4.68
Guardrail Relocation/Safety Enhancements - Total State	Systematic	24	$0.60	-	0.96	0.64	0.94
Tree Removal/Safety Enhancements, Shield Tree(s) - Total State	Systematic	100	$7.50	107	5.55	3.75	2.00
Utility Pole Relocation/Safety Enhancements - Total State	Systematic	80	$6.00	115	3.77	1.71	3.51
Enforcement and Education: Alcohol Related - Total State	Ed & Enf	39	$0.98	34	1.99	1.44	0.68
Enforcement and Education: Speeding Related Crashes - Total State	Ed & Enf	148	$7.70	238	5.86	4.31	1.78
Infrastructure Improvements: Speeding Related Crashes - Total State	Ed & Enf	61	$3.16	61	1.73	1.26	2.51
Enforcement and Education: Unbelted Driver - Total State	Ed & Enf	48	$2.50	69	4.28	2.53	0.99
3-E Corridor Improvements - State Roads	Ed & Enf	1	$1.50	11	1.45	1.70	0.88
Wider Shoulders / Edge Line Rumble Stripes - Total State	Traditional	213	$9.54	274	9.33	4.20	2.27
Cable Median Guide Rail - Total State	Traditional	19	$5.67	-	0.35	1.48	3.83
Local Roads							
Enhanced Curve Sign and Marking Countermeasures - Total Local	Systematic	174	$4.34	147	4.43	1.73	2.51
Standard Pavement Markings - Total Local Rural	Systematic	31	$0.62	13	0.52	0.25	6.97
Alignment Delineation, Lighting - Total Local	Systematic	10	$0.21	3	0.12	0.05	4.59
Tree Removal/Safety Enhancements, Shield Tree(s) - Total Local	Systematic	16	$1.17	21	0.91	0.45	2.57
Enforcement and Education: Alcohol Related - Total Local	Ed & Enf	4	$0.10	4	0.15	0.07	2.97
Enforcement and Education: Unbelted Driver - Total Local	Ed & Enf	2	$0.12	4	0.14	0.06	2.14
Total Cost and Benefit (State and Local Roads)							
	Total Cost ($Million)		$77.75	-	-	-	-
	Annual Cost (Million) for 5 years; Annual Benefit		$15.55	2,531	108.98	60.13	-

Figure 1: Cost Breakdown

Infrastructure		
State Infrastructure	$	61.05
State Engineering, Design, and Inspection Costs	$	15.26
Local Infrastructure	$	6.33
Local Engineering, Design, and Inspection Costs	$	1.58
Total State Engineering, Design, Inspection, and Construction Costs	$	76.31
Total Local Engineering, Design, Inspection, and Construction Costs	$	7.92
Total Infrastructure Costs	**$**	**84.23**
Education and Enforcement		
Annual State Education and Enforcement Costs	$	3.17
Annual Local Education and Enforcement Costs	$	0.04
Total Annual Education and Enforcement Costs	**$**	**3.21**

Saving 60 additional lives per year will take an investment of approximately $84 million over the next 5 to 7 years to implement the infrastructure improvements, or about $14 million per year for six years in safety improvements. In addition, an annual cost of $ 3.2 million is needed to implement the education and enforcement initiatives. The costs can be broken into the following categories: state systematic infrastructure construction improvements – approximately $60 million; local systematic infrastructure construction improvements – approximately $6 million; engineering and inspection costs – approximately $15 million State, $2 million local; and, education and enforcement initiatives– approximately $3.2 million annually.

The data analysis package that was used for the workshop, and that supports the information in Table 7, is attached as Appendix A of this document. To avoid confusion, this package has been modified to reflect the final set of countermeasures, deployment levels, costs, and safety impacts that are in the body of this report rather than the original strategy matrix presented at the workshop. In addition, Appendix B is an Excel file that provides information on each of the highway sections on which the countermeasures in Table 7 were deployed – identifying all countermeasures to consider by section. Appendix C provides further detailed information on targeted crashes for state routes that have highway sections with targeted crashes at or above the crash threshold. District Safety Engineers can use information in Appendix C to determine if the limits of improvement of the defined countermeasure should be extended beyond the limits of the section above the crash threshold.

Key First Actions

There are several key first actions that need to be taken to effectively implement the Plan. Given the existing workloads, probably the greatest implementation barrier facing PennDOT is having sufficient human resources available to undertake these new initiatives in a timely manner. Additional work to successfully implement the critical initiatives – including developing the guidelines for considering and deploying the key countermeasures, field reviewing candidate locations to determine if the countermeasure deployment is appropriate, and assembling District or State wide contract plans to implement the countermeasures – will take a considerable human resource effort.

1. The draft implementation plan should be presented to the Districts and other affected Headquarters organizations, such as the Divisions of Maintenance, Planning, Design, and the Governor's Highway Safety Office to share, review, obtain input, and identify actions each organization needs to consider taking to successfully support implementation of the Plan.
2. Initial funding sources and preparatory materials need to be developed, training provided, and processes established to begin implementation of the low-cost countermeasures being considered for systematic deployment. These countermeasures include sign and marking enhancements for curves, centerline rumble strips on rural non-freeway highways, edge and shoulder rumble strips, and tree removal in rural areas.
3. Once acceptance and funding for the Plan is secured, a critical human resource assessment needs to be undertaken within the Safety Management Office, the LTAP Coordinator function, and at the District level to determine if human resources are adequate to efficiently implement the Plan in a timely manner. If significant deficiencies are identified, supplemental consultant forces will be considered to effectively implement the Plan.
4. The Safety Management Office needs to develop a tracking system that District personnel can use that identifies the action to be taken on each of the candidate cluster locations identified based upon the field review of the location. Actions that are different than those identified in this plan and candidate locations where no action should be taken need to be documented. A similar tracking system needs to be developed to track progress in reviewing targeted local roads and implementing local road countermeasures.
5. The Safety Management Office 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 roadway departure improvements being implemented under other programs, and other information deemed pertinent.

7. The Safety Management Office needs to determine if HSIP funds will be made available to implement identified countermeasures on local roads in this Plan. If so, the processes to provide those funds to local governments need to be developed.
8. Maintenance, design, and planning personnel need to incorporate low-cost, cost-effective countermeasures into existing programs and projects. Meetings need to be arranged with appropriate maintenance, design, and planning personnel to share the candidate locations and further explore and define the processes and responsibilities that need to be established to consider the incorporation of low-cost, cost-effective countermeasures into other program categories, such as the resurfacing program and the surface transportation improvement program. The primary low-cost countermeasures to consider for inclusion in other project types at targeted high-crash sections are as follows: sign and marking enhancements for horizontal curves; centerline rumble strips in rural areas; edge and shoulder rumble strips; expansion of the use of the Safety Edge from safety projects to all projects; tree removal in rural areas; guide rail deficiency corrections; and higher friction surfaces and/or surface drainage improvements.
9. Targeted, frequent and repetitive high-visibility enforcement and education initiatives need to be implemented on corridors with concentrations of speeding, alcohol, or unbelted crashes and fatalities to reduce the frequency of these driving issues on the corridors identified. Meetings need to be arranged with the Governor's Highway Safety Representative and appropriate police personnel to review the crash data that identifies highway sections with concentrations of speeding, unbelted, and alcohol-related crash histories. Targeted, highly visible, and repetitive enforcement and education initiatives need to be developed and considered for implementation at many of these locations to reduce the potential for future similar crashes.
10. A meeting needs to be established with the LTAP coordinator and some representative District Safety Engineers to discuss and determine approaches to involve local governments in implementing identified countermeasures on local roads which have concentrations of crashes that the countermeasures can reduce.
11. At least one comprehensive 3-E approach should be launched on one of the corridors which have the highest number of total and road departure fatalities.

Major Components of the Plan

The remaining sections of this plan provide a detailed description of key implementation steps for each of the major efforts needed to achieve the interim 2020 roadway departure goal. The efforts are categorized as follows:

- Systematic deployment of low-cost, cost-effective countermeasures on State highways.
- Incorporation of low-cost, cost-effective countermeasures into other programmed projects.
- Local road improvements.
- Education and enforcement initiatives.
- Comprehensive 3-E improvements.
- Traditional improvements.
- Implementation of new countermeasures.

Systematic Deployment of Low-Cost Countermeasures on State Highways

This initiative involves the installation of several sets of low-cost, cost-effective countermeasures at locations with high crash histories in an effort to significantly decrease the potential of future crashes. The types of low-cost countermeasures that have been identified for extensive systematic deployment are as follows:

1. Enhanced sign and marking improvements for curves with crash histories.
2. Centerline rumble strips to reduce head-on and opposing-flow sideswipe crashes.
3. Edge and shoulder rumble strips accompanied with a minimum four foot paved shoulder to reduce single vehicle roadway departure crashes.
4. Alignment delineation to reduce night crashes.
5. High friction surfaces to reduce wet pavement crashes.
6. Guide rail improvements to reduce the severity of guide rail crashes.
7. Select tree removal or tree crash prevention countermeasures in rural areas.
8. Utility pole relocation.

The methodology to identify sections of highway that have crashes at or above the threshold is twofold: step down a roadway in uniform, discrete section lengths and identify sections with a number of targeted crash types that equals or exceeds the defined threshold. However, the output from this process needs additional evaluation based upon field conditions or overall route characteristics. As an example, a single curve could span and have crashes in two joining sections. Thus, curve crashes on either side of a section identified as a high-crash curve section need to be reviewed to determine if there are any additional curve crashes that occurred on the same curve, but in the adjoining section. As another example, a rural highway may be 10 miles in length and 75 percent of the sections on the route meet the crash threshold for edge/shoulder rumble strips. For routes with multiple clusters above the threshold, providing rumble strips on the entire route rather than just on those sections that meet the threshold may be an appropriate decision. This may be determined by reviewing the information in Appendices C, conducting field reviews, or plotting the output on GIS maps.

The list of sections of highway that equal or exceed the crash thresholds for each of these countermeasures is provided in Appendix B.

Enhanced Sign and Markings to Reduce Roadway Departures on Curves

Curves on rural and urban State highways with the number of curve crashes at or above threshold levels and considered for sign and marking enhancements are summarized in Tables 8 and 9.

Table 8: Summary of 5 Year State Rural Curve Crashes in Pennsylvania (2007-2011)

AADT	Threshold Crash Level (5 Years)	Number of 1/2 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
<3,000	3	2,580	11,129	1,806	$9.03	2.52	4.28	420.68	18.00	10.61
3,001-10,000	6	708	6,485	496	$2.48	3.01	4.34	217.90	9.46	6.57
>10,000	10	105	1,442	74	$0.37	2.45	3.06	44.82	1.37	1.10
Total State Rural			19,056	2,375	$11.88	-	-	683.39	28.83	18.27

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

[2] Assumes an average cost of $5,000 per 0.5-mile section.

[3] A CMF of 0.7 is used (oversized, left, and right fluorescent yellow, advance warning signs; chevrons; slow and XX mph pavement markings; center and edge lines). This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

Table 9: Summary of 5 Year State Urban Curve Crashes in Pennsylvania (2007-2011)

AADT	Threshold Crash Level (5 Years)	Number of 1/2 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
<3,000	5	154	1,152	108	$0.54	1.31	3.29	41.13	1.35	0.54
3,001-10,000	10	104	1,458	73	$0.36	1.54	3.04	45.93	1.40	0.71
>10,000	15	129	3,059	90	$0.45	1.61	2.69	87.37	2.35	1.40
Total State Urban		-	5,669	271	$1.35	-	-	174.42	5.10	2.65

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

[2] Assumes an average cost of $5,000 per 0.5-mile section.

[3] A CMF of 0.7 is used (oversized, left, and right fluorescent yellow, advance warning signs; chevrons; slow and XX mph pavement markings; center and edge lines). This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

Within the set of rural curves identified in Table 8, those curves with higher crash levels, in which the addition of both a high friction surface and enhanced curve warning signs and markings can be considered, are provided in Table 10.

Table 10: : Net Impact of Adding High Friction Surfaces on Enhanced Signs and Markings for Curves – Curve Roadway Departure Crashes – State Rural Roads (2007-2011)

AADT	Threshold Crash Level (5 Years)	Number of 1/2 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
<3,000	15	18	360	13	$0.76	2.52	4.28	14.11	0.60	0.36
3,001-10,000	20	25	696	18	$1.05	3.01	4.34	24.21	1.05	0.73
>10,000	35	1	41	1	$0.04	2.45	3.06	1.23	0.04	0.03
Total State Rural	-		1,097	31	$1.85	-	-	39.55	1.69	1.12

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

[2] Assumes an average cost of $60,000 per section. 1/2 mile sections are identified for candidate locations, but the improvement will only be a 1,500 foot section. This assumes an average curve length on 1,500 feet including 300 feet on each approach.

[3] A net CMF of 0.65 is used which is a combination of the CMF for Enhanced Signs and Markings and High Friction Surfaces. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

The proposed signing and marking treatments for curves with crashes at or above the crash threshold are as follows:

- Advance oversize fluorescent yellow curve warning signs, both left and right.
- Chevrons with spacing in Table 2C-6 of the 2009 MUTCD.
- Advisory speed plates beneath the advance warning sign, using a standardized approach to determine the appropriate advisory speed in accordance with Table 2C-5 of the 2009 MUTCD. The FHWA document SA-11-22, Procedures for Setting Advisory Speeds on Curves, dated June 2011,[2] will be considered when setting the approach speed.
- "SLOW" and either a "CURVE" legend or curve symbol pavement markings in advance of the curve. Note that the curve pavement marking symbol layout must receive FHWA approval. In addition, alternate pavement marking options to slow high-end approach speeds – such as advisory speeds and the use of peripheral transverse pavement markings – will also be considered.
- Elimination of any pavement edge drop offs 2 inches or greater in depth.

[2] The FHWA document can be found at http://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa1122/fhwasa1122.pdf,

Once acceptance of the Roadway Departure Safety Plan has been accomplished, the basic steps and schedule to implement the sign and marking enhancements on State rural and urban highways are as follows:

1. The Safety Management Office, working with the Traffic Engineering and Operations Section and the District Traffic Units, will establish guidelines for determining the application of the signing and marking enhancements at the identified curves. In general, the guidelines will consider the following principles:

    a) To ensure sign and marking route continuity, all curves on a route within the County that has one or more curves at or above the crash threshold will be reviewed to determine if any of the additional curves that are below the crash threshold need to be upgraded to meet the 2009 MUTCD minimum curve sign requirements regarding advanced warning, advisory speeds, and chevron spacing. If so, these enhancements will also be made.
    b) For curves that have crashes at or above the designated crash threshold, at a minimum all 2009 MUTCD advanced warning, advisory speed, chevron use and spacing requirements for curves will be met and all shoulder drop offs 2 inches or greater will be corrected. Additional enhancements to be considered include oversize advanced curve warning signs; an additional advanced warning sign on the left side of the roadway; florescent yellow reflective sheeting rather than the standard yellow reflective sheeting; a Slow with advisory speed or curve symbol pavement marking legend in advance of the curve.
        i. Based upon the urban/rural designation and AADT group, the minimum additional enhancements beyond existing signs and markings to consider for each curve based upon crash history are as follows:
            - For curves that have crashes at or close to the threshold (e.g. 3 or 4 crashes for rural curves with less than 3,000 AADT and 10-12 crashes for rural curves with AADT greater than 10,000), at least three additional sign and marking enhancements should be considered, including any enhancements necessary to meet the 2009 MUTCD curve sign requirements
            - For curves that have crashes moderately above the crash threshold (e.g. 5 crashes for rural curves with less than 3,000 AADT and 12-15 crashes for rural curves with AADT greater than 10,000), at least four additional sign and marking enhancements should be considered, including any enhancements necessary to meet the 2009 MUTCD curve sign requirements
            - For curves that are well above the crash threshold (e.g. 6 or more crashes on rural curves with less than 3,000 AADT and 16 or more crashes on rural curves with more than 10,000 AADT), all of the additional sign and marking enhancements should be considered, including any enhancements necessary to meet the 2009 curve sign requirements
    c) Any substantive deviations from the above guidelines will be documented including supporting information for the deviation

Schedule: Guidelines finalized and issued within 12 months of RD plan acceptance

2. Once the guidelines are finalized, the Safety Management Office and the Districts will determine how the enhancements will be identified and implemented. Three options will be considered:

    a) A design build contract either at the state, District, or County level where the contractor will be required to review each route and curve using provisions in the contract to determine enhancements before implementation
    b) An engineering evaluation of each identified curve and route to determine and tabulate if and what sign and marking enhancements should be implemented. Engineering evaluation to be conducted by District Traffic staff or consultant reporting to the District. Contract plans developed using review results.
    c) An engineering evaluation of each identified curve and route to determine if and what sign and marking enhancements should be implemented. Engineering evaluation to be conducted by District Traffic staff or consultant reporting to the District. Enhancements to be implemented by County Maintenance forces using evaluation results.

    Schedule: Engineering evaluation completed within 24 months of RD Plan acceptance

3. Contracts will be let and improvements will be implemented

    Schedule: If a design build contract is adopted, contract is let 30 months from RD Plan acceptance. If standard contract is used, contract is let 36 months from RD plan acceptance. If enhancements to be implemented using Maintenance Forces, work can begin following evaluations

High Friction Surfaces for Curves

1. Safety Management Office in cooperation with the Maintenance Division and the District Traffic units will develop guidelines for considering and applying high friction course on designated curves. A specification for the higher friction course will also be developed. The effort will be coordinated with the Maintenance Division such that if the pavement is to be resurfaced in the near future, the high friction surface may be incorporated into the resurfacing contract. This effort may be combined with the initiative to correct highway sections that have a high frequency and proportion of wet pavement crashes.

    Schedule: *Guidelines issued* w*ithin 12 months of acceptance of the Plan*

2. Once the guidelines are finalized, the District will use the guidelines and specification to field review each identified curve with crashes and determine if application of a high friction surface is appropriate. The review will also be coordinated with the Maintenance Division to determine if any other surface improvements should be considered and if the high friction course should be integrated into the resurfacing program. As part of the field review, the limits of any planned high friction surface will be determined along with any added adjustments to the pavement or shoulder to accommodate the high friction surface. The Safety Management office and Districts will determine how to structure the contracts (County, District wide, Statewide).

    Schedule: High friction surface recommendations completed within 18 months of acceptance of the Plan.

3. Once the field review results are completed, the District or their consultant will prepare County or District contract plans to implement the designated improvements generated from the field reviews.

Schedule: Design plans let within 30 months of RD Plan acceptance

Centerline Rumble Strips To Reduce Head-On and Opposing-Flow Sideswipe Crashes

Rural undivided highways are considered for centerline rumble strips if they meet or exceed an AADT of 5,000 vehicles per day or meet or exceed the crash threshold of 3 head-on or opposing-flow crashes in a five year period per 3-mile section. Results are provided in Table 11.

Table 11: Centerline Rumble Stripes – Head-On and Sideswipe, Opposite Direction Crashes – State Rural Roads (2007-2011)

Locality	Threshold Crash Level (5 Years)	Number of 3 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural - 40mph	3	127	461	102	$1.83	2.89	6.84	32.45	2.22	0.94
State Urban - 40mph	3	75	299	60	$1.08	8.04	9.60	21.05	2.02	1.69
Total State		202	760	162	$2.91			53.50	4.24	2.63

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

[2] Typically, the cost for a 3-mile section is $15,000, but to account for systematic continuity the cost is increased to $18,000 per 3-mile section.

[3] A CMF of 0.56 is used.

The basic steps to implement this initiative are as follows:

1. The District Safety Engineer will compile a list of rural undivided highway sections that have 5,000 or greater AADT from the roadway data base and supplement this list with that set of highway sections provided in Appendix B that have three or more head-on or opposing sideswipe crashes in 2007-2011 in a three mile section. This is the set of candidate highway sections to consider centerline rumble strip applications. It is noted that some of the sections in this list may already have centerline rumble strips and some of the highway sections that meet the crash threshold will have more than 5,000 AADT and be duplicated on the list.

   Schedule: *Complete list assembled within 6 months of Plan acceptance.*

2. The District Traffic Unit staff will assemble a list of locations that are at or above either the crash threshold or 5,000 AADT and field review each site to determine if centerline rumble strips are appropriate to consider. The field review will evaluate head-on crashes throughout the route within the county in which the cluster resides to determine if additional sections of the route extended beyond the cluster limits are appropriate. This review will be coordinated with the edge line rumble strip field reviews. Once the field reviews are completed the candidate locations will also be coordinated with the Maintenance Division to determine if any other surface improvements should be considered and if the candidate rumble strips should be integrated into the resurfacing program.

   Schedule: All field reviews completed and a set of candidate locations to install centerline rumble strips is finalized within 15 months of acceptance of the Plan.

3. Contracts will be let and improvements will be implemented

   Schedule: Contracts to install rumble strips for designated routes and sections let within 12 months of approval of field review results.

Edge Line Rumble Stripes and Shoulder Rumble Strips to Reduce Roadway Departure Crashes

Edge line rumble stripes will be implemented under two scenarios.

Highway Sections with Four Feet or Wider Paved Shoulder

Systematic deployment of edge line rumble stripes and shoulder rumble strips will be considered on the following type of highways: rural and urban two- and multi-lane rural highways with legal speed limits of 40 mph or greater; widths of 22 ft. or wider and possessing a crash threshold of at least three or more single vehicle roadway departure crashes in half of a mile; and, having a four foot or greater paved shoulder that is adequate for bicycle travel.

A summary of highway sections that meet this criteria are provided in Table 12.

Table 12: Summary of Edge Line Rumble Stripes (Four Feet or Greater Paved Shoulders)

Speed Limit	Threshold Crash Level (5 Years)	Number of 1/2 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural – 40 mph	4	1,440	7,449	864	$2.59	1.98	3.15	259.23	8.17	5.14
State Urban – 40 mph	4	757	4,901	454	$1.36	1.34	2.46	170.55	4.19	2.28
Total State		2,197	12,350	1,318	$3.95			429.78	12.36	7.42

[1] For edge line rumble stripes, assumes 60% of locations can be improved.

[2] Typically, the cost for a 0.5-mile section is $5,000, but to account for systematic continuity the cost is increased to $3,000 per 0.5-mile section.

[3] A CMF of 0.71 is used.

The basic steps to implement this initiative are as follows:

1. The District Traffic staff or their consultant will field review each identified highway section with crashes at or above the threshold to determine if application of edge line rumble stripe/shoulder rumble strips is appropriate. This evaluation will consider the adequacy of the existing paved shoulder to support bicycle travel ; the condition of the pavement and shoulder to accommodate either an edge rumble stripe or a shoulder rumble strip; and the potential for noise issues associated with any adjacent dwellings. The review will also be coordinated with the Maintenance Division to determine if any other surface improvements should be considered and if the candidate rumble strips should be integrated into the resurfacing program. The review will also include evaluation of the potential for extending

the limits of improvement beyond that identified by the crash data to promote route continuity.

Schedule: Field review recommendations completed within 12 months of acceptance of the Plan.

2. Once the field review results are completed and accepted by PennDOT, District or County wide contract plans to implement the designated improvements generated from the field reviews will be developed.

   Schedule: Contract plans completed and projects let within 24 months of RD plan acceptance.

3. Contracts will be let and improvements will be implemented.

   Schedule: Contracts to install rumble strips for designated routes and sections will be completed within 12 months of contract award

Highway Sections with Less than a Four Foot Paved Shoulder

Edge Line rumble stripes in combination with shoulders widened to four feet and paved will be considered on those sections of highway with 10 or more run off road crashes.

Table 13: Summary of Candidate Highway Sections for shoulder widening/paving and edge line rumble stripes

Shoulder Type	Threshold Crash Level (5 Years) a	Number of 1/2 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements 1	Construction Costs ($ Million) 2	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction 3	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
0 ft Shoulders - State Rural - 40mph	10	174	2,312	139	$6.96	1.41	3.35	181.26	6.08	2.56
1-3 ft Non-Paved Shoulders - State Rural - 40mph	10	2	29	2	$0.07	1.73	4.48	2.00	0.09	0.03
1-3 ft Paved Shoulders - State Rural - 40mph	10	71	962	57	$2.13	1.79	3.61	74.45	2.69	1.33
4 ft or greater Non-Paved Shoulders - State Rural - 40mph	10	19	211	15	$0.38	1.64	2.88	16.33	0.47	0.27
Total State		266	3,514	213	$9.54			274.04	9.33	4.20

[a] 1/2 mile sections on State Roads with RD crashes where Vehicle Count field equals 1 and shoulder width and type criteria is as specified by type.

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

[3] 0' to 4' paved + edge line rumble stripes: $50,000 per 0.5 mile section and a CMF of 0.51.

[3] Avg 2' stabilized to 4' paved + edge line rumble stripes: $42,500 per 0.5 mile section and a CMF of 0.57.

[3] Avg 2' paved to 4' paved + edge line rumble stripes: $37,500 per 0.5 mile section and a CMF of 0.63.

[3] 4' stabilized to 4' paved + edge line rumble stripes: $25,000 per 0.5 mile section and a CMF of 0.63.

The basic steps and schedule to implement this initiative are as follows:

1. The District Traffic staff or their consultant will coordinate with the Design section and the Maintenance section to field review each identified highway section with crashes at or above the threshold to determine if widening the existing shoulder within right of way limits and the application of edge line rumble stripe/shoulder rumble strips is practical and appropriate. This evaluation will consider the width and condition of the existing shoulder, the amount of shoulder and potential pavement reconstruction needed to achieve the widening, potential impacts of shoulder widening on drainage, embankments, and right of way needed ; whether partial but substantial portions of the roadway could support shoulder widening with minimal adverse impacts; any extensions of the limits of work beyond the identified section limits; and a determination if the project will be scheduled for resurfacing in the near future and if the shoulder widening can be incorporated into the scope. Any section that results in costs well above the estimated $50,000 per 1/2 mile or require strip right of way acquisitions will require further review by the Safety Management Division before proceeding with project development.

   Schedule: Field review recommendations for all identified sections completed within 18 months of acceptance of the Plan.

2. Once the field review results are completed and accepted by PennDOT, contract plans to implement the designated improvements generated from the field reviews will be developed.

   Schedule: Contract plans completed and projects let within 36 months of RD plan acceptance.

3. Contracts will be let and improvements will be implemented.

   Schedule: Contracts to install rumble strips for designated routes and sections will be completed within 12 months of contract award

Alignment Delineation

Raised pavement markers (RPMs) and other methods to delineate the alignment of the roadway for night driving will be considered on those sections of highway which have high incidences and proportions of night crashes. Table 14 below shows the number of State road sections for systematic deployment of alignment delineation countermeasures.

Table 14: Alignment Delineation – Roadway Departure Crashes – Night – State Rural Roads

Locality	Threshold Crash Level (5 Years)	Number of 1/2 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural	8	374	3,734	150	$0.75	2.12	3.60	30.47	1.10	0.65

[1] Assumes 40% of locations can be improved.

[2] Assumes an average cost of $5,000 per 0.5-mile section for state roads.

[3] A CMF of 0.85 for dark crashes is used. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

* Need a dark to total crash ratio of at least 0.42

The basic steps and schedule to implement this initiative are as follows:

1. The Safety Management Office will work with others in the Traffic Operations Division and Districts to choose the RPM and other delineation products (potentially from existing installations) and develop guidelines to install alignment delineation on highway sections that are at or above the threshold in the above table. The Safety Office will coordinate with District Traffic and Safety personnel to determine if this initiative will be undertaken by District personnel or by consultant forces. Note that the guidance will integrate sign and marking enhancements on curves and consider the treatment and funding alternatives for the application of delineation on the entire route rather than on just those sections of the route that are at or above the crash threshold. It will also include inclusion of limited promising new marking materials that have the potential of providing superior reflectivity.

   Schedule: Guidelines developed within 12 months of RD Plan acceptance

2. District or their consultant personnel will use guidelines to field review each identified highway section with crashes and determine the appropriateness of installing delineation now or deferring until the next overlay. District or consultant personnel will assemble District-wide or county-wide contract construction plans to implement the improvements or determine to implement with County Maintenance Forces.

   Schedule: Sections and routes identified for delineation installations have improvements determined within 6 months of guideline issuance.

3. Contracts will be let and improvements will be implemented.

   Schedule: All identified delineation sections implemented within 30 months of acceptance of the Plan.

High-Friction Surfaces

High-friction surfaces will be considered on those rural tangent and curve sections of highway that have at least 20 wet pavement crashes in 5 years per half mile on rural state highways and 30 wet pavement crashes on urban highways, and a wet/total ratio of at least 0.53, and a skid number of 30

or less. This initiative will be coordinated with the curve high friction initiative summarized in Table 10 to avoid overlap. In addition to identifying sections of highway that have a propensity for wet pavement crashes, the friction characteristics of the surface need to be tested to determine if low friction values may be contributing to the wet pavement crashes. It is noted that some of the sections are probable concrete surfaces. In these cases, in addition to evaluating the friction characteristics of the surface, the cross slope of the pavement and the number of lanes need to be considered, as water accumulation on the surface and hydroplaning may be the primary contributor to the wet pavement crashes. If this is the case, lateral grooving of the concrete surface should be considered as a primary treatment. Table 15 below provides information on the number of highways that meet the crash thresholds identified.

Table 15: High Friction Surfaces – Roadway Departure Crashes – Wet – State Rural Roads (2007-2011)

Locality	Threshold Crash Level (5 Years)	Number of 1/2 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural - 40mph	20	32	842	16	$ 1.60	1.31	2.16	31.58	0.68	0.41
State Urban - 40mph	30	15	683	8	$ 0.75	0.50	1.53	17.42	0.27	0.09
Total		47	1,525	24	$ 2.35			48.99	0.95	0.50

[1] Assumes 50% of locations that are tested below a skid number of 30 can be improved and are not included in the curve improvements.

[2] Assumes an average cost of $100,000 per 0.5-mile section for state roads.

[3] A CMF of 0.5 is used. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

* Need a wet to total crash ratio of at least 0.53

The basic steps and schedule to implement this initiative are as follows:

1. The Safety Management Office will work with Design, Maintenance, and District Office personnel to develop guidelines for the use of micro-textures, epoxies, other high-friction surfaces, and lateral grooving on concrete surfaces to be applied on sections of highway with high incidences of wet pavement crashes. As a starting point, if the section does not have any identified need for higher surface friction characteristics (no sharp curves with design speeds 10 mph or more below overall operating speeds or no intersections that may require heavy mainline braking), skid-resistant aggregates or a micro-surface should be considered for the overlay; if the section may require higher surface friction values (sharp curvature or hard mainline braking approaching an intersection), a higher friction course such as Tyre Grip will be considered. If the pavement is concrete and is more than two lanes wide, the cross slope of the pavement, number of lanes that need to be drained, and other surface drainage characteristics will be evaluated to determine if lateral grooving of the pavement should be considered to effectively drain the pavement and reduce the potential for hydroplaning. Also, guidelines will be established for including cross-section improvements if severe wheel rutting exists.

2. Identified wet pavement sections will be skid tested to determine friction values for the pavement sections identified in Table 15. Generally, those sections having skid numbers of 30 or less will be considered for high-friction surfaces.

3. District or their consultant personnel will use the guidelines and skid test results to field review each identified highway section with wet pavement crashes above the threshold that have low skid numbers and will determine the appropriateness of applying a high-friction surface or lateral grooving using the guidelines. As part of the field review, the appropriate limits for the improvement will also be defined.

4. District or their consultant personnel will assemble District or County-wide contract construction plans to implement the improvements.

Schedule: Guidelines and specifications for using high friction surfaces issued within 12 months of RD Plan acceptance. Sections and routes identified for high friction surfaces or lateral grooving will be field reviewed within 18 months of acceptance of the Plan and a determination of improvements finalized.

5. Contracts will be let and improvements will be implemented.

   Schedule: All identified surface improvements implemented within 42 months of acceptance of the Plan.

Guide Rail Upgrades

The data analysis of Pennsylvania roadway departure crashes showed that there are a few 0.5-mile sections of guide rail where three or more guide rail related fatalities, incapacitating injuries, or overturns occurred in the 5-year data analysis period. These sections potentially have guide rail deficiencies, including insufficient guide rail height for vehicles with a higher center of gravity that are contributing to the severity of crashes. Each of these sections needs to be field checked to determine if guide rail deficiencies exist (inadequate terminal end, height less than FHWA recent guideline of 27 ¾ inches; and desirable heights of 31 inches, etc.).

Table 16 shows the deployment levels, costs, and benefits for potential guide rail upgrades on these sections.

Table 16: Guide Rail Relocation/Safety Enhancements – Roadway Departure Crashes – State Roads

Locality	Threshold Crash Level (5 Years)	Number of 1/2 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural	3	11	34	9	$0.22	13.85	18.95	0.00	0.26	0.19
State Urban	3	19	69	15	$0.38	16.28	25.58	0.00	0.71	0.45
Total			103	24	$0.60			0.00	0.96	0.64

[1] Assumes 80% of locations can be improved by guard rail upgrade to a successfully tested device.

[2] Assumes an average cost of $25,000 per 0.5-mile section for state roads.

[3] An average CMF of 0.75 is used. It is not likely that crashes will be reduced, so the CMF is applied to estimate incapacitating injury crash and fatality reduction.

* Includes only guardrail crashes where a fatality or incapacitating injury crash occurred.

The basic steps and schedule to implement this initiative are as follows:

1. District or their consultant personnel will field review each identified highway section with three or more severe guide rail crashes to determine potential guide rail deficiencies and guide rail heights. Guide rail heights below 31 inches will be considered for upgrading.
2. The Safety Management Office and the Design Division will evaluate the recent guide rail crash testing criteria and results and make a determination if the existing standard 27 and 3/4 inch height of strong post guide rail should be increased to 31 inches in accordance with the FHWA Office of Safety advisory.

3. District or consultant personnel will identify improvements and determine if District or County wide contracts or Maintenance Forces should implement the improvements.
4. Contracts will be let and improvements will be implemented.

   Schedule: All identified guide rail sections will be field reviewed and deficiencies identified within 12 months of RD Plan acceptance. All deficiencies corrected within 30 months of RD Plan acceptance.

Select Tree Removal in Rural Areas

The fixed object associated with the greatest number of roadway departure fatalities is trees. Most of these fatalities occur in rural areas. One of the challenges associated with this initiative is that tree removal alone may not be the sole low-cost countermeasure that needs to be implemented; removal or relocation of other vulnerable fixed objects also needs to be considered. In addition, many vulnerable trees may be located beyond the ditch line and on private property. Processes need to be developed to consider working with property owner to allow for removal of vulnerable trees off of the right of way(or replace the tree at a less vulnerable location or with more crash-impact-friendly shrubbery). In addition, some sections with high numbers of tree crashes will not be suitable for tree removal, and alternate countermeasures such as edge rumble stripes or delineation may be considered to reduce the likelihood of tree collisions. Sections of Interstate highway that have clusters of tree crashes create challenging problem since these sections probably have acceptable alignment, standard recovery areas, and shoulder rumble strips. Speed coupled with high traffic volume contributes to the problem. Extending the clear zone beyond the 30 foot recovery area needs to be considered in those areas which have high frequencies of tree crashes and in which trees are prevalent around the 30 foot clear zone

A hierarchy of questions that need to be asked in identifying the appropriate countermeasure to reduce future tree crashes include:

1) Should/can the tree be removed cost effectively?
   a) If the answer is yes, are there other improvements needed to improve the safety of the section, such as removing other vulnerable fixed objects and minor re-grading?
      i) Also, if the tree is off the right-of-way, can arrangements be made to accommodate the property owner and have the tree removed?
   b) If the tree can't be removed, are there alternatives to tree removal such as placement of edge/shoulder rumble strips or other cost effective enhancements to keep drivers on the road that should be pursued, and that will reduce the potential for vehicles running off the road?
   c) If trees can't be removed and other improvements can't be implemented to better keep drivers on the road, can reflective stripes be placed on the trees, particularly if a substantial number of the tree crashes occur at night.

The number of sections, crash threshold, costs, and safety impacts of this initiative are provided in Table 17.

Table 17: Tree Removal/Safety Enhancements – Tree Crashes (Any Harmful Event) – State Rural Roads (2007-2011)

Locality	Threshold Crash Level (5 Years)	Number of 3 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Interstate, State Rural	5	41	350	16	$1.23	4.23	5.15	14.00	0.72	0.59
Interstate, State Urban	5	13	93	5	$0.39	2.35	3.53	3.72	0.13	0.09
Non-Int. State Rural	8	196	2,225	78	$5.88	3.45	5.28	89.00	4.70	3.07
Local Rural	10	39	526	16	$1.17	2.16	4.34	21.04	0.91	0.45
Total State		250	2,668	100	$7.50			106.72	5.55	3.75
Total Local	-	39	526	16	$1.17			21.04	0.91	0.45
Total		289	3,194	116	$8.67			127.76	6.46	4.20

[1] Assumes 40% of state locations can be addressed. Assumes 40% of local locations can be addressed. Other improvements to reduce roadway departure frequencies in the vicinity of the struck trees, or reduced speed to reduce severity. A field review will be needed to determine the appropriate countermeasure.

[2] Assumes an average cost of $75,000 per 3-mile section on state roads, and $150,000 per local road.

[3] An average CMF of 0.5 is used.

The basic steps and schedule to implement this initiative are as follows:

1. Safety Management Office and District Traffic staff will develop guidelines to reduce the severity of tree crashes on sections that have high frequencies of tree crashes. Note that the guidance will provide a process to consider removal of trees both within and beyond right-of-way limits; property owner considerations; other complementary roadway departure countermeasures, such as the removal of other fixed objects adjacent to the trees and minor re-grading to create a clear zone; identification and options for considering environmental and historical factors associated with the vulnerable trees; and a set of alternate countermeasures, including edge rumble strips, cable guide rail shielding, and tree delineation to reduce the likelihood of tree crashes should the tree not be removed. Safety Project Manager and District personnel will determine if guidelines are to be implemented by Districts or consultant.

   Schedule: *Guidelines issued within 12 months of acceptance of the Plan.*

2. District personnel or their consultant will use guidelines to field review each identified tree section with crashes and determine appropriate tree removal or mitigation improvements. District personnel or their consultant will assemble District-wide or county-wide contract construction plans to implement the improvements.

   Schedule: Improvement sets identified for all identified sections within 24 months of acceptance of the Plan.

3. Contracts will be let and improvements will be implemented.

   Schedule: All identified improvements implemented within 48 months of acceptance of the Plan.

Select Utility Pole Treatments

Utility poles are the fixed object with the second highest occurrence of roadway departure fixed object fatalities. One of the challenges associated with this initiative is that moving a utility pole may not be the sole low-cost countermeasure that needs to be implemented; removal or relocation of other vulnerable fixed objects also needs to be considered. In addition, many vulnerable utility poles may be located at the outside edge of right-of-way limits with minimal opportunity to increase lateral clearance without the need to acquire additional right-of-way. In addition, some sections with high numbers of utility pole crashes will not be suitable for moving; in these cases, alternate countermeasures such as decreasing the number of poles or applying edge rumble strips or delineation may be considered to reduce the likelihood of utility pole collisions.

A hierarchy of questions should be asked to identify the appropriate countermeasure to reduce future utility pole crashes:

> Should/can the vulnerable utility poles be moved laterally within existing right of way? Can poles be consolidated on a route to reduce the frequency of poles?
>
> a) If the answer is yes, are there other improvements needed to improve the safety of the section (e.g., removing other vulnerable fixed objects, minor re-grading)?
>
> b) If the utility pole cannot be moved or consolidated in number, can other alternatives be implemented to reduce the likelihood of pole crashes?
>
> i) ii) Can shoulder widening and/or edge rumble stripes be installed to reduce the likelihood of vehicles leaving the roadway?
>
> iii) If a substantive number of pole crashes occur at night, can reflectivity bands be placed on the poles?

The number of sections, crash threshold, costs, and safety impacts of this initiative are provided in Table 18.

Table 18: Utility Pole Relocation/Removal/Safety Enhancements – Utility Pole Crashes (First Harmful Event) – State Roads (2007-2011)

Locality	Threshold Crash Level (5 Years)	Number of 3 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural	12	49	687	39	$2.94	1.52	3.31	54.96	1.82	0.83
State Urban	12	51	746	41	$3.06	1.46	3.27	59.68	1.95	0.87
Total State		100	1,433	80	$6.00			114.64	3.77	1.71

[1] Assumes 80% of locations can be improved by pole relocation, other improvements to reduce roadway departure frequencies in the vicinity of the struck poles, or reduced speed to reduce severity. A field review will be needed to determine the appropriate countermeasure.

[2] Assumes an average cost of $75,000 per 3-mile section.

[3] An average CMF of 0.5 is used as an overall average for all possible utility pole countermeasures.

The basic steps and schedule to implement this initiative include:

1. The Safety Management Office will develop a proposed approach for utility pole movement, removal, and treatments. Guidance should provide a process that addresses moving/removing/consolidating utility poles both within and beyond right-of-way limits; other complementary roadway departure countermeasures, such as the removal of other fixed objects adjacent to poles and minor re-grading to create a clear zone; identification and options for considering environmental and historical factors associated with the utility poles; and a set of alternate countermeasures, including edge rumble strips and utility pole delineation, to reduce the likelihood of utility pole crashes should the pole not be moved or removed.

   Schedule: Guidelines issued within 12 months of acceptance of the Plan.

2. District personnel or their consultant will use guidelines to field review each identified utility pole section and determine appropriate countermeasures.

   Schedule: All pole locations reviewed and recommended enhancements identified within 24 months of Plan acceptance.

3. In situations where implementation of the recommendations will be contracted, District personnel or their consultant will assemble District-wide or county-wide contract construction plans to implement the improvements.

   Schedule: Contracts let within 36 months of Plan acceptance.

Incorporating Low-Cost, Cost-Effective Countermeasures at Crash Locations within the Limits of Work for Programmed Projects

A considerable number of project types are implemented throughout Pennsylvania. Within the contract limits of some of these projects, sections with moderate to high crash histories exist where cost-effective, low-cost countermeasures may be considered for incorporation into the project to reduce the potential for future crashes. An example may be a rural two-lane highway that has head-on crashes in excess of the crash threshold and where centerline rumble strips should be considered for incorporation into the resurfacing project. This initiative is to develop and implement a process to identify programmed projects under design development, link those projects with information on sections within a project's limits that have crash histories at or above the thresholds defined in the Roadway departure and Intersection Plans, and determine if low-cost, cost-effective countermeasures identified in the Plans should be incorporated into the project to reduce the potential of future crashes.

There are a number of issues that need to be addressed for this initiative to be successful, including:

1. **Type of project on which to consider incorporating low-cost safety countermeasures** – Reconstruction projects will probably address most of the safety issues that low-cost countermeasures are designed to address. Specialty project types such as transportation enhancements may not be appropriate to consider for incorporating low-cost safety measures (except if the project has landscaping, tree, and shrubbery improvements). Bridge projects are usually limited to the bridge itself, which may restrict the potential to incorporate these countermeasures. Resurfacing and 3-R projects offer the greatest opportunity for incorporation of low-cost countermeasures since the primary improvement is normally limited to providing a smooth and structurally sound surface.

2. **Type of low-cost countermeasures to consider for incorporation into projects** – The predominant low-cost countermeasures that need to be considered for inclusion in programmed projects should meet the minimum crash thresholds defined for the systematic low-cost countermeasure initiative indicated in Appendix B, including the following:

    a. Curve warning enhancements.

    b. Shoulder widening and paving to four feet in combination with edge rumble stripes in rural areas.

    c. Centerline rumble strips in rural areas.

    d. Alignment delineation.

    e. Tree removal in rural areas.

    f. Utility pole relocation.

    g. Use of the safety edge under the following conditions: at the edge of pavement if a non-paved shoulder is specified; at the outer edge of a paved shoulder; and during construction if a lift exceeding 2 inches will be open to traffic for a period of time. This can be incorporated as a requirement on all applicable construction contracts. A recent evaluation indicates a 5.7% reduction in crashes when the safety edge is applied to projects, making it a very cost-effective countermeasure.

    h. Use of a micro-texture or similar high-skid surface on sections that have 20 or more wet pavement crashes within a 0.5 mile section; a wet-to-total crash ratio above .42 ; and a pavement cross section that is relatively flat, susceptible to accumulating water, and would not be corrected by the pavement overlay.

    i. Conversion of low-volume, four-lane undivided sections to three-lane sections using pavement markings if five or more roadway departure crashes occur within 6,000 feet and if a capacity analysis indicates that the modification will not create congestion.

3. **Funding** – The method to finance safety improvements needs to be clarified within Pennsylvania. The two basic options are to fund the safety as part of the existing project funding or to fund the safety portion with HSIP funding.

4. **Process** – The process by which low-cost, cost-effective safety countermeasures are to be considered and included in other projects needs to be developed between the Safety Management Office and the Divisions of Design, Maintenance, and Traffic Operations. Some of the questions that need to be addressed include the following:

    a. When in the design development stage should the consideration of these countermeasures be given such that if the countermeasure is to be included it will not delay construction letting?

    b. Who should identify projects that have crash histories above the threshold? Who will perform the analyses to determine the appropriate countermeasure?

    c. Who will make the decision to include or exclude?

    d. What can be done to incorporate designated low-cost improvements into the plan easily and efficiently?

Key Implementation Steps

The key steps needed to effectively consider the initiative are as follows:

1. Finalize a list of issues that need to be addressed to consider inclusion of low-cost, cost-effective countermeasures in other projects.
2. The Safety Management Office should establish a meeting between the Design, Maintenance, and Safety Offices to further explore the inclusion of low-cost, cost-effective safety countermeasures into other projects, including discussing identified issues that need to be addressed. At that meeting, copies of the candidate improvement locations (Appendix B) should be provided to all attendees. Attendees should reach consensus on the types of countermeasures that should be considered for inclusion in the various program projects.
3. The Maintenance and Design Divisions should provide the Safety Management Office a list of programmed projects that will be let over the next 2 fiscal years with sufficient time to evaluate and identify cost effective countermeasures that can be included in the contract plans without delaying letting. The above steps should be replicated on an annual basis.
4. After approximately one complete cycle of the above steps, the Safety Management Office should schedule a follow up meeting with the Maintenance and Design Division Offices to review the process and make adjustments for further improvement.

Roadway Departure Countermeasures on Local Roads

A number of roadway departure countermeasures will be pursued on local rural roads to reduce roadway departure fatalities, including the following:

a) Curve signing for local rural roads with high frequencies of curve crashes.

b) Standard centerline and edge line pavement markings on local roads that have a high frequency of road departure crashes.

c) Tree removal or crash mitigation on local roads that have frequencies of tree crashes.

d) Milled Centerline Rumble Strips on rural local roads that have a 'high flexible' pavement structure and a high frequency of head-on and opposing flow crashes.

The LTAP Coordinator will play a pivotal role in coordinating the identification and review of candidate locations and countermeasures, contract construction plan development, and State/County coordination.

Two key implementation issues need to be addressed before proceeding with safety enhancements on local roads:

1. PennDOT should make a determination if HSIS funds will be available to local governments to design and implement countermeasures on routes identified in the RD and Intersection Plans.
2. Does the LTAP Coordinator have the capacity by himself to work with the identified municipalities; review the local roads which have crashes at or above the crash thresholds; determine the applicability of installing the defined countermeasure associated with the crash types; and assist the municipality to develop contract plans or to use local forces to implement the enhancements? If not, should consultant assistance be provided to the LTAP coordinator to implement the improvements on local roads using HSIS funds?

The type of low cost countermeasures to reduce road departure crashes on local roads are as follows:

Curve Signing Enhancements on Rural Local Roads

The local road crash databases were analyzed to identify a set of local rural roads that had high concentrations of curve crashes.

This initiative is to upgrade the curve warning signs on these roads using the 2009 MUTCD criteria for curve warning signs, including the following:

- Chevrons with spacing in Table 2C-6 of the 2009 MUTCD, if required.
- Advisory speed plates beneath the advance warning sign using a standardized approach to determine the appropriate advisory speed in accordance with Table 2C-5 of the 2009 MUTCD, if required. The FHWA document SA-11-22, Procedures for Setting Advisory Speeds on Curves, dated June 2011,[3] will be considered when setting the approach speed. Elimination of any pavement edge drop offs 2 inches or greater in depth.
- Any optional enhancements such as the use of oversize advanced warning signs; florescent yellow reflective signs; an additional advanced curve warning sign on the left side of the roadway.
- In addition, any single curve that has five or more crashes on a local road will also be considered for the enhanced treatment for State highways, which includes:
    - "SLOW" and either a "CURVE" legend or curve symbol pavement markings in advance of the curve.
    - Advance oversize, rather than standard size fluorescent yellow curve warning signs, both left and right.

[3] The FHWA document can be found at http://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa1122/fhwasa1122.pdf,

Table 19: Standard Curve Signing – Curve Roadway Departure Crashes – Local Rural Roads

Speed Limit	Threshold Crash Level (5 Years)	Number of Local Roads	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements 1	Construction Costs ($ Million) 2	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction 3	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Local Rural - 35mph	15	51	1,153	41	$1.02	1.02	3.32	41.97	1.39	0.43
Local Rural - 40mph	8	59	728	47	$1.18	2.09	4.41	26.79	1.18	0.56
Local Urban - 35mph	15	106	2,569	85	$2.12	0.94	2.37	78.10	1.85	0.74
Local Urban - 40mph	8	1	10	1	$0.02	1.34	2.38	0.34	0.01	0.00
Total Local Roads		-	4,460	174	$4.34	-	-	147.20	4.43	1.73

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

[2] Assumes an average cost of $25,000 per local road.

[3] A CMF of 0.75 is used (oversized, left, and right fluorescent yellow, advance warning signs; chevrons; slow and XX mph pavement markings; center and edge lines). This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes.

The basic steps and schedule to implement this initiative include:

1. The Safety Management Office and the LTAP Coordinator will develop a proposed approach for curve sign and marking enhancements on local roads. The guidelines will be dependent on the availability of HSIS funds to implement the improvement. In addition, the guidelines will be similar to that developed to improve curve signing on the state highway system.

   Schedule: *Guidelines and a funding decision issued within 12 months of acceptance of the Plan.*

2. The LTAP Coordinator will arrange a meeting with the appropriate local Officials to brief them on the program and determine their interest in implementing improvements. Once the guidelines are finalized, and in those municipalities that agree to pursue improvements, the LTAP Coordinator will use the guidelines and template(s) to field review each identified route with crashes and determine appropriate sign and marking improvements.
   Schedule: Curve sign and marking recommendations completed within 24 months of acceptance of the Plan.
3. Once the method of funding the improvements and field review results are completed for local roads on the list and in which Local Officials agree to participate, the LTAP Coordinator will meet with the appropriate local officials to review the results and set the method to contract the work.

   Schedule: All field review results and meetings held with Local officials completed within 30 months of guideline acceptance and approval.

4. Contracts will be let and improvements will be implemented.

   Schedule: Contracts to enhance signs and markings for 50% of all routes let within 42 months of approval of plan acceptance; remaining enhancements let within 54 months of acceptance of the Plan.

Standard Center and Edge Line Pavement Markings

A significant number of rural local roads do not have any pavement markings. This initiative is to apply standard pavement markings on un-marked local rural roads that have a substantial number of road departure crashes.

Table 20: Standard Center and Edge Line Pavement Markings – Roadway Departure Crashes – Local Rural Roads

Number of Lanes, Locality	Threshold Crash Level (5 Years)	Number of Local Roads	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Local Rural - 40mph	5	281	2,364	112	$2.25	2.19	4.32	24.59	1.06	0.54
Local Urban - 40mph	5	50	472	20	$0.40	0.85	2.85	4.91	0.14	0.04
Total Local Rural		331	2,836	132	$2.65			29.49	1.20	0.58

[1] For edge line rumble stripes, assumes 40% of locations can be improved.

[2] Assumes an average cost of $20,000 per local road.

[3] A CMF of 0.87 is used.

The basic steps and schedule to implement this initiative include:

1. The Safety Management Office and the LTAP Coordinator will develop a proposed approach for applying standard pavement markings on local roads. The guidelines will be dependent on the availability of HSIS funds to implement the improvement.

   Schedule: Guidelines and a funding decision issued within 6 months of acceptance of the Plan.

2. Once the guidelines are finalized, the LTAP Coordinator will use the guidelines to field review each identified route with crashes and determine if it is appropriate to apply standard pavement markings. The LTAP Coordinator will arrange a meeting with the appropriate local Officials to brief them on the program and determine their interest in implementing improvements.

   Schedule: Standard pavement marking recommendations completed within 24 months of acceptance of the Plan.

Tree Removal or Tree Crash Mitigation

Tree crash fatalities on rural local roads are a substantive concern in that 214 people died on rural local roads when a tree was the first harmful event.

Table 21: Tree Removal or Tree Crash Mitigations – Local Rural Roads

Locality	Threshold Crash Level (5 Years)	Number of 3 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Local Rural	10	39	526	16	$ 1.17	2.16	4.34	21.04	0.91	0.45

[1] Assumes 40% of local locations can be addressed. Other improvements to reduce roadway departure frequencies in the vicinity of the struck trees, or reduced speed to reduce severity. A field review will be needed to determine the appropriate countermeasure.

The basic steps and schedule to implement this initiative include:

1. The Safety Management Office and the LTAP Coordinator will develop a proposed approach for tree removal or tree crash mitigation enhancements on local roads. The guidelines will be dependent on the availability of HSIS funds to implement the improvement. In addition, the guidelines will be similar to that developed to remove trees or mitigate tree crashes on the state highway system.

   Schedule: *Guidelines and a funding decision issued within 12 months of acceptance of the Plan.*

2. Once the guidelines are finalized, the LTAP Coordinator will use the guidelines to field review each identified route with crashes and determine appropriate tree removal or mitigation improvements. The LTAP Coordinator will arrange a meeting with the appropriate local Officials to brief them on the program and determine their interest in implementing improvements.

   Schedule: Tree removal or tree crash mitigation recommendations completed within 24 months of acceptance of the Plan.

3. Once the method of funding the improvements and field review results are completed for local roads on the list and in which Local Officials agree to participate, the LTAP Coordinator will meet with the appropriate local officials to review the results and set the method to complete the work.

   Schedule: All field review results and meetings held with Local officials completed within 30 months of guideline acceptance and approval.

4. Contracts will be let and improvements will be implemented.

   Schedule: Contracts or actions to remove trees or implement tree crash mitigatio0n initiatives for 50% of all routes let within 42 months of approval of plan acceptance; remaining enhancements completed within 54 months of acceptance of the Plan.

Center Line Rumble Strips

At the technical workshop held in Harrisburg on October 12, 2012, the LTAP Coordinator indicated that a limited number of local governments have implemented center line rumble strips on rural local roads. There are a few local rural roads with a substantial number of head on and

opposite direction sideswipe crashes. This list will be provided to the LTAP coordinator for field review and center line rumble strip applications using guidance developed for the state highway system.

Education and Enforcement Corridor Initiatives

This initiative combines education and enforcement actions on corridors stretching 5 miles in length that have high concentrations of total and roadway departure crashes involving either alcohol, speeding, or unbelted drivers.

The data was analyzed to identify sections of highway that have concentrations of speed or unbelted driver crashes both on and off the Interstate as well as concentrations of alcohol-related crashes. Combined enforcement tactics may impact speed and unbelted driver violations. Alcohol-related crashes are concentrated in the late evening-early morning hours, and the associated enforcement tactics emphasize sobriety checkpoints. Therefore, the alcohol enforcement sections were separated from the other enforcement sections. Summaries of the targeted sections for education and enforcement are provided in Tables 22 through 24.

Table 22: Enhanced Corridor Enforcement – Total and Roadway Departures Crashes – Alcohol-Related – State Roads

Locality	Threshold Crash Level (5 Years)	Number of 5 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
State Rural - 35mph	15	4	65	3	$0.17	4.46	6.46	1.50	0.10	0.07
State Rural - 40mph	20	8	185	6	$0.33	6.77	8.23	4.38	0.36	0.30
State Urban - 35mph	40	6	309	5	$0.25	2.72	4.53	3.76	0.17	0.10
State Urban - 40mph	30	31	1,465	25	$1.29	4.06	5.68	23.91	1.36	0.97
Total State	-	49	2,024	39	$2.04			33.54	1.99	1.44

[1] Assumes 80% of locations will have sufficient enforcement capabilities to implement enhanced alcohol enforcement (i.e. sobriety checkpoints).

[2] Assumes an enforcement cost of $52,000 per 5-mile section for the 5 year program.

[3] An average CMF of 0.8 is used as an overall average for all possible enhanced corridor enforcement countermeasures. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes. Estimated from speed and safety belt enforcement effectiveness information in NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices. http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811081.pdf

Table 23: Enhanced Corridor Enforcement – Total and Roadway Departures Crashes – Speed Related – State Roads

Locality	Threshold Crash Level (5 Years)	Number of 5 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Interstate, State Rural - 40mph	50	25	1,589	20	$1.04	2.27	2.45	24.79	0.61	0.56
Interstate, State Urban - 40mph	70	41	8,541	33	$1.71	1.03	1.65	84.04	1.38	0.86
Non-Int., State Rural - 35mph	50	3	224	2	$0.12	2.54	3.52	3.60	0.13	0.09
Non-Int., State Rural - 40mph	50	63	4,299	50	$2.62	2.76	3.53	69.13	2.44	1.91
Non-Int., State Urban - 35mph	70	9	882	7	$0.37	1.60	2.66	8.04	0.21	0.13
Non-Int., State Urban - 40mph	70	44	4,764	35	$1.83	1.57	2.26	48.02	1.08	0.76
Total State	-	185	20,299	148	$7.70			237.63	5.86	4.31

[1] Assumes 80% of locations will have sufficient enforcement capabilities to implement enhanced enforcement (at least 10 hours per week of highly visible active enforcement per section)

[2] Assumes an average annual enforcement cost of $52,000 per 5-mile section for the 5 year program.

[3] An average CMF of 0.85 is used as an overall average for all possible enhanced corridor enforcement countermeasures. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes. Estimated from speed and safety belt enforcement effectiveness information in NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices. http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811081.pdf

Table 24: Enhanced Corridor Enforcement – Roadway Departure Crashes – Unbelted Driver – State Roads

Locality	Threshold Crash Level (5 Years)	Number of 5 mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Interstate, State Rural - 40mph	30	-	-	-	$ -	10.24	10.17	0.00	0.00	0.00
Interstate, State Urban - 40mph	50	15	1,193	12	$0.62	3.66	6.69	28.06	1.88	1.03
Non-Int., State Rural - 35mph	40	-	-	-	$ -	4.45	6.36	0.00	0.00	0.00
Non-Int., State Rural - 40mph	30	12	417	10	$0.50	6.77	9.10	11.81	1.07	0.80
Non-Int., State Urban - 35mph	50	19	1,374	15	$0.79	1.63	4.05	15.17	0.61	0.25
Non-Int., State Urban - 40mph	50	14	874	11	$0.58	3.31	5.19	13.84	0.72	0.46
Total State	-	60	3,858	48	$2.50			68.88	4.28	2.53

[1] Assumes 80% of locations can be improved by incorporating speed reduction traffic calming measures through pavement markings. No Interstate Highways included.

[2] Assumes an average cost of $52,000 per 5-mile section for the 5 year program.

[3] An average CMF of 0.30 is used as an overall average for all possible enhanced corridor enforcement countermeasures. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes. Estimated from speed and safety belt enforcement effectiveness information in NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices. http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811081.pdf

The crash data has identified a limited number of Interstate and non-Interstate sections of highway with high concentrations of speed-related, unbelted injury, or alcohol related crashes. This effort involves inviting representatives of the police personnel responsible for enforcement along these sections to initiate a coordinated education and enforcement approach by using a combination of targeted education and highly visible enforcement strategies. In addition, police and local officials may be consulted to determine the acceptability of initiating a vigorous enforcement initiative that would result in issuing a significant number of traffic violations. The objective of the effort is to reduce total and roadway departure fatalities on these sections by a minimum of 15 percent. The effort begins with a preliminary meeting with the Governor's Highway Safety Representative to a) identify the number of enforcement grants that currently exist that cover portions of these corridors and determine the potential to concentrate additional resources on these corridors, and b) identify sources of revenue to finance the initiative on other corridors not covered by existing grants. In addition to the enforcement component, meeting topics will also include media initiatives to advise motorists that use the corridors of the targeted, driver-related crash problem. Following funding source analyses, meetings are arranged between the appropriate police organizations responsible for enforcement along the identified sections of highway and local officials in order to determine interest in initiating a comprehensive education and enforcement initiative to reduce the number of future fatalities due to speed, alcohol, and unbelted drivers.

Key Steps for Implementing Education and Enforcement Safety Corridors

Phase 1 – Preparatory

1. Select corridors to implement targeted education and enforcement (this done by the Governor's Highway Safety representative and the Safety Manager).
2. Determine if there are safety grants that could be used to improve safety along the corridor and if adjustments to these grants should be considered to reduce the potential for future targeted crashes through increased targeted enforcement in the corridor.

Phase II – Meet with Appropriate Police Personnel

1. Identify the police organizations responsible for enforcement on the corridors and arrange a meeting with police.
2. Apprise the police of the concentration of targeted driver-related crashes on the candidate corridors.
3. Request a written commitment to enhance highly visible repetitive targeted enforcement on the identified corridors.
4. Advise the meeting participants that if a written commitment for highly visible repetitive enforcement is provided, the data and the increased enforcement should be shared with the media in a joint press conference.
5. Collectively agree on an initial set of corridors on which to implement the enforcement measures, develop a coordinated strategy and schedule to announce the information to the media, and begin visible enforcement. Also, agree on an education component to apprise motorists of the increased targeted enforcement on the corridor, including the potential to install targeted enforcement signs. Agree to a 6 to 12 month follow-up meeting to evaluate the impact of the initiative and determine whether further actions are needed and if the initiative should be expanded to remaining corridors.

Phase III – Implementation

1. Meet with magistrates or District justices who have jurisdiction over the selected traffic corridor, explain the driver safety crash concerns on the corridor, and ask for their input and cooperation when visible enforcement begins.
2. Begin visible enforcement.
3. Hold a joint PennDOT-police press event for the corridor.
4. Periodically meet with police and magistrates to monitor enforcement levels and obtain any insight from police on observed changes in driving habits as a result of the added enforcement and signing. If anything newsworthy results, provide a press release.

Phase IV – Evaluation

1. After a full year of crash data becomes available, perform an initial "before and after" comparison of crashes on the corridor comparing the changes in targeted crashes that the enforcement has reduced (i.e., alcohol, speeding, unbelted) in the "after" period to the crash statistics from the "before" period. Follow up after 3 years of data are available to perform a more complete effectiveness evaluation.

2. Potentially include a "before and after" comparison of speed distributions and a safety belt survey to determine if high-end speeding is being reduced and if more people are buckling up on the route.
3. Meet with the police, share the evaluation information, and make a determination as to whether the initiative should be expanded to the remaining corridors.

Comprehensive 3-E Engineering, Education, and Enforcement for Corridors

Table 25 identifies 5-mile long corridors with the highest concentrations of severe roadway departure crashes that are candidates for combined education, enforcement, and engineering initiatives.

Table 25: Candidate Corridors for 3-E (Engineering, Education, Enforcement) Initiatives (2007-2011)

District	County Name	MPO	Route	RD Crashes	RD Fatalities	Fatalities per 100 Crashes	Total Crashes	Total Fatalities
12	FAYETTE	SPC	40	217	12	5.53	627	17
3	LYCOMING	Williamsport	15	249	11	4.42	412	16
2	CLEARFIELD	North Central	53	199	11	5.53	341	13
8	PERRY	Harrisburg	850	112	10	8.93	165	11
10	BUTLER	SPC	308	62	10	16.13	113	11
9	SOMERSET	S. Alleghenies	219	250	9	3.60	418	10
2	CENTRE	Centre	144	202	9	4.46	331	9
5	MONROE	NEPA	209	337	8	2.37	1,192	16

The crash data has identified eight State route corridors that have had eight or more fatal roadway departure crashes over the past 5 years. The intent of this objective is to advance a set of 3-E initiatives on at least one of these corridors to reduce the potential for future severe roadway departure crashes. For the selected pilot corridor(s), this initiative will have as its objective a reduction in corridor roadway departure fatalities by a minimum of 25 percent through the application of a combination of low-cost infrastructure improvements coupled with targeted education and enforcement initiatives. While the selection of the corridor has been based upon high frequencies of severe roadway departure crashes, the approach may be broader and encompass other corridor concerns such as intersections, 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 better understand the problems that need to be addressed and relate the patterns to potential countermeasures. A multi-disciplinary team is then formed to review the crash analysis, discuss the safety problems on the corridor, jointly field review the corridor to gain personal and group consensus on the major safety issues, and collectively develop an overall set of 3-E countermeasures to improve safety on the corridor. 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 ensure that substantive safety progress along the corridor is being made.

The goal of the corridor safety study is to reduce fatal and disabling injury crashes on designated high-volume arterials exhibiting high frequencies of severe crashes by using low-cost, near-term

solutions combined with highly visible enforcement, education, and emergency medical service initiatives.

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

- District Traffic and Safety Engineers.
- District Press Spokesperson.
- District Maintenance Manager or designee.
- Governors Highway Safety Representative.
- Representative of State or local police responsible for enforcement on the corridor.
- Local government representative.

Additional team members may also include the local emergency medical services coordinator, a metropolitan planning organization representative, and a highway design representative.

Once a corridor has been identified for a study, the District Traffic or District Safety Engineer should perform an analysis of the crash data for 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.

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 assess areas of concern defined from the crash analysis and team discussions. 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 Traffic and District Safety Engineers and the District Press Spokesperson 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 cost-effective improvements.

Key Steps to Implement 3-E Corridor Improvements

1. The Safety Management Office, select District Offices, and the Governor's Highway Safety Office review the identified corridors and select at least one of the corridors to implement 3-E improvements.
2. The District Safety Engineer analyzes data for the corridor selected, investigating all major crash patterns, and prepares a report of findings for each corridor.
3. The District Traffic Engineer and the Safety Office select a multidisciplinary team for the corridor to determine actions to reduce future crashes.
4. A meeting of the multi-disciplinary teams is held, field reviews of the corridor are scheduled and completed, sets of comprehensive 3-E improvements are identified, and a brief corridor report is prepared summarizing actions and improvements proposed to reduce future fatalities. As part of the report, estimated costs and schedules are also prepared.

5. Participating agencies review and approve the report, which includes approving their roles as defined in the report.
6. Implementation of the report begins, including education and enforcement activities and developing and letting of contracts to implement infrastructure improvements.
7. The corridor approach is evaluated, lessons learned are identified, and a decision to expand, expand with modifications, or terminate the corridor safety approach is made.

Traditional Roadway Departure Countermeasures

Currently, roadway departure improvements are generated within the HSIP program by identifying and studying crash locations that have high crash rankings. One additional initiative will be undertaken within the traditional roadway departure program as follows:

a. Median barriers or other improvements on full access control highways with more than occasional head-on and opposing-flow crashes (see Table 26).

Median Barrier Installations – Interstate

PennDOT has been installing median barrier protection on the Interstate system, starting with those Interstates which have the narrowest of unprotected medians. However, a review of the crash data files indicates that head-on and opposing-flow crashes continue to occur on the Interstate system, with some sections having higher frequencies of cross over crashes. This initiative is to place cable median guide rail in those sections of Interstate and non-Interstate freeways that exhibit high frequencies of cross over crashes.

Key steps to implement this countermeasure are as follows:

1. The Safety Management Office and/or consultant will review the list of median barrier candidate improvement locations in Appendix B and remove any that have median barriers recently added. Of the remaining sections, the District Safety staff will field review and determine if cable median guide rail is appropriate to install.
2. Contract construction plans for installation of cable median barrier will be developed for priority segments based upon field review results and funds available.

Median Barrier Installations – Non-Interstate Divided Highways with Grass or Earth Medians

A review of the crash files indicates that a limited number of severe cross median crashes are occurring on non-Interstate freeways. Certain sections of highway have experienced higher frequencies of cross median crashes than other sections. This initiative is to identify those sections of non-Interstate freeways which have high numbers of cross median crashes and determine if cable median guide rail should be installed to prevent future intrusions.

The summary of enhancements to Interstate and non-Interstate highways is provided in Table 26.

Table 26: Cable Median Barrier – Head-On and Sideswipe, Opposite Direction Crashes – Grass, Gravel, or Other Non-Barrier Median Types

Locality	Threshold Crash Level (5 Years)	Number of 3 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Cost ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Interstate, State Rural - 40mph	4	18	87	13	$3.78	8.67	5.26	0.00	0.00	1.06
Interstate, State Urban - 40mph	4	3	16	2	$0.63	8.54	4.88	0.00	0.00	0.19
Non-Int., State Rural - 40mph	5	2	11	1	$0.42	5.29	5.88	0.00	0.09	0.08
Non-Int., State Urban - 40mph	5	4	23	3	$0.84	4.76	7.94	0.00	0.26	0.15
Total State		27	137	19	$5.67			0.00	0.35	1.48

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

[2] Assumes an average cost of $300,000 per 3-mile section.

[3] A CMF of 1 in terms of incapacitating injury crashes and fatalities is used. Reduction in total crashes unlikely.

Key steps to implement this countermeasure are as follows:

1. The District Safety Engineer will review the list of locations in Appendix B and determine if cable median guide rail is appropriate to install on the identified sections.
2. Contract construction plans for installation of weak post cable median barrier will be developed for priority segments based upon funds available.

Implementation of New Countermeasures

This initiative involves the limited and careful evaluation and possible deployment of new roadway departure countermeasures that offer the potential to reduce roadway departure crashes and fatalities beyond that which can be expected from existing countermeasures. One major roadway departure countermeasures have been identified that fall into this category: traffic calming to reduce high end speeds at selected rural sites.

Traffic Calming

Pennsylvania has minimal experience with the proposed traffic calming countermeasures. In addition, the actual effectiveness of rural traffic calming countermeasures has not yet been adequately validated. Nevertheless, rural traffic calming countermeasures fill gaps that the existing countermeasures cannot. PennDOT will proceed cautiously with the deployment of this countermeasure. To reduce risk of failure, concentrating initial deployment on those sections with high numbers of the roadway departure crashes associated with speed, particularly in those areas where point speed reductions are needed such as entering a built up section or approaching a sharp curve. The limited deployment of an adequate number of traffic calming improvements will be made to evaluate the effectiveness of the improvement. Further expansion of traffic calming countermeasures will be dependent on achieving a favorable evaluation of the limited deployment. Any implementation issues or concerns identified from this initial deployment will be addressed and resolved before further implementation of the countermeasure is considered. Once all identified issues are resolved, sufficient additional improvements of the countermeasure will improve the

estimate of the effectiveness of the countermeasure in reducing targeted roadway departure crashes. When a better estimate of the effectiveness of the countermeasure is available, the countermeasure will be deployed cost-effectively, depending upon the availability of funds and other priorities.

The extent to which traffic calming may be applied on Pennsylvania's highways to reduce speed related crashes and fatalities is expressed in Table 27.

Table 27: Infrastructure Traffic Calming Measures to Reduce Speeding-Related Crashes – State Roads (2007-2011)

Locality	Threshold Crash Level (5 Years)	Number of 2 Mile Sections	Number of Crashes in 5 Years (2007-2011)	Estimated Number of Improvements [1]	Construction Costs ($ Million) [2]	Fatalities per 100 Crashes	Incapacitating Injury Crashes per 100 Crashes	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Crash Reduction	Annual Estimated Fatality Reduction
Non-Int., State Rural - 35mph	40	3	191	2	$0.12	2.54	3.52	3.30	0.12	0.08
Non-Int., State Rural - 40mph	40	25	1,350	20	$1.04	2.76	3.53	22.36	0.79	0.62
Non-Int., State Urban - 35mph	50	8	508	6	$0.33	1.60	2.66	5.00	0.13	0.08
Non-Int., State Urban - 40mph	50	40	2,886	32	$1.66	1.57	2.26	30.48	0.69	0.48
Total State	-	76	4,935	61	$3.16			61.13	1.73	1.26

[1] Assumes 80% of locations can be improved by incorporating speed reduction traffic calming measures through pavement markings. No Interstate Highways included.

[2] Assumes an average cost of $25,000 per 2 mile section for the 5 year program.

[3] An average CMF of 0.7 is used as an overall average for all possible enhanced corridor enforcement countermeasures. This number is multiplied by the RD/total crashes ratio to estimate the crash reduction for RD crashes. Estimated from speed and safety belt enforcement effectiveness information in NHTSA's Countermeasures That Work: Highway Safety Countermeasure Guide For State Highway Safety Offices. http://www.nhtsa.gov/staticfiles/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811081.pdf

Types of traffic calming may be found in FHWA Report HRT-08-067. In addition, the use of peripheral transverse pavement markings on a continuous section rather than for a point-specific location should be considered to reduce excessive speeds throughout a section of roadway.

The key steps that need taken to consider these enhancements are as follows:

1. The Safety Management Office should Review FHWA-HRT-08-067, *Traffic Calming on Main Roads through Rural Communities,* and identify appropriate rural traffic calming measures to pilot in Pennsylvania.
2. The Safety Management Office, in coordination with the District Traffic Engineers, should review identified sections of roadway with speed related crashes (Table 30) and select locations within these sections where it is appropriate to consider applying traffic calming countermeasures to reduce speed, identify the number of initial improvements to install, and prepare an evaluation plan and financing for each of the selected new countermeasures.
3. The District Traffic Offices should arrange for the installation of selected countermeasures identified in the evaluation plans.

4. The Safety Management Office and District Traffic Engineers should evaluate the countermeasure and determine if its use should be expanded, modified, or terminated.
5. If expanded, the Safety Management Office should issue guidance for further deployments at remaining sites with speed related crashes.

Performance Measures

Two types of performance measures are proposed:

1. Production performance measures assess the performance of the products implemented as well as the processes, guidelines, and projects determined in the Plan that are needed to achieve the goal.
2. Effectiveness performance measures assess the effectiveness of implemented countermeasures in reducing targeted crashes and compare actual to estimated effectiveness.

Specific product and effectiveness performance measures are identified in Tables 28 and 29.

Production Performance Measures

Table 28: Production Performance Measures

Countermeasure or Action	Measure	Target Completion Date	Actual Completion
Systematic Improvements-State Highways			
Curve sign and marking enhancements – State, systematic	2650 curves	50% by Oct. 2014; 50% by Oct 2015	Actual no. of curves
Curve sign and marking enhancements – State -high friction surface–systematic	31 curves	Oct. 2015	Actual no. of curves
Centerline Rumble strips – systematic – total	160 3 mile sections	Oct. 2014	Actual centerline rumble strip miles
Edge rumble stripes – systematic – total (4 foot or > existing paved shoulder)	1300 0.5-mile sections	Oct 2014	Actual edge rumble strip miles
Edge rumble stripe plus shoulder widening – systematic – total	100 1.0-mile sections	Oct 2016 2015	Actual edge rumble strip miles
Alignment Delineation	150 1-mile sections	Oct. 2015	Actual miles delineated
High Friction Surfaces	24 sections	Oct 2015	Actual number completed per year
Guide Rail Upgrades	24 sections	Oct. 2014	Actual number completed
Tree Removal or Protection	116 sections	Oct. 2015	Actual no. completed
Utility Pole Safety	80 sections	Oct. 2015	Actual no. completed
Systematic Improvements- Local Roads			
Local Road Curve Sign Initiative	Identified Routes	50% by Oct 2015: remaining by Oct 2016	
Standard Pavement Markings	Identified Routes	50% by July 2015	
Milled Center Line Rumble Strips	Identified Routes	Oct. 2015	
Milled Edge Rumble Strips	Identified Routes	Oct. 2015	
Traditional Countermeasures -State Roads			
Interstate Weak Post Median Barrier-	Identified Routes	50% by Oct. 2014;100% by Oct. 2015	Actual miles completed
Non-Interstate Weak Post Median Barrier	Identified Routes		
New Countermeasures-State Roads			

Countermeasure or Action	Measure	Target Completion Date	Actual Completion
Evaluation of rural traffic calming measures	Number of traffic calming countermeasures being evaluated	Under evaluation by Jan. 2014	Actual number of different types under evaluation
Incorporation of Low Cost, Cost Effective Countermeasures at Crash Locations within the Limits of Work for Programmed Projects			
Low Cost Countermeasures are incorporated into resurfacing projects	% Programmed projects incorporate identified safety measures	Oct. 2014	Actual per cent of program projects safety is incorporated
Education and Enforcement Corridor Initiatives			
Targeted Education and Enforcement Alcohol Corridors (State and Local)	40 corridors	Oct 2013	Actual number of corridors implemented
Targeted Education and Enforcement Speeding Corridors (State and Local)	145 corridors	Oct. 2013	Actual number of corridors implemented
Targeted Education and Enforcement Unbelted Corridors (State and Local)	50 corridors	Oct 2013	Actual number of corridors implemented
3-E Corridors			
3-E Improvements on high crash corridors	Date at least one corridor is	One corridor implemented by Jan 2015;	Actual date completed

Effectiveness Performance Measures– Program Effectiveness in Reducing Targeted Crashes

Table 29: Effectiveness Performance Measures

Countermeasure	Year Improvements Implemented	Year Evaluation Plan Developed	Year Evaluation Completed	Expected Crash Reduction	Actual Crash Reduction
Curve sign and marking enhancements – systematic					
Centerline Rumble strips – systematic					
Edge/shoulder rumble strips (non-Interstate) – systematic					
Alignment Delineation					
High Friction Surfaces					
Tree removal – systematic					
Resurfacing Projects with safety enhancements					
Targeted Education and Enforcement Alcohol Corridors					
Targeted Education and Enforcement Speed Corridors					
Targeted Education and Enforcement Unbelted Corridors					
3-E Targeted Engineering, Education, and Enforcement Corridors					
Cable Median barrier					
New Traffic Calming Countermeasures					

Summary

The number of roadway departure fatalities and incapacitating injuries within Pennsylvania can continue to measurably decline over the next several years. New and special actions can increase the rate of roadway departure fatality reductions. The existing approach of emphasizing moderate- to high-cost improvements at high-crash roadway departure sections must be complemented with the systematic deployment of a large number of low-cost, cost-effective countermeasures and the use of a coordinated enforcement and education approach on corridors that have a high number of roadway departure fatalities.

The countermeasures, deployment levels, costs, and estimated 60 lives saved annually are shown in Table 30. While the level of funds and direction of effort is well beyond that currently being pursued for roadway departure safety, the expected outcome – preventing over 2,500 crashes and 60 fatalities annually on Pennsylvania's highways – is worth the investment.

Table 30: Strategy Matrix – Summary of Roadway Departure Countermeasures: Deployment Levels; Costs; Crash, Incapacitating Injury Crash, and Fatality Reductions

Countermeasure	Approach	Estimated Number of Improvements [1]	Associated Costs ($ Million) [2]	Annual Targeted Crash Reduction [3]	Annual Estimated Incapacitating Injury Reduction	Annual Estimated Fatality Reduction	$ (million) Required to Save One Annual Life
State Roads							
Enhanced Curve Sign and Marking Countermeasures - Total State Rural	Systematic	2,375	$11.88	683	28.83	18.27	0.65
Enhanced Curve Sign and Marking Countermeasures Plus High Friction Surfaces - Total State Rural	Systematic	31	$1.85	40	1.69	1.12	1.66
Enhanced Curve Sign and Marking Countermeasures - Total State Urban	Systematic	271	$1.35	174	5.10	2.65	0.51
Centerline Rumble Stripes - Total State Rural	Systematic	162	$2.91	54	16.85	3.53	0.82
Edge Line Rumble Stripes or Shoulder Rumble Strips - Total State Rural	Systematic	1,656	$4.97	400	12.92	7.79	0.64
Alignment Delineation - Total State	Systematic	150	$0.75	30	1.10	0.65	1.16
High Friction Surfaces - Total State	Systematic	24	$2.35	49	0.95	0.50	4.68
Guardrail Relocation/Safety Enhancements - Total State	Systematic	24	$0.60	-	0.96	0.64	0.94
Tree Removal/Safety Enhancements, Shield Tree(s) - Total State	Systematic	100	$7.50	107	5.55	3.75	2.00
Utility Pole Relocation/Safety Enhancements - Total State	Systematic	80	$6.00	115	3.77	1.71	3.51
Enforcement and Education: Alcohol Related - Total State	Ed & Enf	39	$0.98	34	1.99	1.44	0.68
Enforcement and Education: Speeding Related Crashes - Total State	Ed & Enf	148	$7.70	238	5.86	4.31	1.78
Infrastructure Improvements: Speeding Related Crashes - Total State	Ed & Enf	61	$3.16	61	1.73	1.26	2.51
Enforcement and Education: Unbelted Driver - Total State	Ed & Enf	48	$2.50	69	4.28	2.53	0.99
3-E Corridor Improvements - State Roads	Ed & Enf	1	$1.50	11	1.45	1.70	0.88
Wider Shoulders / Edge Line Rumble Stripes - Total State	Traditional	213	$9.54	274	9.33	4.20	2.27
Cable Median Guide Rail - Total State	Traditional	19	$5.67	-	0.35	1.48	3.83
Local Roads							
Enhanced Curve Sign and Marking Countermeasures - Total Local	Systematic	174	$4.34	147	4.43	1.73	2.51
Standard Pavement Markings - Total Local Rural	Systematic	31	$0.62	13	0.52	0.25	6.97
Alignment Delineation, Lighting - Total Local	Systematic	10	$0.21	3	0.12	0.05	4.59
Tree Removal/Safety Enhancements, Shield Tree(s) - Total Local	Systematic	16	$1.17	21	0.91	0.45	2.57
Enforcement and Education: Alcohol Related - Total Local	Ed & Enf	4	$0.10	4	0.15	0.07	2.97
Enforcement and Education: Unbelted Driver - Total Local	Ed & Enf	2	$0.12	4	0.14	0.06	2.14
Total Cost and Benefit (State and Local Roads)							
Total Cost ($Million)			$77.75	-	-	-	-
Annual Cost (Million) for 5 years; Annual Benefit			$15.55	2,531	108.98	60.13	-

Appendix A

Appendix A is a separate Word File that contains the 2007 to 2011 Pennsylvania crash data analysis used to develop the Roadway Departure Implementation Plan along with the final strategy matrix of countermeasures upon which the Plan is based.

Appendix B

Appendix B is a separate Excel file that provides information on highway locations that have multiple countermeasures.

- Countermeasures are listed in half mile segment lengths by section beginning segment number and beginning offset. The first line in the Example 1 table below shows the location of the route identification (County, Route, MPO, District), route location information (beginning segment, beginning offset), and section length (variable dependent on countermeasure)

Example 1

							Countermeasures (Number of Crashes)																
COUNTY	DISTRICT	ROUTE	MPO	BEG Segment	BEG Offset	Section Length	CSM	CSMFB	CLRS	ELRS/SRS	ELRS	SRS	ADL	HFS	GR	TR	UP	II	EEA	EES	EER	43LC	3E
							8					13											
									5							19							

Appendix C

Appendix C is a Word file that provides one line of crash information for all targeted crashes on a route that has at least one section at or above the specified threshold for a given countermeasure. Information in Appendix C may be useful to District Safety Engineers in determining if a given countermeasure should be extended in length beyond the section limits identified in the clusters based upon the prevalence and distribution of targeted crashes along the route.