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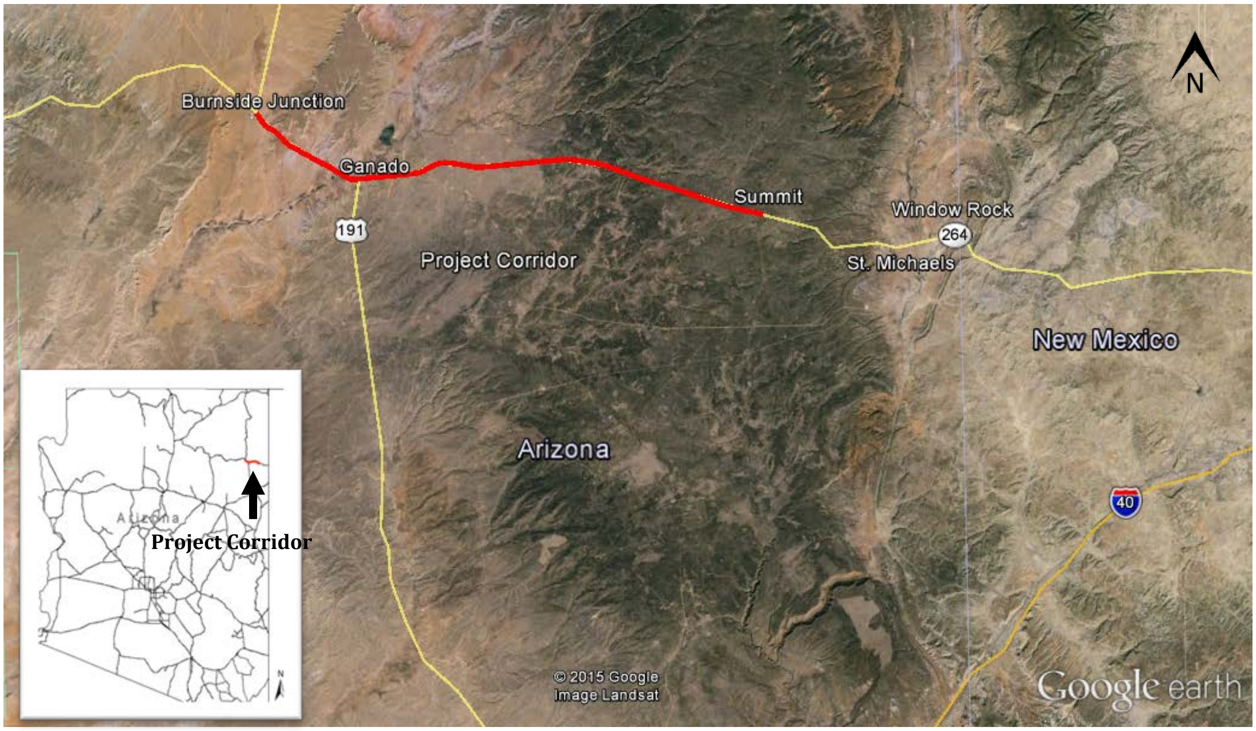
Case Study: Arizona SR 264 Burnside Junction to Summit - Safety Improvement Evaluation

Agency: Arizona Department of Transportation (ADOT)
Location: Navajo County, Arizona
Region: Southwest Region
Setting: Rural

Overview

The Arizona Department of Transportation (ADOT) Traffic Safety Section recognized that a significant portion of Arizona's fatal crashes were of the run-off-roadway crash type along rural two-lane highways, as is typical for most states with significant mileage of rural highways. The ADOT Traffic Safety Section took a systemic approach and reviewed two-lane rural highways with a higher potential for run-off-roadway crashes. One of the priority corridors for shoulder widening as a federal Highway Safety Improvement Program (HSIP) funded project was State Route 264 (SR 264) from Burnside Junction to Summit in Northern Arizona. This is a 24.55 mile corridor from Milepost (MP) 441.19 in Burnside Junction to MP 465.74 at the Summit. This section of SR 264 is located in Navajo County, Arizona, within the ADOT Holbrook District and is shown in Figure 1. SR 264 through this section is classified as a rural minor arterial and runs east-west. The area of interest is currently a two-lane rural highway, with intermittent right- and left-turn lanes and passing lanes.

Figure 1 – Vicinity Map



Source: Google Earth

Performance-Based Practical Design is a decision making approach that helps agencies better manage transportation investments and serve system-level needs and performance priorities with limited resources. Performance-Based Practical Design can also be articulated as modifying a traditional design approach to a "design up" approach where transportation decision makers exercise engineering judgment to build up the improvements from existing conditions to meet both project and system objectives. Performance-Based Practical Design uses appropriate performance-analysis tools, considers both short and long term project and system goals while addressing project purpose and need. The following case study on SR 264 in Arizona is an example of developing a performance-based practical design for the shoulder width and project segmentation.

During the project scoping evaluation by the ADOT Traffic Safety Section, it was determined that the project would be split into two separate segments which are intended to be prioritized based on the potential reduction of the total number of crashes. The mile post (MP) limits of the two segments are as follows:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

Using the American Association of State & Highway Transportation Officials (AASHTO) Highway Safety Manual (HSM), 2010, Predictive Method, expected total crashes were estimated for the purpose of evaluating the effect of:

- Design alternatives; and
- Segment Prioritization

The effect on traffic safety was analyzed for the following improvement alternatives:

- Shoulder Widening Alternative A - Widening the existing 1-foot shoulders to 5 feet;
- Shoulder Widening Alternative B - Widening the existing 1-foot shoulders to 8 feet; and
- Improving superelevation to bring into compliance with AASHTO recommendations.

The following provides a summary of the three traffic safety alternatives:

Shoulder Widening Alternative A – Widen Existing Roadway to 34 feet

The purpose of Alternative A is to widen the existing roadway to 34 feet to provide 5-foot shoulders. The proposed improvements would widen the existing 1-foot shoulders to 5-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures and providing delineators and recessed pavement markers. The original intent was for this alternative to be 32 feet wide with 4-foot shoulders; however it was widened to 5-foot shoulders to be able to meet the FHWA recommendation for a 4-foot bikeable width outside of the rumble strip.

Shoulder Widening Alternative B – Widen Existing Roadway to 40 feet

The purpose of Alternative B is to widen the existing roadway to 40 feet to provide the standard shoulder width. The proposed improvements would widen the existing 1-foot shoulders to 8-foot shoulders. The existing travel lane width would remain 12 feet. The improvements would include adding centerline and shoulder rumble strips, flattening side slopes, installing guardrail, extending drainage structures, and providing delineators and recessed pavement markers.

Superelevation Improvement Consideration

An additional consideration is to improve the superelevation on horizontal curves located within the project limits to bring the cross slope into compliance with the AASHTO recommended minimum superelevation rates. The superelevation improvements were evaluated independently of any additional improvements for the purpose of developing a benefit-cost ratio.

Approach

Analysis of Existing Conditions

SR 264 is an undivided highway consisting of one 12-foot travel lane in each direction with approximate 1-foot paved shoulders on each side. Climbing lanes are present for eastbound travel between MP 441.2 and MP 442.6, westbound travel between MP 442.6 and MP 443.8, and eastbound travel between MP 447.6 and MP 448.8. There are existing turn lanes at MP 446.3, 446.6, 446.9 (US 191), 448.3 and 452.1. There are four major structures located within the project limits including one structural plate pipe arch, one pedestrian overpass, and two bridges at Fish Wash and Ganado Wash. There is existing guardrail at Ganado Wash Bridge (MP 446.20), at MP 447.0, and at Fish Wash Bridge (MP 451.30). An aerial view of the location of interest is shown in Figure 2.

Figure 2 – Aerial View of Project

Source: Google Earth

As reported by the Data Team of the Multimodal Planning Division (MPD), the 2010 Average Annual Daily Traffic (AADT) within the project limits varies between 4,100 and 6,500 vehicles per day as shown in Table 1.

Table 1: 2010 AADT

SR 264	2010 AADT (vehicles per day)
MP 441.02-MP 446.18	5,010
MP 446.18-MP 446.91	6,429
MP 446.91-MP 448.37	5,199
MP 448.37-MP 475.50	4,102

Crash data for the most recent 4-year period (2007-2010) were used in this evaluation since 2011 crash data was not available to use at the time of this study. Tables 2 and 3 below summarize the total number of crashes, as well as the severity and manner of collision.

Table 2: Crash Severity, 2007-2010

Severity	Number
Fatal	6
Incapacitating Injury	3
Non-Incapacitating Injury	1
Possible Injury	24
No Injury (PDO)	22
Total	*56*

Table 3: Manner of Collision, 2007-2010

Manner of Collision	Number
Head On	2
Left Turn	3
Rear End	13
Angle (Other than Left Turn)	5
Sideswipe (Opposite Direction)	2
Sideswipe (Same Direction)	4
Single Vehicle	27
Total	*56*

A total of 56 crashes were found to be associated to SR 264 within the project limits between 2007 and 2010. The average annual crash frequency is 14 crashes per year.

As reported by the Data Team of the MPD, the 2036 Projected AADT for SR 264 within the project limits varies between 5,400 and 12,150 vehicles per day as shown in Table 4**.**

Table 4: 2036 Design Year AADT

SR 264	2036 Projected AADT (vehicles per day)
MP 441.02-MP 446.18	9,900
MP 446.18-MP 446.91	12,150
MP 446.91-MP 448.37	7,350
MP 448.37-MP 475.50	5,400

A safety analysis was performed by ADOT's consultants for this project using the procedures outlined in the *Highway Safety Manual* (HSM). The HSM provides guidance on how to analyze highway sections that are reasonably homogeneous with respect to key variables such as traffic volume, highway cross-section, highway classification, and surrounding geometric conditions. The proposed improvements are not anticipated to impact traffic operations, since all alternatives have one travel lane in each direction. Therefore a traffic operational analysis was not performed for this study.

Safety Analysis

Implementation of the Predictive Method requires the development of three main parts: a Safety Performance Function (SPF), Crash Modification Factors (CMFs), and a local calibration factor (C). The SPF uses roadway geometry, roadway characteristics, and traffic conditions to determine a base condition for a particular category of highway. For the purpose of this study, SR 264 falls under the category of a rural two-lane, two-way road as defined in Chapter 10 of Part C of the HSM. CMFs are then applied to the SPF to create a site-specific function that more accurately reflects the existing or proposed conditions of the roadway. Finally, a calibration factor can be applied to account for jurisdictional/regional variations in climate, driver population, etc. At the time of this study, ADOT has not developed a local calibration factor. So, a local calibration factor was not applied.

Table 5 shows the base parameters of the SPF for a Rural Two-Lane, Two-Way Road along with the parameters used in developing the SPF for the existing and proposed conditions. Notable variations from the base condition include the shoulder width, roadside hazard rating, and centerline rumble strips.

Table 5: Base Parameters for the SPF for Rural Two-Lane, Two-Way Road

Roadway Element	Existing SR 264 (1 foot Shoulder)	HSM Base Condition	Alternative A (5 foot Shoulder)	Alternative B (8 foot Shoulder)
Lane width	12 feet	12 feet	12 feet	12 feet
Shoulder width	1 foot	6 feet	5 feet	8 feet
Shoulder type	Paved	Paved	Paved	Paved
Roadside hazard rating	6	3	2, except 4 for guardrail sections	2, except 4 for guardrail sections
Driveway Density	Per survey & Holbrook District turnout database	≤ 5 per mile	Per survey & Holbrook District turnout database	Per survey & Holbrook District turnout database
Horizontal curves: length, radius, and presence or absence of spiral transitions	Per best-fit alignment	None	Per best-fit alignment (match existing)	Per best-fit alignment (match existing)
Horizontal curves: Superelevation	Per as-builts & survey	None	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Grades	Per as-builts & survey	≤ 3%	Per as-builts & survey (match existing)	Per as-builts & survey (match existing)
Centerline rumble strips	None	None	Present	Present
Passing lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Two-way left-turn lanes	Per survey	None	Per survey (match existing)	Per survey (match existing)
Lighting	Present @ US 191 Intersection	None	Present @ US 191 Intersection (match existing)	Present @ US 191 Intersection (match existing)
Automated speed enforcement	None	None	None	None

Utilizing the Interactive Highway Safety Design Model (IHSDM) software and the parameters listed above, the Predictive Method was applied to each alternative to calculate a predicted total number of crashes for the study period of 2016 to 2036. An expected total number of crashes was calculated by including site specific crash data in the predictive analysis using the Empirical Bayes (EB) Method.

Existing Conditions with Projected AADT Values

Using the methodology detailed above, an expected total number of crashes was calculated for SR 264 from Burnside Junction to Summit, as shown in Table 6.

Table 6: Existing Conditions Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes
Total	636.38
Fatal and Injury (FI)	283.40
Property Damage Only (PDO)	352.98

The expected total number of crashes over the 20-year analysis period is 636.38 crashes, which equates to a crash frequency of 31.82 crashes per year.

Analysis of Roadside Design Alternatives

Proposed Conditions with Projected AADT Values

Using the same methodology as before, an expected number of crashes was calculated for SR 264 for each of the alternatives previously mentioned and is summarized in Table 7.

Table 7: Expected Crashes with Proposed Shoulder Widening

Crash Severity Level	2016 2036 Expected Total Number of Crashes		
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders
Total	636.38	531.58	504.16
Fatal and Injury (FI)	283.40	230.45	216.80
Property Damage Only (PDO)	352.98	301.13	287.36
Reduction in Total Crashes over Existing Conditions	-	104.80	132.22

The proposed improvements for alternatives A and B respectively reduce the expected number of crashes compared to the existing conditions by 104.80 and 132.22 crashes over the 20-year analysis period. The corresponding Crash Modification Factors (CMFs) for Alternatives A and B are approximately 0.84 (16% reduction) and 0.79 (21% reduction), respectively.

Superelevation Improvements with Projected AADT Values

The Predictive Method was also used to evaluate the effect of improving superelevation rates on the total expected number of crashes. The analysis was performed assuming that the superelevation improvements were being made independent of all other improvements. The results of the superelevation analysis are shown in Table 8.

Table 8: Expected Crashes with Proposed Superelevation

Crash Severity Level	2016 2036 Expected Total Number of Crashes	
	Existing Conditions	Superelevation
Total	636.38	635.26
Fatal and Injury (FI)	283.40	282.71
Property Damage Only (PDO)	352.98	352.55
Reduction in Total Crashes over Existing Conditions	-	1.12

The effect of bringing existing superelevation rates into compliance with the AASHTO minimum values reduced the total number of expected crashes by 1.12 crashes over the 20-year analysis period. This reduction corresponds to a rounded CMF of 1.00 (0.2% reduction).

Benefit-Cost Ratio

Crash Severity Proportions

In order to perform a benefit-cost ratio Analysis in accordance with the procedures contained in the *Arizona Highway Safety Improvement Program Manual*, 2010, it was required that the total expected crash frequency be broken into five severity levels:

- Fatal
- Incapacitating injury
- Non-incapacitating injury
- Possible injury
- Property damage only (PDO)

Table 10-3 in the HSM provides default proportions for crash severity. The HSM values are based on State of Washington data (2002-2006). The project being located within the Navajo Nation, it was believed that it would be more appropriate to develop proportions based on data from this region. In order to calculate the necessary proportions, a data query of crashes on three rural two-lane, two-way state highways within the Navajo Nation and the Hopi Tribe in Arizona was performed. The segments queried were:

- SR 264 from US 160 to the State Border (approximately 150 roadway miles)
- US 160 from US 89 to the State Border (approximately 160 roadway miles)
- US 191 from I-40 to US 160 (approximately 130 roadway miles)

Five years of crash data were used (2007-2011). The total number of crashes for each severity level were determined and the percentages of the total were calculated. Table 9 illustrates the crash severity percentages used in the analysis.

Table 9: Navajo and Hopi State Highway System Rural Two-Lane Two-way Roadway Segment Crashes (2007-2011)

Severity Level	Percent of Total
Fatal	*12.4%*
Incapacitating Injury	*4.9%*
Non-Incapacitating Injury	*13.0%*
Possible Injury	*23.2%*
Property Damage Only (PDO)	*46.5%*

It should be noted that the percent of fatal crashes in this tribal region is significantly higher and the percent of property damage only crashes is much lower than the data presented in the Highway Safety Manual for rural two-lane, two-way roadways. The contributing factors resulting in this significant difference is unknown at this time. Likewise, it is unknown if these proportions may be applicable to all two-lane, two-way roadways in Arizona. The above proportions should not be used for other regions of Arizona without querying crash data from the specific region under study.

These percentages were then multiplied by the total expected crash frequencies derived from the Predictive Method results summarized earlier in this report. Annual averages were calculated by evenly distributing the total crashes over the 20-year analysis period.

8-foot Shoulders versus 5-foot Shoulders

A benefit-cost ratio analysis was performed in order to select the alternative that is expected to provide the most safety benefit with respect to cost. The estimates for each alternative included pavement, pipe extensions, and earthwork as the three major items quantified for cost. These cost estimates resulted in a total project cost of approximately $26.3 million for 8-foot shoulders and $16.5 million for 5-foot shoulders. For the sole purpose of comparing alternatives, an annual maintenance cost of $0 was assumed for each alternative. Tables 10 and 11 display the calculations of the benefit-cost ratios for the 8-foot shoulder and 5-foot shoulder, respectively.

Table 10: Benefit-Cost Ratio Tabulation for 8-foot Shoulder

	Benefits				
Severity	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	21%	0.83	$5,800,000	$4,806,228
Incapacitating Injury	1.56	21%	0.33	$400,000	$130,956
Non Incapacitating Injury	4.14	21%	0.87	$80,000	$69,485
Possible Injury	7.38	21%	1.55	$42,000	$65,109
No Injury	14.80	21%	3.11	$4,000	$12,429
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$5,084,207

Costs	Annual Costs
Total Construction Costs	$26,300,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$2,678,713
Annual Maintenance Cost	0
Total Annual Costs	$2,678,713

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$5,084,207	$2,678,713	1.90

CRF = Crash Reduction Factor

Table 11: Benefit-Cost Ratio Tabulation for 5-foot Shoulder

Severity	Annual Benefit Tabulation				
	Annual Average	Estimated CRF Reduction	Total Reduction	Unit Cost	Annual Benefit
Fatal	3.95	16%	0.63	$5,800,000	$3,661,888
Incapacitating Injury	1.56	16%	0.25	$400,000	$99,776
Non Incapacitating Injury	4.14	16%	0.66	$80,000	$52,941
Possible Injury	7.38	16%	1.18	$42,000	$49,607
No Injury	14.80	16%	2.37	$4,000	$9,469
Unknown	0.00	0%	0.00	$4,000	$0
				Total Annual Benefits	$3,873,681

Costs	Annual Costs
Total Construction Costs	$16,500,000
Project Life (years)	20
Interest Rate (%)	8%
Capital Recovery Factor	0.1019
Annual Construction Cost	$1,680,561
Annual Maintenance Cost	0
Total Annual Costs	$1,680,561

Benefit / Cost		
Annual Benefit	Annual cost	Benefit-Cost Ratio
$3,873,681	$1,680,561	2.30

It is important to note that both alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would be to widen the shoulder to 8 feet since it would lead to the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. As an example, Table 12 includes the theoretical safety benefit of 5-foot shoulders versus 8-foot shoulders with a set annual budget of $10,000,000 to spend on shoulder widening on roadways with similar conditions. This summary is an oversimplification since the construction cost and benefit are unique to each roadway segment, however this example shows that applying the 5-foot shoulder systemically with an annual budget of $10 million would result in an increase in over 54 miles of shoulder widening and an over $4 million annual safety benefit.

Table 12: Theoretical Systemic Safety Benefit for $10 Million Annual Budget

	Annual Cost per Mile	Number of Miles	Annual Benefit per Mile	Total Benefit
Alternative A: 5-foot Shoulders	$68,455	146.1	$157,787	$23,049,928
Alternative B: 8-foot Shoulders	$109,113	91.7	$207,096	$18,980,036

Superelevation Improvements

A benefit-cost ratio analysis was performed to evaluate the benefit of bringing the existing superelevation into compliance with AASHTO criteria with respect to cost. A planning level cost estimate for bringing the superelevation into compliance was calculated on a per linear foot (LF) basis for two different improvement strategies including full curve reconstruction and differential overlay (See Appendix B). The unit costs for full reconstruction and differential overlay were calculated to be $143.61/LF and $67.08/LF, respectively. These unit costs were then multiplied by the total length of curvature for each curve to estimate the cost of superelevation improvements to each individual curve. For the purpose of this study, it was assumed that 1.9% was the maximum superelevation improvement that could be applied using differential overlay, which corresponds to a 6-inch overlay on the high side of the curve. Using this guideline, it was determined that each curve could be brought to within 1% of AASHTO compliance using only differential overlay. The benefit-cost ratio for each curve using differential overlay is summarized in Table 13.

Table 13: Benefit-Cost Ratio for Superelevation Improvements

	MP	% out of Compliance	CRF	Differential Overlay		
				Annual Benefit	Annual Cost	Benefit Cost Ratio
Curve 1	464.37	1.6%	1.7%	$ 1,119	$ 4,074	0.27
Curve 2	462.06	1.6%	1.4%	$ 373	$ 2,037	0.18
Curve 3	460.47	1.6%	1.6%	$ 773	$ 3,056	0.25
Curve 4	458.39	1.6%	1.2%	$ 1,570	$ 8,148	0.19
Curve 5	456.78	1.6%	1.1%	$ 5,189	$ 11,204	0.46
Curve 6*	454.55	-	0.0%	$ 0	$ 0	0.00
Curve 7	452.44	1.6%	1.2%	$ 5,491	$ 11,204	0.49
Curve 8	450.71	1.6%	1.3%	$ 7,448	$ 26,482	0.28
Curve 9	449.59	1.6%	1.3%	$ 3,407	$ 16,296	0.21
Curve 10	446.49	1.7%	1.1%	$ 1,937	$ 8,148	0.24
Curve 11	445.85	1.6%	0.9%	$ 740	$ 4,074	0.18
Curve 12	445.66	1.6%	0.5%	$ 356	$ 4,074	0.09
Curve 13	445.30	1.4%	0.9%	$ 394	$ 2,037	0.19
Curve 14	445.05	1.6%	0.7%	$ 375	$ 3,056	0.12
Curve 15	443.11	1.6%	1.2%	$ 2,730	$ 12,222	0.22
Curve 16	442.21	2.1%	1.8%	$ 5,690	$ 8,148	0.70
Curve 17	441.79	2.1%	2.0%	$ 4,215	$ 11,204	0.38
			Totals	**$ 41,807**	**$ 135,464**	**0.31**

*Curve 6 is a large radius flat curve

Prioritization of Segments

At the time of this report, the proposed widening improvements were split into two segments of approximately equal construction cost with the following limits:

- Segment I (MP 441.19 – MP 452.00)
- Segment II (MP 452.00 – MP 465.74)

To prioritize the segments, the Predictive Method was applied assuming improvements to each segment were implemented independent of the other. The segment that had the greatest reduction in the expected number of crashes over the entire project limits would be considered for prioritization of construction timing. The segments were evaluated assuming 5-foot shoulders. The results of this analysis are shown in Table 14.

Table 14: Segment Prioritization Expected Crashes

Crash Severity Level	2016 2036 Expected Total Number of Crashes For Entire Project Limits	
	Segment I 5 foot Shoulders, Segment II Existing Conditions	Segment II 5 foot Shoulders, Segment I Existing Conditions
Total	593.09	574.87
Fatal and Injury (FI)	260.70	253.16
Property Damage Only (PDO)	332.39	321.71
Reduction in Total Crashes over Existing Conditions	43.29	61.51
Percent Reduction in Total Crashes over Existing	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for receiving priority in construction timing over Segment I based on estimated safety impact. Additional factors were considered in the prioritization decision, such as environmental impacts, right-of-way needs, construction phasing and coordination with other projects. Please note that further modifications in the segmentation were made by ADOT's Statewide Project Management Group based on a number of factors.

Results

Using the aforementioned resources and the HSM Predictive Method, the safety improvements of each alternative were quantified and compared to maintaining the existing conditions of the highway. The expected crash totals over the 20-year analysis period is summarized in Table 15.

Table 15: 2016-2036 Expected Total Number of Crashes

	2016 2036 Expected Total Number of Crashes			
	Existing Conditions	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total	636.38	531.58	504.16	635.26
Reduction in Total Crashes over Existing Conditions	N/A	104.80	132.22	1.12
Percentage Reduction in Total Crashes over Existing Conditions	N/A	16.5%	20.8%	0.2%

Because of budgetary constraints, the proposed project was split into two separate segments to be constructed independently. As a result, each segment was evaluated for prioritization based on the potential reduction in the total number of crashes over the 20-year analysis period. Segment I included the west half of the project limits between MP 441.19 and MP 452.00. Segment II included the east half of the project limits between MP 452.00 and MP 465.74. Expected total crashes for the entire project limits were estimated for construction of Segment I first, with existing conditions remaining in Segment II. Similarly, expected total crashes for the entire project limits were estimated for construction of Segment II, with existing conditions remaining on Segment I. The results of this analysis are summarized in Table 16.

Table 16: 2016-2036 Expected Total Number of Crashes by Segment

	2016 2036 Expected Total Number of Crashes For Entire Project Limits		
	Existing Conditions	Segment I 5 foot Shoulders with Segment II Existing Conditions	Segment II 5 foot Shoulders with Segment I Existing Conditions
Total	636.38	593.09	574.87
Reduction in Total Crashes over Existing Conditions	N/A	43.29	61.51
Percentage Reduction in Total Crashes over Existing Conditions	N/A	6.8%	9.7%

Segment II was expected to have a greater reduction in the expected total number of crashes and was considered for construction prior to Segment I from a safety perspective.

However, additional factors were considered in the prioritization decision due to the small percentage difference (2.9%) in crash reduction between Segment I and Segment II.

The benefit-cost ratios in Table 17 were calculated using crash severity distributions for Navajo County two-lane two-way state highways in the ADOT Holbrook District and planning level cost estimates for each alternative.

Table 17: Safety Alternative Benefit-Cost Ratio

	Alternative A 5 foot Shoulders	Alternative B 8 foot Shoulders	Superelevation Improvements
Total Annual Benefit	$3,873,681	$5,084,207	$41,807
Total Annual Cost	$1,680,561	$2,678,713	$135,464
Benefit-Cost Ratio	2.30	1.90	0.31

The benefit-cost ratio for widening to 5-foot shoulders exceeded the benefit-cost ratio for widening to 8-foot shoulders. It is important to note that both shoulder widening alternatives have a benefit-cost ratio greater than 1.0. Without funding constraints, the preferred alternative would have been to widen the roadway to 8-foot shoulders since it would expect to result in the largest reduction in crashes. However, there is a limited amount of HSIP funding and the intent is to apply safety funds to more effective alternatives. Based on this, ADOT decided to move forward with 5-foot shoulders for this project.

Due to additional budget constraints and coordination with adjacent projects, the project was divided into three segments of between six and nine miles each. The projects will be constructed with segments starting from the east. This is consistent with the prioritization of segment crash analysis summarized previously that showed Segment II on the eastern end having a larger crash reduction than Segment I on the western end.

The proposed superelevation improvements for all curves had a reduction of 1.2 crashes over the 20-year project timeframe and an overall benefit-cost ratio of 0.31. In addition, each curve was evaluated individually to determine if there was a benefit for superelevation improvements on a single curve. Due to the minimal crash reduction associated with superelevation, the largest benefit-cost ratio was 0.7 for curve 16 and therefore superelevation improvements are not recommended on any curves.

Strategies Employed

- HSM Part C – Predictive Method
- IHSDM Software

Publications Used/Produced Through this Effort

- Traffic Safety Evaluation, Using the Highway Safety Manual and the Interactive Highway Safety Design Model, SR 264 Burnside Junction to Summit, Kimley-Horn, 2012
- Transportation Research Board Annual Meeting – Poster Session, Application of HSM Predictive Method and IHSDM to Design Decision Making, ADOT and Kimley-Horn 01/2013

Lessons Learned

- The Predictive Method within Part C of the Highway Safety Manual defines a useful procedure to quantify the estimated safety impacts of project alternatives so that more cost-effective decisions can be made on reducing fatal and serious injury crashes.
- The Interactive Highway Safety Design Model was a straight forward software tool that guided us through the quantitative safety analysis consistent with the HSM.

Point of Contact

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- Mike Colety, Kimley-Horn (702-862-3609, Mike.Colety@Kimley-Horn.com)

References and Resources

- Highway Safety Manual (HSM). American Association of State Highway and Transportation Officials. Washington, DC. 2010. http://www.highwaysafetymanual.org/Pages/default.aspx
- Interactive Highway Safety Design Model (IHSDM). Federal Highway Administration. Washington, DC. http://www.ihsdm.org