Statewide Shoulders Study

Task MPD 059-14

Executive Summary

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Study Overview

Located adjacent to a roadway's travel lanes, highway shoulders are essential components on any road section. Highway shoulders serve several purposes:

- Creates a safe zone for vehicles to safely exit travel lanes during emergency situations
- Allows motorists an area to maneuver if they exit the travel lane
- Increases sight distance of horizontal curves
- Provides bicyclists with a safe area adjacent to vehicle travel lanes
- Increases driver's sense of safety
- Provides structural support to highway pavement
- Protects the highway surface from damage caused by water flow
- Creates a storage area during snow removal

Shoulder improvements can lead to a plethora of safety and operational improvements, such as reduction in crashes, safe pedestrian and bicycle facilities, mitigation of drainage issues, and increased roadway capacity. Potential safety hazards can occur when a vehicle leaves the travel way and there is a significant material and elevation difference between highway pavement and shoulder surfaces. This elevation difference can affect vehicle stability, reduce a driver's ability to handle the vehicle, and often cause head-on, sideswipe, rollover, and fixed object crashes. Shoulder paving is recognized as a positive countermeasure to reduce a shoulder drop-off hazard that will accommodate stopped vehicles to avoid encroachment from the travel way, facilitate maintenance work, provide access for emergency vehicles, and protect pavement structural integrity. A paved shoulder can also assist in preventing damage to the road structure caused by water infiltration and can provide motorists with a warning system when veering off the roadway (i.e., rumble strips).

Purpose and Need

With the ultimate purpose of enhancing safety and improving mobility, the *Statewide Shoulders Stud*y was initiated to develop a prioritized list of candidate locations for shoulder improvements. The need for this study stems directly from ADOT's desire to increase safety and mobility along the Arizona State Highway System. The project purpose is demonstrated with the following statement of need:

- **Create Methodology.** As the first statewide, shoulder improvement prioritization project conducted in Arizona, a methodology needs to be developed that utilizes available data to accurately identify deficiencies. A statewide and district-level prioritization is needed in order to appropriate limited funds for priority projects.
- **Develop List of Shoulder Improvement Locations.** Currently, there is no statewide or ADOT Engineering District-wide listing of prioritized locations for shoulder improvement projects. This document will serve as

guidance for determining priority roadway segments within each ADOT District and throughout the State that require funding.

- **Develop Feasible, Cost Effective Implementation Plan.** High priority projects need to be evaluated for feasibility and cost-effectiveness. Due to limited funding, innovative and cost effective alternatives beyond traditional pavement applications need to be explored.

Technical Advisory Committee

This study was guided by a Technical Advisory Committee (TAC). The role of the TAC was to provide technical guidance, support, advice, suggestions, recommendations, and to perform document reviews throughout the study process. TAC members included representatives from:

- ADOT Multimodal Planning Division
- ADOT Phoenix Engineering District
- ADOT Tucson Engineering District
- ADOT Prescott Engineering District
- ADOT Yuma Engineering District
- ADOT Flagstaff Engineering District
- ADOT Holbrook Engineering District
- ADOT Kingman Engineering District
- ADOT Globe Engineering District
- ADOT Safford Engineering District
- ADOT Roadway Engineering Group
- ADOT Maintenance Group
- ADOT Bridge Group
- ADOT Right of Way
- ADOT Traffic Safety Section
- Federal Highway Administration (FHWA)

Stakeholder Outreach

The first phase of stakeholder outreach included individual meetings with each ADOT District staff. Meetings with the Districts were conducted April 22 - April 30, 2014. The primary purpose of these meetings was to obtain feedback from each of the Districts about the following:

- Review and verify existing shoulder width conditions
- Review general and shoulder related crash data analysis results
- Identify any inconsistencies or errors in the background data
- Obtain Districts preference for preliminary project locations based on their understanding of local conditions
- Identify already planned and programmed improvements, if any
- Obtain consensus on evaluation criteria and preliminary prioritization methodology

The second phase of stakeholder outreach was conducted October 8 – 15, 2014 and involved individual meetings with ADOT District staff. The primary purpose of these meetings was to review:

- Design guidelines used to define deficiencies
- Listing of preliminary candidate locations
- District suggested locations
- Crash data analysis results
- Recommended ranking/prioritization criteria

The study team presented the design guidelines used to define shoulder deficiencies. ADOT's Roadway Design Guidelines were used as the primary criteria to identify shoulder deficiencies. Highway Safety Manual (HSM) indicated that widening the shoulder from 6 – 8 ft may not yield a significant reduction in crashes; the study team recommended that roadway segments that had at least 6 ft of shoulder width be eliminated from consideration for two-lane highways. District staff concurred with the recommendation and asked the study team to confirm that shoulder related crashes were not a concern before eliminating those segments from consideration. District staff also concurred with the study team's suggestion to remove segments that have 8 – 10 ft shoulder on multilane highways unless crash analysis warrants the need for shoulder improvements.

A full listing of comments received during the stakeholder outreach meetings is included in the *Working Paper 1: Existing Conditions* and *Working Paper 2: Evaluation Criteria and Plan for Improvements*.

Identification and Prioritization Methodology

Two-lane highways and multilane highways have different physical and traffic characteristics and their mobility and safety performance is evaluated using different parameters. For this reason, separate methodologies were developed to identify and prioritize:

- Shoulder improvements on two-lane highways
- Shoulder improvements on multilane highways

Methodology to Identify Shoulder Improvements on Two-Lane Highways

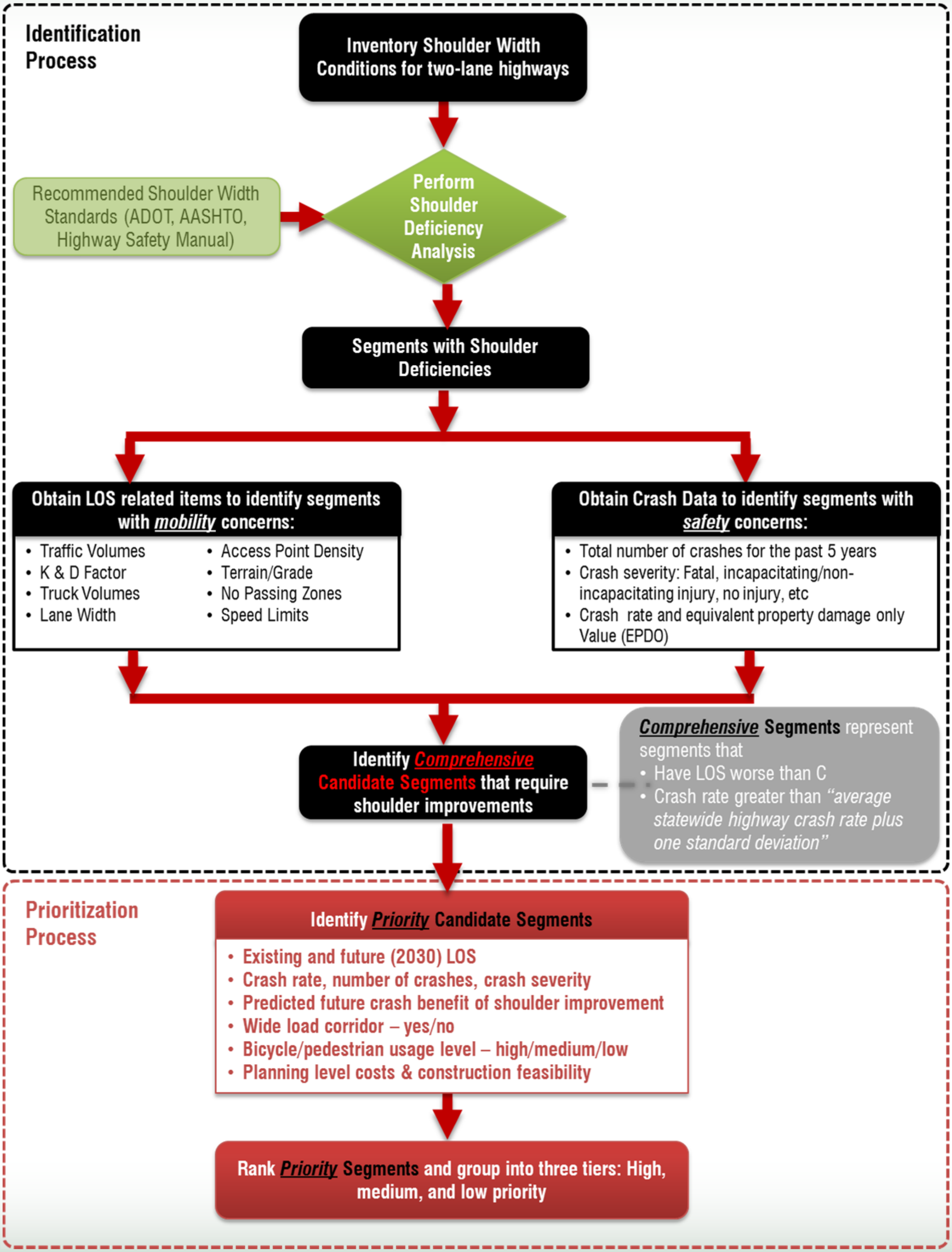
Figure 1 illustrates the steps utilized to identify and prioritize potential locations for shoulder improvements on two-lane highways. Once preliminary lists of potential candidates were identified, they were ranked on a statewide basis using the criteria and score ranges listed in Table 1.

Table 1: Prioritization Criteria for Shoulder Improvements on Two-Lane Highways

Criteria	Max Points	Points Distribution
Mobility – 25%	**25**	
Existing LOS: PTSF – Percent Time Spent Following	5	Z-score method*
Existing LOS: PFFS – Percent of Free Flow Speed	5	Z-score method*
Future LOS: PTSF – Percent Time Spent Following	5	Z-score method*
Future LOS: PFFS – Percent of Free Flow Speed	5	Z-score method*
Wide load corridor	5	5 points if segment was a wide load corridor; 0 points if NOT a wide load corridor
Safety – 50%	**50**	
Existing Crash Rate	15	Z-score method*
Existing Crash Severity (EPDO)	15	Z-score method*
Future Crash Severity (Potential Future Crash Benefit)	10	Z-score method*
Bicycle/Pedestrian Usage Level	10	10 points for segments with high bike/ped usage; 0 points if NOT a bike/ped corridor
Construction Feasibility - 25%	**25**	
Cost Per Lane Mile	10	Proportional distribution of points based on cost per lane mile
Potential Number of Bridges that Require Widening	15	0 bridges = 15 pts; 1 bridge = 12 pts; 2 bridges = 10 pts; 3 bridges = 8 pts; 4 bridges = 6 pts; 5 bridges = 4 pts; 6 bridges = 2 pts; Greater than 6 bridges = 0 pts

**Each record's z-score was determined based on its relative distance from the mean of all records. Based on the record's z-score, a proportional point value between 0 and Max Points was then assigned to each record.*

Figure 1: Identification Process for Shoulder Improvements on Two-Lane Highways



Methodology to Identify Shoulder Improvements on Multilane Highways

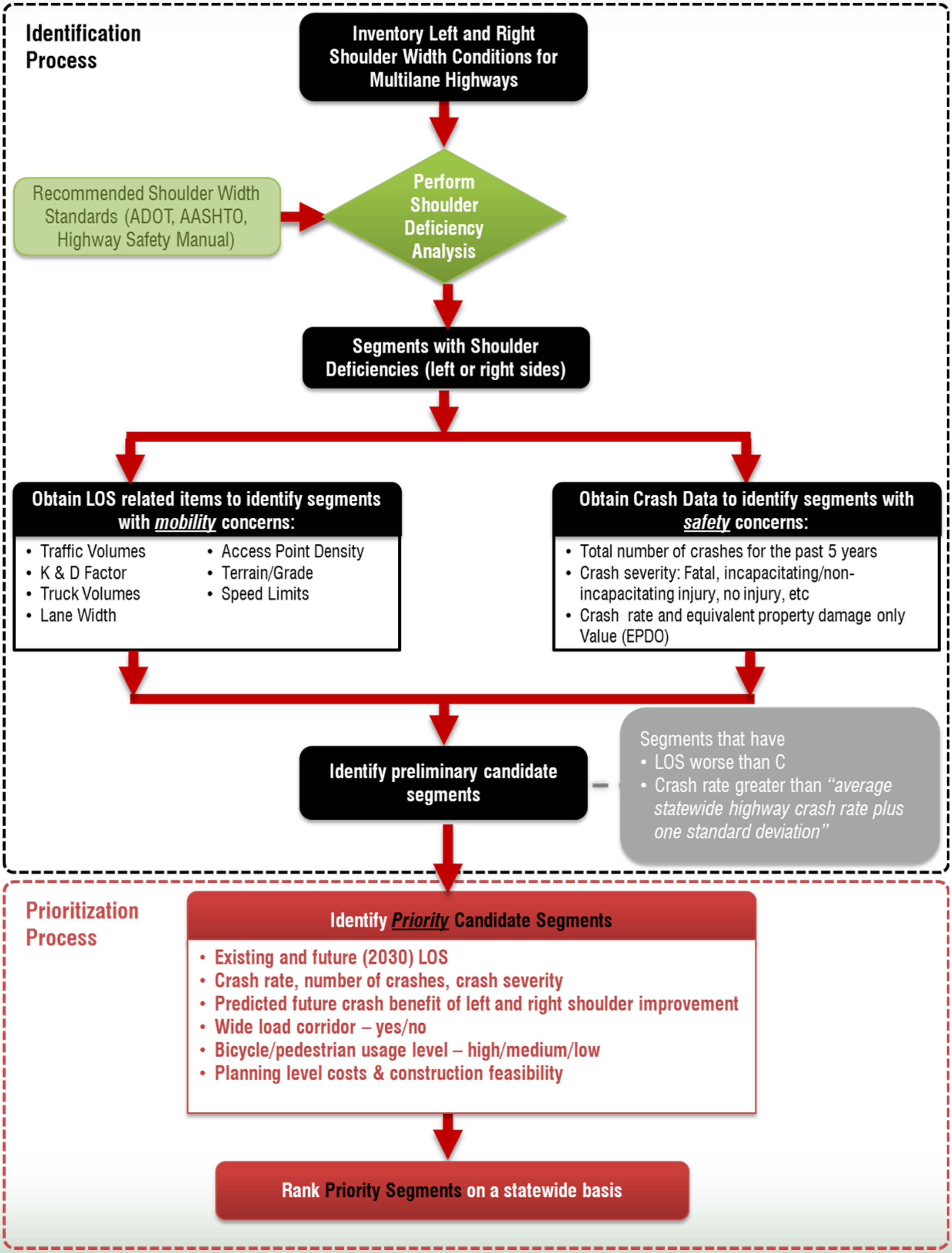
Figure 2 illustrates the steps utilized to identify and prioritize potential locations for shoulder improvements on multilane highways. Once preliminary lists of potential candidates were identified, they were ranked on a statewide basis using the criteria and score ranges listed in Table 2.

Table 2: Prioritization Criteria for Shoulder Improvements on Multilane Highways

Criteria	Max Points	Points Distribution
Mobility – 25%	**25**	
Existing LOS: Density	10	Z-score method*
Future LOS: Density	10	Z-score method*
Wide Load Corridor	5	5 points if segment was a wide load corridor; 0 points if NOT a wide load corridor
Safety – 50%	**50**	
Existing Crash Rate	15	Z-score method*
Existing Crash Severity (EPDO)	15	Z-score method*
Potential Future Crash Reduction Level – Right Shoulder	12	Z-score method*
Potential Future Crash Reduction Level – Left Shoulder	3	Z-score method*
Bicycle/Pedestrian Usage Level	5	10 points for segments with high bike/ped usage; 0 points if NOT a bike/ped corridor
Construction Feasibility 25%	**25**	
Cost Per Lane Mile	10	Proportional distribution of points based on cost per lane mile
Potential Number of Bridges that Require Widening	15	0 bridges = 15 pts; 1 bridge = 12 pts; 2 bridges = 10 pts; 3 bridges = 8 pts; 4 bridges = 6 pts; 5 bridges = 4 pts; 6 bridges = 2 pts; Greater than 6 bridges = 0 pts

***** *Each record's z-score was determined based on its relative distance from the mean of all records. Based on the record's z-score, a proportional point value between 0 and Max Points was then assigned to each record.*

Figure 2: Identification Process for Shoulder Improvements on Multilane Highways



Shoulder Improvements on Two-Lane Highways

For two-lane highways, a shoulder deficiency analysis was conducted to identify all highway segments that did not meet minimum shoulder width standards. These segments were then evaluated against the following criteria to identify ***comprehensive candidate locations*** for shoulder improvements.

- LOS C or worse
- Crash rate is greater than "average statewide highway crash rate plus one standard deviation"

A review of the ***comprehensive candidate locations*** revealed that several segments were too long and may not be feasible for implementation. To help the Districts further prioritize the segments, each larger segment was divided into smaller segments. These smaller segments were evaluated against the following additional set of criteria to generate a list of **priority candidate locations** that would be easier to implement.

- Existing and future (2030) LOS
- Crash rate, number of crashes, crash severity
- Predicted future crash benefit of shoulder improvement
- Wide load corridor – yes/no
- Bicycle/pedestrian usage level – high/medium/low
- Planning level costs & construction feasibility

Example:

Comprehensive **Candidate Location** Vs ***Priority*** **Candidate Location**

Example:

SR 64: MP 196 to MP 233 ----> ***Comprehensive*** Candidate Location

SR 64: MP 202 to MP 204
SR 64: MP 218 to MP 220
SR 64: MP 224 to MP 226
--> ***Priority*** Candidate Locations

The **priority candidate locations** were scored and ranked at both Statewide and District level and grouped into three tiers – high, medium, and low priority. The results for each District are summarized in the following sections:

- ***Comprehensive candidate locations*** that need shoulder improvements
- Priority segments for shoulder improvements.

Locations identified for shoulder improvements in Tables 3 - 11 represent only the general problem area and not the exact location and length of the shoulder improvements.

Planning Level Cost Estimates

Planning level cost estimates were developed based on typical per-mile/foot construction costs for widening and are expressed in 2015 dollars and have not been field verified. The following assumptions were used to derive the planning level cost estimates for the Tier 1 (priority) candidate segments:

- Widening shoulder to 8 FT: $900,000/mile for flat terrain
  - For each segment, the actual footage of additional shoulder width needed was estimated and the cost was then prorated. For example, if the candidate segment currently has a 2 FT shoulder, the prorated cost to widen the shoulder an additional 6 FT to meet the 8 FT standard was estimated.
  - Existing actual shoulder widths varied within each candidate segment; therefore, segments were divided into 0-2 FT, 3-5 FT, 5-8 FT, and 8 FT or greater shoulder widths. The midpoint of the candidate segments shoulder width range was utilized as the basis for calculating cost estimates. For example, an average shoulder width of 1 FT was utilized for candidate segments with a shoulder width range between 0-2 FT, 4 FT for segments with a 3-5 FT range, and so forth.
- Topographical constraints:
  - Segments with rolling terrain – an additional 10% was added to the base widening cost
  - Segments with mountainous terrain: an additional 20% was added to the base widening cost
- Bridge Widening: $200/SQFT
  - The number of bridges within each candidate segment was obtained from the National Bridge Inventory database. Each bridge's overall length, width, and deck width was also obtained.
  - For each bridge, the additional square footage needed to widen the bridge was determined.
  - The cost to widen each bridge was then estimated.
- Costs associated with acquiring right-of-way, widening culverts, and environmental mitigation are not included in estimates.
- Unless otherwise noted, recommended projects are not yet funded.

Due to topographical or other physical constraints adjustment factors may need to be applied to the cost estimates to account for increased construction costs. During project implementation the costs for each project may vary; therefore, during the design phase a detailed analysis should be performed to determine actual costs.

Flagstaff District

Table 3 presents the list of candidate locations for shoulder improvements on two-lane highways in the Flagstaff District. The candidate locations are ranked at the statewide and district level and grouped into three tiers – high, medium, and low priority. Table 4 summarizes the priority candidate improvement locations by tier.

Table 3: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
S 064	Both	185.6	187.2	MP185.6 - MP187.2
S 064	Both	187.9	194.0	MP187.9 - MP190
				MP190 - MP192
				MP192 - MP194
S 064	Both	196.0	233.6	MP196 - MP198
				MP198 - MP200
				MP200 - MP202
				MP202 - MP204
				MP204 - MP206
				MP210 - MP212
				MP212 - MP214
				MP214 - MP216
				MP216 - MP218
				MP218 - MP220
				MP220 - MP222
				MP222 - MP224
				MP224 - MP226
				MP226 - MP228
				MP228 - MP230
				MP230 - MP232
S 064	Westbound	234.3	235.3	MP234.3 - MP235.3
S 064	Both	236.0	237.0	MP267 - MP268
S 064	Both	281.7	289.5	MP284 - MP286
S 067	Both	579.0	610.0	
S 098	Both	294.0	361.0	MP298 - MP300
				MP300 - MP302
				MP302 - MP304
				MP308 - MP310
				MP318 - MP320
				MP328 - MP330

Table 3: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District (Continued)

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
				MP330 - MP332
				MP342 - MP344
				MP344 - MP346
				MP348 - MP350
				MP350 - MP352
				MP352 - MP354
				MP354 - MP356
S 179	Both	299.0	304.5	MP299 - MP302
				MP302 - MP304.5
S 389	Both	0.0	32.1	
SA089	Both	374.0	389.8	MP374 - MP376
				MP380 - MP382
				MP384 - MP386
				MP386 - MP389.8
SA089	Both	390.4	398.7	
U 089	Both	456.6	461.8	MP461.8 - MP460.7
U 089	Both	469.6	470.8	MP469.6 - MP470.8
U 089	Both	471.6	472.3	MP471.6 - MP472.3
U 089	Both	474.5	475.4	MP474.5 - MP475.4
U 089	Both	477.4	478.3	MP477.4 - MP478.3
U 089	Both	493.1	494.1	MP493.1 - MP494.1
U 089	Both	505.7	507.1	MP505.7 - MP507.1
U 089	Both	509.2	512.2	MP509.2 - MP512.2
U 089	Both	519.9	521.2	MP519.9 - MP521.2
U 089	Both	524.4	556.8	MP548 - MP550
				MP550 - MP552
				MP552 - MP554
				MP554 - MP556.8
U 160	Both	311.0	324.0	MP311 - MP314
				MP314 - MP316
				MP316 - MP318
				MP318 - MP320
U 160	Eastbound	324.0	332.0	

Table 3: Two-Lane Highways - Candidate Shoulder Improvement Locations in Flagstaff District (Continued)

Route	Dir	BMP	EMP	Priority Segments: (Segments that exceed LOS and Crash Rate Threshold)*
Flagstaff District				
U 160	Both	332.0	356.0	MP336 - MP338
				MP340 - MP342
				MP342 - MP344
				MP344 - MP346
				MP346 - MP348
				MP350 - MP352
				MP352 - MP354
				MP354 - MP356
U 160	Eastbound	356.0	358.0	MP356 - MP358
U 160	Both	358.0	362.0	MP358 - MP360
				MP360 - MP362
U 180	Both	218.0	237.4	MP218 - MP220 MP220 - MP223.2 MP223.2 - MP226
U 180	Both	239.4	244.2	
U 180	Both	245.4	264.0	
U 180	Eastbound	264.0	265.6	
UA089	Both	524.0	537.3	
UA089	Both	538.5	546.0	
UA089	Southbound	546.0	548.0	
UA089	Both	548.0	609.0	MP590 - MP592
UA089	Both	610.2	612.3	

Priority segments represent segments that
- Have LOS worse than C
- Crash rate greater than "average statewide highway crash rate plus one standard deviation"
District Rankings are Provided in the Following Table