Publication No. FHWA-HIF-14-018

Case Study: K-177 Modernization Project

Agency: Kansas Department of Transportation

Location: Morris and Geary Counties, Kansas
Region: Central
Setting: Rural

Overview

The Kansas Department of Transportation (KDOT) selected K-177 from Council Grove to I-70 as a modernization project with a set construction budget of $25 million (FY 2017), but construction costs to completely reconstruct this 22.9-mile corridor were estimated to be $67 million. As a result, KDOT conducted extensive modeling of current and projected operations and safety, which allowed them to select a project scope that achieves the performance objectives of a modernization project within the given budget constraints. The selected scope is projected to operate at a Level of Service B for its design life, increase passing opportunities on the project corridor by 14 percent, and result in a projected 13 percent decrease in the expected number of crashes compared to no-build conditions. In addition to engineering analysis, KDOT assembled a representative group of stakeholders from local communities to provide feedback regarding the selection of proposed improvements. Project construction letting is scheduled for March 2017.

Background

The Transportation Works for Kansas (T-WORKS) program, funded by the Kansas Legislature in May of 2010, utilized local input to identify highway preservation projects, highway modernization and expansion projects, and other types of transportation improvements for the benefit of the entire state. The program has a budget of approximately $7.8 billion over a ten-year period. As a part of the T-WORKS program, KDOT identified Kansas Highway 177 (K-177) from the city of Council Grove to the interchange with I-70 as a modernization priority through the local consult process. After considering other regional priorities, a construction budget of $25 million (FY2017) was appropriated to the project with an anticipated construction letting in 2017. KDOT selected this highway project for the following reasons:

- Improvements will increase safety. Local officials cited little to no shoulders, steep drop-offs, and horizontal and vertical curves as reasons for investing in increasing the safety of the highway.
- The project has strong regional support. This segment of K-177 was identified as one of the higher priority projects in the region.
- Because of the size and scope of the work, KDOT considered the K-177 project to be an excellent candidate to apply a practical improvement approach and design to a budget.
- K-177 is important to the local economy. More than 15 regional employers rely on K-177 to transport materials and goods and to provide commuter connection for their employees. These employers include large and prominent entities like Kansas State University and Fort Riley.
- Improvements will support expanded tourism. The Flint Hills, the scenic region through which K-177 is built, is a popular destination for locals and visitors alike. In addition, promoting tourism in the Flint Hills is a high priority for the State.

The project is 22.9 miles long and follows the existing K-177 rural, two-lane alignment in Geary and Morris Counties. The northern limit of the project is the I-70 eastbound on-ramp on the south side of the I-70/K-177 interchange. The southern limit of the project is approximately five miles north of the City of Council Grove. The project study area also includes the north and south intersections of K-177 with K-4 in the vicinity of the community of Alta Vista. The Union Pacific Railroad crosses under K-177 near Alta Vista.

In January of 2012, KDOT initiated a conceptual study of the K-177 corridor to determine practical improvements that could be achieved within the $25 million construction budget. They estimated that complete reconstruction of the 22.9-mile corridor would cost an estimated $67 million. To stay within the project budget, KDOT determined early that a strategic, performance-based approach would be necessary. To meet that challenge, the project team developed a strategy utilizing data analysis, feedback from local stakeholders, and evaluation of alternatives.

Approach

Public Involvement Process

The project team assembled a 19-member Project Advisory Committee, comprised of local decision makers, stakeholders and citizen volunteers who provided input and feedback to the project team at milestones throughout the study process. Members of this committee were identified and selected based on their geographical location, interest in the project, and their ability to communicate to various constituent groups within their respective communities. In addition to the committee, KDOT obtained public input through two public meetings and through public officials briefings held prior to each public meeting.

Through these interactions with local stakeholders, KDOT obtained information on the public's concerns and priorities, identifying locations with perceived higher safety concerns, determining preferences on use of road closures and detours, and evaluating that information within the context of the project's construction budget.

Analysis of Existing Conditions

The existing highway was constructed between 1934 and 1960 and currently has a posted speed limit of 60 mph. There are 13 horizontal curves within the project corridor, five of which have spiral curve transitions. Nine of the horizontal curves do not meet current 60-mph design criteria. There are 124 vertical curves, and the maximum grade found on the corridor is 6 percent. Of the vertical curves, 10 crest and 19 sag curves currently do not meet current 60-mph criteria for stopping sight distance. In addition, approximately 50 percent of the corridor is marked for passing. There are no auxiliary passing or climbing lanes within the corridor. The corridor includes 21 rural unsignalized public-road intersections. All of the intersections are stop-controlled on the minor roads. These minor roads carry substantially lower volumes of traffic than K-177.

The roadside features along K-177 contribute to its overall safety performance. Clear zone issues include but are not limited to steep foreslopes, the presence of guardrail and rock outcroppings, and the proximity of drainage structures with respect to the edge of pavement. Desirable foreslopes for a KDOT highway range from 4H:1V to 6H:1V. The existing K-177 corridor has foreslopes in certain locations that have been estimated using LIDAR information as steep as 1.5H:1V.

Consultants for KDOT completed traffic operational and safety analyses for this project using the procedures outlined in the *Highway Capacity Manual* (HCM) and the *Highway Safety Manual* (HSM), respectively. Both resources provided 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 land use. The variations in cross sections along the corridor are relatively minor and traffic volumes change substantially at only a few locations.

Traffic Operational Analysis. For the traffic operational analysis, the project team members determined it most appropriate to divide the corridor into two sections at Humboldt Creek Road as one of the larger changes in traffic volume along the corridor occurs at this intersection. Table 1 describes the two traffic operational analysis sections and their boundaries. An advantage of this division point is that Section S (south of

Humboldt Creek Road) can logically be classified as level terrain and Section N (north of Humboldt Creek Road) can logically be classified as rolling terrain for the traffic operational analysis.

Table 1. K-177 Analysis Sections for Traffic Operational Analysis (Table 3.1 from KDOT Project Report)

Section	Beginning Location			Ending Location			Length (mi)	AADT (veh/day)	
	Intersection	Station	State MP	Intersection	Station	State MP		2017	2037
S	Wildlife Area Intersection [a]	1000+00	71.256	Humboldt Creek Rd	1546+34	82.611	11.355	2000	2550
N	Humboldt Creek Rd	1546+34	82.611	I-70 South Ramp Terminal	2208+47	94.144	12.540	1750	2250

[a] This is an unnamed intersection approximately 0.6 miles north of the bridge over Munkers Creek.
MP = mile post
AADT = annual average daily traffic

Traffic operational analyses incorporated the traditional traffic operational analysis methods for two-lane highways presented in Chapter 15 of the *Highway Capacity Manual* (HCM). Comparable analyses involved the use of the TWOPAS computer simulation model for two-lane highways. It is important to note that the HCM traffic operational analysis procedures for two-lane highways were developed with the TWOPAS model, so TWOPAS results are fully consistent with HCM concepts, but are potentially more accurate. TWOPAS had several key advantages over the HCM for this type of operational analyses. In particular, TWOPAS considers the actual horizontal and vertical alignment of the roadway, while the HCM procedure for general segments only classifies terrain as level, rolling, or mountainous. TWOPAS also allows analysts to specify input values for mean speed and standard deviation of speed separately for passenger cars and trucks. The HCM uses as input a single value for free-flow speed that does not distinguish between vehicle types and does not permit the variation in speed, represented here by its standard deviation, to be adjusted for individual roadway segments. TWOPAS is stochastic, accounting for randomness in a system, while the HCM is deterministic. Finally, TWOPAS allows analysts to specify input data for the percent of traffic traveling in platoons at the beginning of the roadway section being analyzed, while the HCM does not.

The consultants performing the operational analysis had the objective of determining the level of service for existing and future conditions. The HCM defines levels of service for two-lane highways in terms of two service measures, average travel speed and percent time spent following. On rural highways like K-177, average travel speeds are usually sufficiently high (above 55 mph for virtually every conceivable traffic flow level) that speed has minimal influence on level of service. Based on speed considerations alone, K-177 would always operate at LOS A. Time spent following represents the percentage of a motorist's total travel time that is spent following in platoons behind slower vehicles before finding an opportunity to pass. The criteria for percent time spent following considers the level of platooning on a two-lane highway. Platoons build up as drivers with higher desired speeds come up behind slower vehicles and find they are unable to pass. Platoons form on two-lane highways because passing maneuvers using the opposing travel lane, where permitted, generally serve only a portion of the total passing demand. KDOT gives consideration to installing passing lanes when the traffic operational level of service in the design year falls below LOS B.

The project team conducted HCM analyses for both 2017 and 2037 conditions using site characteristic data, the mean speeds as free-flow speeds, and a peak hour factor of 0.95. They conducted separate analyses (using both TWOPAS and HCM, to account for differences in the programs) for each of the two analysis sections and for each direction of travel. Each run simulated one entire hour of traffic flow and five replicate results were made for each of the two analysis sections and for each direction of travel, using both 65/35 and 35/65 directional splits. The reported results are based on averages of the five replicated runs. The reported results represent the direction of travel with the highest traffic flow (i.e., the direction of travel with 65% of the total flow).

Table 2 presents the traffic operational analysis results for both the HCM analysis (modeled using the Highway Capacity Software) and the TWOPAS analysis for the two analysis years, the two analysis sections (Section S – south of Humboldt Creek Road and Section N – north of Humboldt Creek Road), and the two directions of travel. The table shows the design hour volumes modeled, the values of average travel speed and percent time spent following estimated by the HCM and TWOPAS methodologies, and the resulting LOS.

The project team generally considered the TWOPAS results to be more realistic than the HCM results because, as explained above, TWOPAS considers the actual horizontal and vertical alignment of the roadway, considers separate speed distribution data for passenger cars and trucks, and considers site-specific data for the percent of traffic entering a section traveling in platoons. Results indicated that the level of service in the design year (2037) will be at LOS B or better throughout the corridor, so there was no apparent short- or medium-term need to provide passing lanes in the K-177 corridor. Any potential need for passing lanes in the project corridor appeared to be well into the future beyond the year 2037. Indeed, these results indicated that traffic operations did not need to be a major concern and that the development of design concepts should focus on safety improvement needs.

Table 2. K-177 Operational Analysis Results (Table 3.2 from KDOT Project Report)

Section (Design Year)	Peak Direction	DHV (veh/hr)		HCM LOS			TWOPAS LOS		
		Vd	Vo	ATSd	PTSFd	LOS	ATSd	PTSFd	LOS
S (2017)	NB	140	80	58.7	44.9	B	58.9	36.9	B+
	SB	140	80	58.9	43.3	B	58.7	37.7	B+
S (2037)	NB	180	100	58.0	49.4	B-	58.3	41.0	B
	SB	180	100	56.8	51.5	C+	57.8	44.2	B
N (2017)	NB	120	70	59.7	47.4	B-	60.7	33.7	A-
	SB	120	70	57.9	46.5	B-	58.8	36.1	B+
N (2037)	NB	160	90	58.6	52.3	C+	60.1	40.3	B
	SB	160	90	58.2	48.0	B-	57.5	43.8	B

Vd = Analysis Direction Volume Vo = Opposing Direction Volume
ATSd = Average Travel Speed PTSFd = Percent Time Spent Following

Safety Analysis. The project team conducted a traffic safety analysis including a review of crash history data and an analysis of current expected crash frequencies and future no-build expected crash frequencies. The latter analysis used the crash prediction methodology for two-lane highways in Chapter 10 of the AASHTO *Highway Safety Manual* (HSM) and the FHWA Interactive Highway Safety Design Model (IHSDM) software.

KDOT supplied crash data for all reported crashes occurring within or near the project limits during the five-year period from 2005 to 2009, inclusive. The project team reviewed crash data both in computerized data files and as copies of police crash reports, and they assigned each crash to an intersection or roadway segment. Intersection crashes included each crash that was reported to have occurred at an intersection or that was related to the operation of an intersection. The remaining crashes were considered roadway segment crashes and were assigned to a particular roadway segment defined by two successive public road intersections.

The project team identified 111 recorded crashes in the five-year period, 100 occurred within roadway segments, compared to 11 crashes at intersections. The crashes included

31 fatal-and-injury crashes (28%), and 80 property-damage-only (PDO) crashes (72%). The team calculated an overall crash rate for the five-year study period of 1.502 crashes per million vehicle-miles of travel, roughly equal to the statewide average for rural two-lane highways with no access control.

The team also performed an HSM analysis using IHSDM on the expected performance of the corridor. The HSM models were calibrated for this project using calibration factors for rural two-lane highways provided by KDOT. These calibration factors adjust the predicted crash frequencies so that they are representative of the conditions found in Kansas rather than the average conditions in other states used to develop the HSM models. The Empirical Bayes (EB) procedure was employed to combine the predicted and observed crash frequencies.

The HSM analysis indicated that the long-term expected average crash frequency for an equivalent five-year period would be 26 fatal-and-injury crashes (29%) and 64 PDO crashes (71%). This corresponds to a total expected crash rate for the K-177 corridor during the study period of 1.35 crashes per million veh-mi of travel, which is approximately 10 percent lower than the recent statewide average of 1.50 crashes per million veh-mi for rural two-lane highways with no access control, and the specific rate calculated for the study period on this corridor.

A review of roadway segment crashes indicated that there were a total of zero fatal crashes (0%), 27 injury crashes (27%), and 73 property-damage-only (PDO) crashes (73%). The number of crashes occurring on individual road sections during the five-year review ranged from zero to 20, but of the 20 road sections studied, 18 of them had crash totals of 8 or fewer. The other two sections were the longest sections, each over 3 miles in length. The section with the highest number of crashes was the northernmost section, bordered by the intersection with the I-70 south ramp terminal.

The overall observed crash rate per mile per year during the five-year review period was 0.87 crash per mile per year. The crash rates for individual road sections ranged from zero to 1.46 crashes per mile per year for road sections at least 0.50 mile in length. Approximately 88% of roadway segment crashes were either animal collisions (38%), fixed-object crashes (28%), or overturning crashes (22%). Single-vehicle crashes represented 93% of total crashes. The data indicated that 43% of crashes occurred on the roadway, while 57% involved leaving the roadway.

During the five-year review period, there were a total of only 11 intersection crashes within the K-177 corridor. Eight intersections experienced one crash each during the five-year review period, while twelve intersections experienced no crashes at all during the five-year review period. The only intersection that experienced more than one crash was the I-70 south ramp terminal, which had three crashes during the five-year review period.

The only fatal crash within the five-year review period occurred at the south junction of K-4 with K-177. This crash, which was the only crash that occurred at this intersection during the five-year review period, involved a multiple-vehicle collision during nighttime conditions. The driver approaching K-177 eastbound on K-4 failed to stop at the stop sign and entered K-177 in front of an oncoming vehicle. It was reported that there was a light snow cover on the roadway surface at the time of the crash. The vehicle traveling on K-4 sustained the fatality. The team also conducted a broader review of fatal crashes along the K-177 corridor for a period of 15 years (1995 through 2010, inclusive). This review found a total of 11 fatal crashes in the corridor over 15 years, or 5.4 crashes per hundred million veh-mi, compared to the statewide average of 1.935 crashes per hundred million veh-mi for the period 2007 through 2011. Analysis of the locations of these crashes in the safety review suggested that specific roadway segments could have above-average fatal crash experience and would be worth considering in that context when evaluating specific alternatives in each segment.

Upon completing the operational and safety analyses, the project team then devised a method to address targeted sections and the corridor as a whole. Ultimately they divided the corridor into nine segments so that alternatives could be developed in smaller increments. This allowed the team to address areas of concern and maintain the $25 million project budget, considering a range of design alternatives within each segment.

Analysis of Roadside Design Alternatives

The project team first identified what types of improvements could realistically be undertaken, while also being sensitive to the opportunities for more extensive improvements to the corridor in future programs. The project team used the Roadside Safety Analysis Program (RSAP) to determine the benefit that different shoulder and clear zone widths would provide in a variety of scenarios. RSAP, available from the Transportation Research Board, analyzes the benefit/cost of different roadside treatments. The potential reduction of occurrences and severity of crashes creates the benefit, and the cost is calculated from initial improvement and maintenance costs.

The scenarios included different heights of embankment at: 7 feet, 13 feet, 20 feet and 26 feet; a rock embankment; and a ditch section. After analysis, the general trend of the results showed that a 30-foot clear zone provided a higher benefit/cost ratio than a 26-foot clear zone. Further, an 8-foot shoulder, as recommended by the AASHTO *Green Book*, provides significant benefits. The project team computed incremental benefit-cost ratios versus the do-nothing alternative of 9.97 to 2.65 for embankment heights ranging from 7 feet to 26 feet, respectively.

Results

The KDOT Program Review Committee approved the project scope on August 22, 2012 and design criteria were approved by the Deputy Secretary and State Transportation Engineer on January 28, 2013. Figure 1 shows a summary of the project; elements of this project will include:

1. Widening the typical section throughout the entire corridor from its existing 26-ft cross-section (13-ft lanes, no shoulders) to a 40-foot roadway, including 12-ft lanes and 8-foot composite shoulders. Typical sideslopes will be 6:1 within the clear zone.
2. Reconstructing approximately 4.6 miles of the existing alignment.
3. Retaining existing pavement located beyond the limits of reconstruction portions of the project. KDOT will complete any surface treatment to the retained pavement at a later date.
4. Replacing a bridge over the Union Pacific Railroad, and extending a separate bridge in the corridor. These bridge and associated approach roadway improvements are not included in the $25 million corridor construction budget, but KDOT added them to the scope using other funds to take advantage of efficiencies (e.g., planning, design, traffic control, etc.) through this project.

Table 6.0 - Recommended Alternative

Alternative	Description	Length (mi)	Const. Cost (2017 Dollars)	Crash Analysis		Benefits							Carry Traffic Through
				Calculated Crash Rate	% Improvement	Shoulders	Roadside	Curves	Hills	Sight Distance	% Passing	% Improvement[a]	
Segment 1	ALT 1 [S, R]	2.61	$1,153,000	40.3	12.4%	X	X	-	-	-	52%	0%	X
Segment 2	ALT 6 [S, R, P]	0.49	$2,212,000	38.2	12.4%	X	0	0	0	0	0%	0%	X
Segment 3	ALT 2 [RC(E)]	2.50	$5,979,000	29.2	13.6%	X	X	-	X	X	99%	80%	X
Segment 4	ALT 1 [S, R]	1.62	$1,622,000	23.7	12.9%	X	X	-	-	-	60%	0%	X
Segment 5	ALT 1 [S, R]	3.08	$1,337,000	44.3	12.1%	X	X	-	-	-	48%	0%	X
Segment 6	ALT 4 [RC(O)]	1.58	$6,341,000	17.6	26.4%	X	X	X	X	X	100%	163%	-
Segment 7	ALT 1 [S, R]	2.74	1,027,000	28.1	11.4%	X	X	-	-	-	70%	0%	X
Segment 8	ALT 1A [S, R, C]	3.69	$2,803,000	58.8	11.6%	X	X	X	-	-	54%	0%	-
Segment 9	ALT 1 [S, R]	2.62	$2,300,000	27.1	11.3%	-	-	-	-	-	50%	0%	X
TOTALS			$24,774,000		13.1%						62%	14%	

Segment descriptions can be found in Table 4.3.

a $\%passing_{after} - \%passing_{before} = \%increase$

Key

S	Add Shoulders
R	Improve Roadside Conditions
RC(E)	Reconstruction - Existing Alignment
RC(O)	Reconstruction - Offset Alignment
SD	Improve Sight Distances
C	Improve Horizontal Curves
G	Guardrail Improvements
P	Partial Re-profile
B(E)	Bridge Improvements - Existing Alignment
B(O)	Bridge Improvements - Offset Alignment
SP	Special Improvements

Note: Refer to Table 4.3 for more information

Figure 1. Recommended Improvements to K-177 Corridor (Table 6.0 from KDOT Project Report)

Strategies Employed

Strategies used throughout the project included the two-pronged public involvement process and the analysis and methodology tools mentioned previously (i.e., HSM, HCM, TWOPAS, IHSDM, RSAP). The overarching strategy used in this project was "design to budget". KDOT had a specific budget available to complete this project, and no additional expenses could be approved. As a result, KDOT had to determine which improvements were most important and how many high-priority improvements could be made within the budget. To that end, KDOT assembled and evaluated a set of alternatives for each of the nine segments on the corridor. Alternatives included improvements to shoulders, roadside conditions, sight distances, horizontal curves, guardrails, and bridges; alternatives also included partial and full reconstruction. KDOT weighed their options under the following four scenarios:

- Improve each segment.
- Highest benefit-cost rating.
- Most full reconstruction.
- Advisory committee input.

Considering all of the data and input and weighing their relative benefits, KDOT decided on the set of improvements shown in Figure 1.

Publications Used/Produced Through this Effort

KDOT and their consultants produced a detailed project report describing the process they used to develop the concept into an approved project scope. The report, which was the primary source of information for this case study, discusses the public involvement process, existing conditions, evaluation and assembly of alternatives, and the description of the recommended project. Appendices in the report contain a technical memorandum and maps on existing conditions, a summary of public input received, discussion of the operations and safety analyses, and maps and plan profiles of the proposed improvements. The report may be obtained from KDOT by request. Report information is as follows:

K-177 Modernization Project Design Concept Study – From North of Council

Grove to I-70. Project Numbers 177-64 KA-2368-01 & 177-31 KA-2869-01. Alfred Benesch & Company in association with Midwest Research Institute. March 2013.

Lessons Learned

For KDOT this was a refinement in how they developed a project's scope. First, the public was engaged earlier in the scope development process. Second, the agency used a much more robust analysis to prioritize and determine the project scope. Lastly, they developed the scope under a constrained budget.

Although the scoping process used traditional design principles, it resulted in an atypical scope in that it utilized a different improvement for each segment. While this is unique, a consistent cross section was maintained throughout for driver expectancy. The result was a scope that was consistent for the driver but also allowed KDOT to optimize the benefits to the corridor as a whole by mixing the improvement types.

PBPD Website

http://kdotapp.ksdot.org/perfmeasures/

Point of Contact

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Visuals

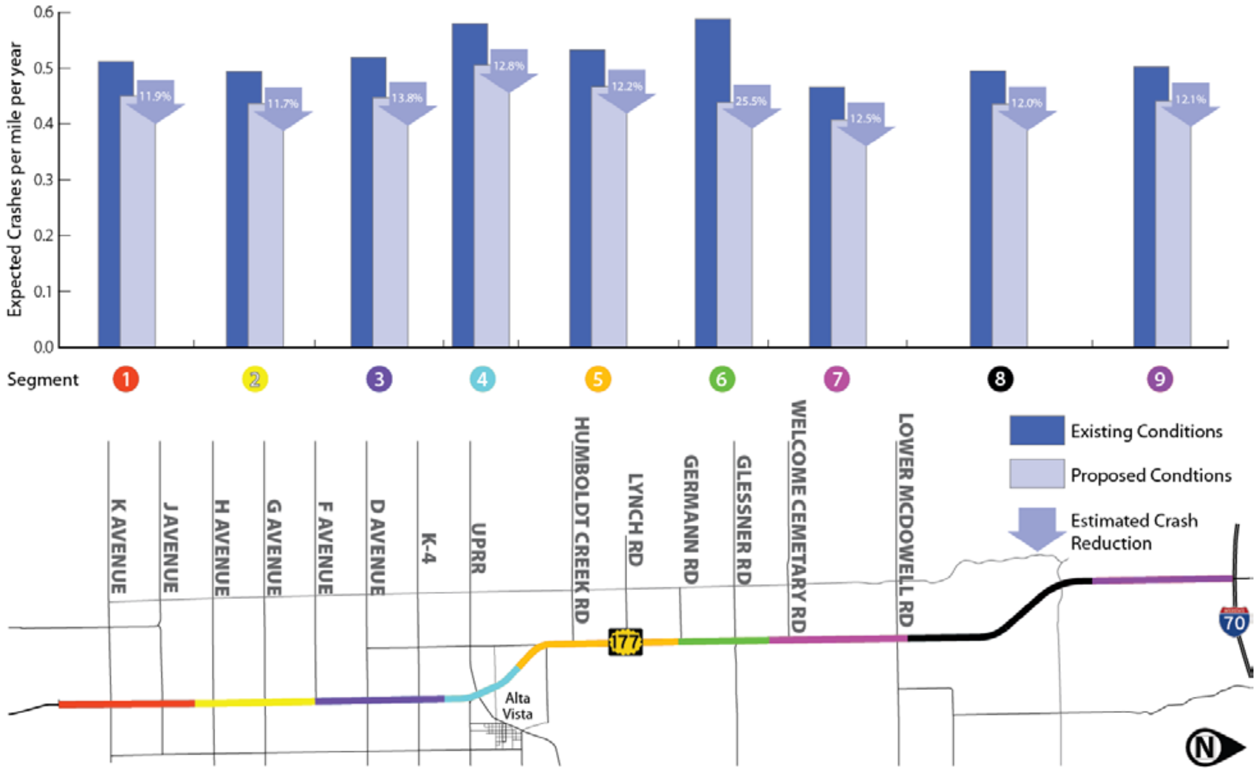

Figure 2. Projected Change in Crash Frequency on K-177 as a Result of the Modernization Project (Figure 5.5 from KDOT Project Report)

Quotes

"This is a perfect example of performance-based practical design, because 'design to budget' requires us to define our performance measures and prioritize them. The end result is an optimized design that meets traditional design principles and addresses the project and public's needs."

-- Amy Rockers, KDOT

References and Resources

- Alfred Benesch & Company in association with Midwest Research Institute. *K-177 Modernization Project Design Concept Study – From North of Council Grove to I-70*. Project Numbers 177-64 KA-2368-01 & 177-31 KA-2869-01. Kansas Department of Transportation. Topeka, KS. March 2013.
- *Highway Capacity Manual* (HCM). Volume 1. Transportation Research Board (TRB). Washington, DC. 2010. http://www.hcm2010.org/
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- Interactive Highway Safety Design Model (IHSDM). Federal Highway Administration. Washington, DC. http://www.ihsdm.org/