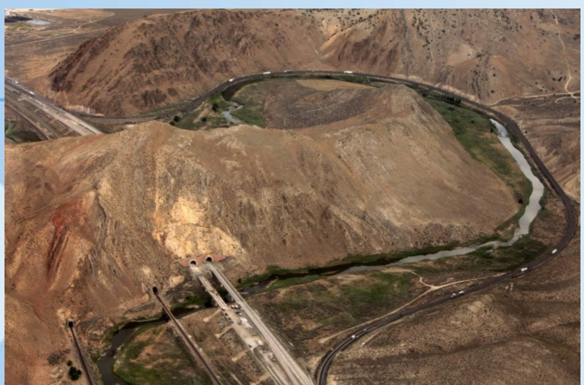
Nevada Demonstration Project:

Construction Manager at Risk Contracting for Rehabilitation of I-80 Carlin Tunnels in Elko County, NV

Final Technical Brief
July 2015

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.



U.S. Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of the Highways for LIFE (HfL) pilot program is to accelerate the use of innovations that improve highway safety and quality while reducing congestion caused by construction. **LIFE** is an acronym for **L**onger-lasting highway infrastructure using **I**nnovations to accomplish the **F**ast construction of **E**fficient and safe highways and bridges.

Specifically, HfL focuses on speeding up the widespread adoption of proven innovations in the highway community. Such “innovations” encompass technologies, materials, tools, equipment, procedures, specifications, methodologies, processes, and practices used to finance, design, or construct highways. HfL is based on the recognition that innovations are available that, if widely and rapidly implemented, would result in significant benefits to road users and highway agencies.

Although innovations themselves are important, HfL is as much about changing the highway community’s culture from one that considers innovation something that only adds to the workload, delays projects, raises costs, or increases risk to one that sees it as an opportunity to provide better highway transportation service. HfL is also an effort to change the way highway community decision makers and participants perceive their jobs and the service they provide.

The HfL pilot program, described in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1502, includes funding for demonstration construction projects. By providing incentives for projects, HfL promotes improvements in safety, construction-related congestion, and quality that can be achieved through the use of performance goals and innovations. This report documents one such HfL demonstration project.

Additional information on the HfL program is at www.fhwa.dot.gov/hfl.

NOTICE

1. Report No.	2. Government Accession No	3. Recipient's Catalog No
3. Title and Subtitle Nevada Demonstration Project: Construction Manager at Risk Contracting for Rehabilitation of I-80 Carlin Tunnels in Elko County, NV		5. Report Date July 2015 6. Performing Organization Code
7. Authors Hyung Lee, Ph.D., P.E., Shreenath Rao, Ph.D., P.E.		8. Performing Organization Report No.
9. Performing Organization Name and Address Applied Research Associates, Inc. 100 Trade Centre Drive, Suite 200 Champaign, IL 61820		10. Work Unit No. (TRAIS) C6B 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Office of Infrastructure Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final Technical Brief 14. Sponsoring Agency Code

15. Supplementary Notes
Contracting Officer's Representative: Julie Zirlin
Contracting Officer's Task Manager: Ewa Flom

16. Abstract
As a part of the HfL initiative, the FHWA provided a $1.2 million grant to the Nevada Department of Transportation (NDOT) to rehabilitate the highway structures on I-80 Elko County. This project involved (1) Rehabilitation of Carlin Tunnels, (2) Reconstruction of pavement structures, (3) Rehabilitation of eight bridge structures, and (4) Operational improvements to highway and tunnels.

The key innovation employed on this project was the construction manager at risk (CMAR) method of construction delivery, which was expected to extend the service life of the highway structures while significantly reducing the duration of construction. Another important element of this project was to completely renovate the lighting system within the Carlin Tunnels using new light-emitting diode (LED) luminaires. In fact, this is the first project in North America that used an LED lighting system for highway tunnels.

The overall objective of this project was to improve the structural condition of I-80 through Carlin Canyon and provide operational and safety improvements, which was accomplished innovatively through this project.

17. Key Words	18. Distribution Statement
Highways for LIFE, construction manager at risk, CMAR, Safety, light-emitting diode, LED, tunnel	No restriction. This document is available to the public through the Highways for LIFE website: http://www.fhwa.dot.gov/hfl/

Security Classif.(of this report)	19. Security Classif. (of this page)	20. No. of Pages	21. Price
Unclassified	Unclassified	23	

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SI* (MODERN METRIC) CONVERSION FACTORS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
(none)	mil	25.4	micrometers	μm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2 (psi)	poundforce per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
		DENSITY		
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
μm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	poundforce	lbf
kPA	kiloPascals	0.145	poundforce per square inch	lbf/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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ABBREVIATIONS AND SYMBOLS

AADT	annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ASR	alkali-silica reactivity
CM	construction manager
CMAR	construction manager at risk
DBB	design-bid-build
FHWA	Federal Highway Administration
GMP	guaranteed maximum price
HfL	Highways for LIFE
HPS	high-pressure sodium
IES	Illuminating Engineering Society of North America
IRI	International Roughness Index
ITS	Intelligent Transportation System
LED	light-emitting diode
NDOT	Nevada Department of Transportation
OBSI	onboard sound intensity
OSHA	Occupational Safety & Health Administration
PBS	Plantmix Bituminous Surface
RFP	Request for proposals
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SEP-14	Special Experimental Project Number 14

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

Highways for LIFE (HfL) is the Federal Highway Administration's (FHWA) initiative to advance longer-lasting and promote efficient and safe construction of highways and bridges using innovative technologies and practices. The HfL program provides incentive funding to highway agencies to try proven but little-used innovations on eligible Federal-aid construction projects. The HfL team prioritizes projects that use innovative technologies, manufacturing processes, financing, contracting practices, and performance measures that demonstrate substantial improvements in safety, congestion, quality, and cost-effectiveness. An innovation must be one the applicant State has never or rarely used, even if it is standard practice in other States. Recognizing the challenges associated with deployment of innovations, the HfL program provides incentive funding for up to 15 demonstration construction projects a year. The funding amount typically totals up to 20 percent of the project cost, but not more than $5 million.

The HfL program promotes project performance goals that focus on the expressed needs and wants of highway users. They are set at a level that represents the best of what the highway community can do, not just the average of what has been done. The goals are categorized into the following categories:

1. **Safety**
    a. Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
    b. Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported on Occupational Safety and Health Administration (OSHA) Form 300.
    c. Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.
2. **Construction Congestion**
    a. Faster construction —Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
    b. Trip time during construction — Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
    c. Queue length during construction—A moving queue length of less than 0.5 miles in a rural area or less than 1.5 miles in an urban area (in both cases at a travel speed 20 percent less than the posted speed).
3. **Quality**
    a. Smoothness—International Roughness Index (IRI) measurement of less than 48 inches/mile.
    b. Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test method.

1. **User Satisfaction**
    a. An assessment of how satisfied users are with the new facility compared to its previous condition and with the approach used to minimize disruption during construction. The goal is a measurement of 4 or more on a 7-point Likert scale.

PROJECT OVERVIEW

As a part of the HfL initiative, the FHWA provided a $1.2 million grant to the Nevada Department of Transportation (NDOT) to rehabilitate the highway structures on I-80 Elko County. This project involved:

1. Rehabilitation of Carlin Tunnels.
2. Reconstruction of pavement structures.
3. Rehabilitation of eight bridge structures.
4. Operational improvements to highway and tunnels.

The key innovation employed on this project was the construction manager at risk (CMAR) method of construction delivery, which was expected to extend the service life of the highway structures while significantly reducing the duration of construction. Another important element of this project was to completely renovate the lighting system within the Carlin Tunnels using new light-emitting diode (LED) luminaires. In fact, this is the first project in North America that used an LED lighting system for highway tunnels.

PROJECT DETAILS

PROJECT LOCATION AND BACKGROUND

This project is located on Interstate Route 80 from milepost 7.43 to 10.11, approximately 7 miles east of Carlin, Nevada. Figure 1 shows an aerial view of the project location. This section of I-80 in Elko County carries an approximated annual average daily traffic (AADT) of 11,000 vehicles through a local canyon over the Humboldt River. Figure 2 shows the limits of the project along with the locations of the existing superstructures, including the Carlin Tunnels and the bridge structures over the Humboldt River.

Figure 1. Map. Aerial view of the project location in Elko County, NV.

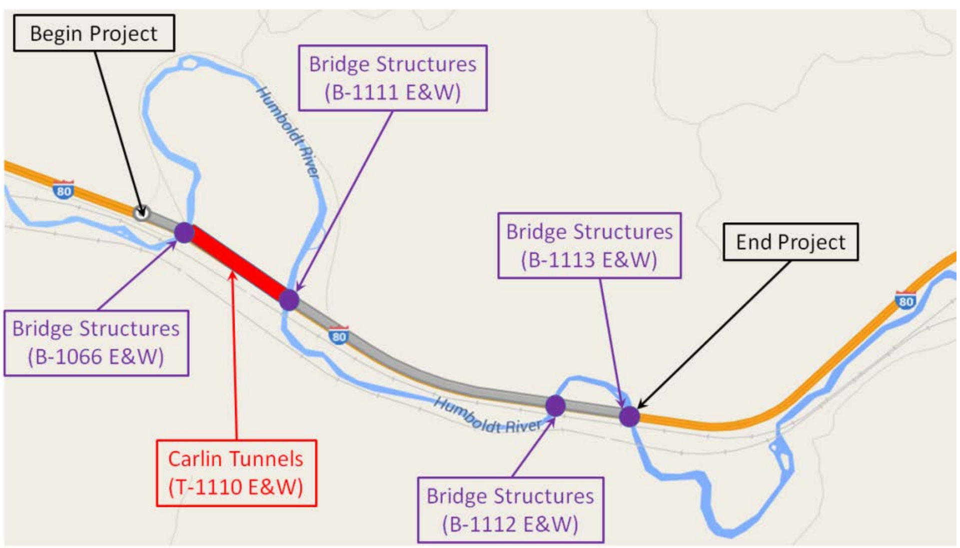


Figure 2. Map. Project limits along I-80.

First opened to traffic in 1975, the Carlin Tunnels (T-1110 E&W) consist of twin-bore tunnels that are lined with reinforced concrete. Figure 3 shows a picture looking into the existing tunnel. Each tunnel is approximately 1,400 feet in length and has cut-and-cover portal sections at each end. Based on NDOT's assessment of the structures, it was determined that the Carlin Tunnels were generally in good condition. However, large cracks and significant deterioration were observed in areas near the portal headwalls, and visible signs of alkali-silica reactivity (ASR) were detected on the walls and slabs.

The existing pavement structure within the Carlin Tunnels was constructed in 1972 as part of the original tunnel construction. No major rehabilitation work has been performed, and the pavement section was in poor condition. The rigid pavement on the east and west side of the Tunnels was last constructed in 1995 with 11 inches of concrete on 3 inches of cement-treated base. Slabs near the Tunnels have developed continuous cracks of approximately 500 feet in length. Previous attempts to repair these sections with crack stitching techniques have been unsuccessful. Figures 3 and 4 show the cracks that are visible from the surface of the existing pavement.

Figure 3. Photo. Existing Carlin Tunnel and the approach slabs with surface distress.

Figure 4. Photo. Rigid pavement in the vicinity of the Carlin Tunnels showing visible cracks on the surface.

A total of eight bridges near the Carlin Tunnels (B-1066 E&W, B-1111 E&W, B-1112 E&W, and B-1113 E&W) also showed a need for rehabilitation. Each is a three-span bridge with composite steel I-girders. The steel girders and diaphragms showed localized paint failures with associated surface corrosion of the exposed steel (Figure 5). In addition, as shown in Figure 6, the concrete wearing surface of the approach slabs showed longitudinal and map cracks up to 1/16 inches wide and isolated cracks up to 1/8 inches wide. Recommended repairs included replacing the bridge deck wearing surface, bridge rails, approach slabs, expansion joints, and relief joints, in addition to removing the existing lead-based paint and repainting the superstructure.

Figure 5. Photo. Corrosion of the existing bridge steel girders.

Figure 6. Photo. Existing bridge approach slab showing longitudinal and map cracking.

PROJECT DESCRIPTION

To address the deficiencies and improve the structural condition of the I-80 structures, NDOT scoped the project activities to rehabilitate the existing tunnels, pavements, and bridges. Some of the major work elements included in NDOT's I-80 project are as follows:

1. Rehabilitation of Carlin Tunnels: Replacing roadway slabs and damaged wall tiles, repairing safety walks, and other structural rehabilitation. Figure 7 shows a typical cross-section of the proposed tunnel structure and the pavement within the tunnel.
2. Reconstruction of pavement structures: Full-depth reconstruction of concrete pavement within and adjacent to the Carlin Tunnels, and transition to rubblization with Plantmix Bituminous Surface (PBS). Figure 8 shows a typical cross-section of the proposed pavement structure with PBS.
3. Rehabilitation of bridge structures: Seismic retrofitting, repainting, and other structural rehabilitation. As an example, Figure 9 shows a typical cross-section of the B-1112 E&W bridge structure.
4. Operational improvements to highway and tunnels: Removing the existing tunnel lighting and upgrading with a new LED system, as well as installing Intelligent Transportation Systems (ITS) which include photometric controls, central system integration, and incident detection and communications.

Figures 10 through 14 show some pictures taken during construction.

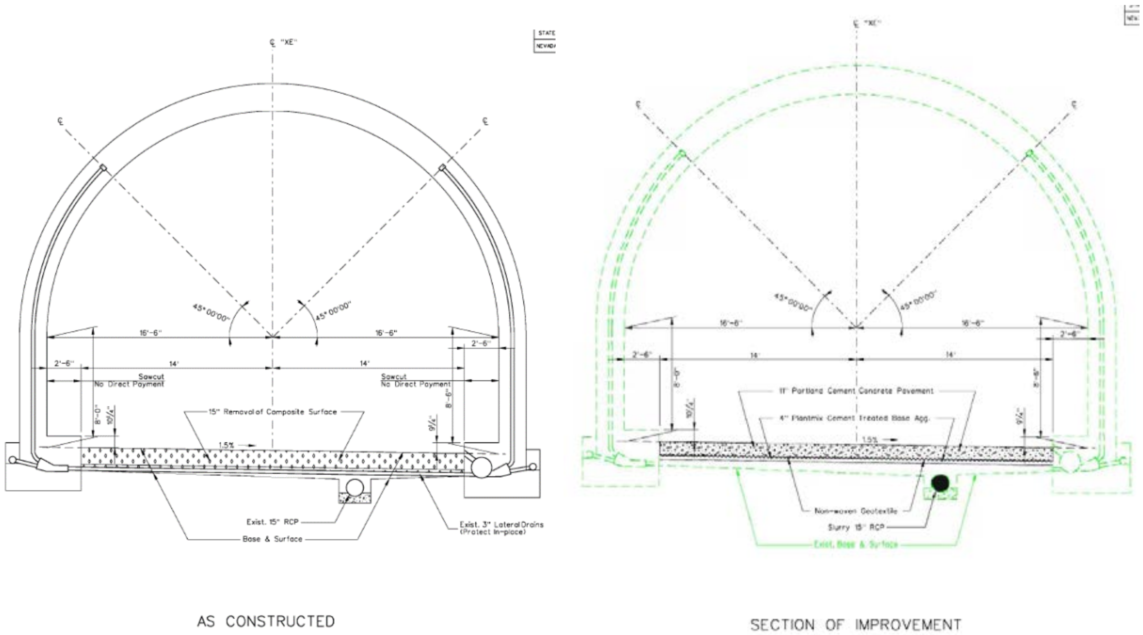
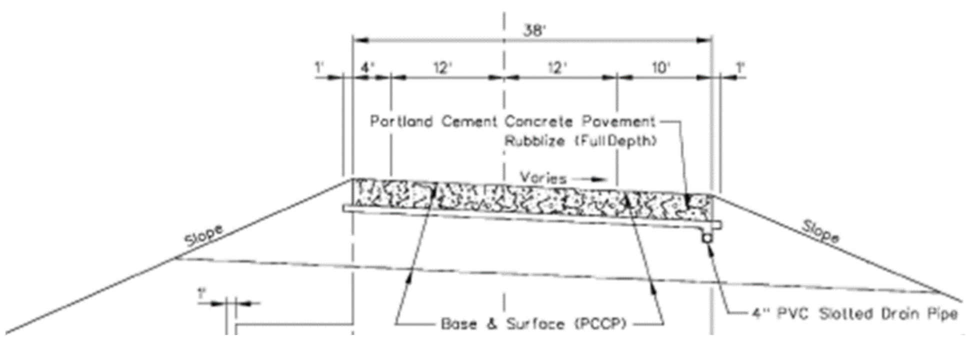
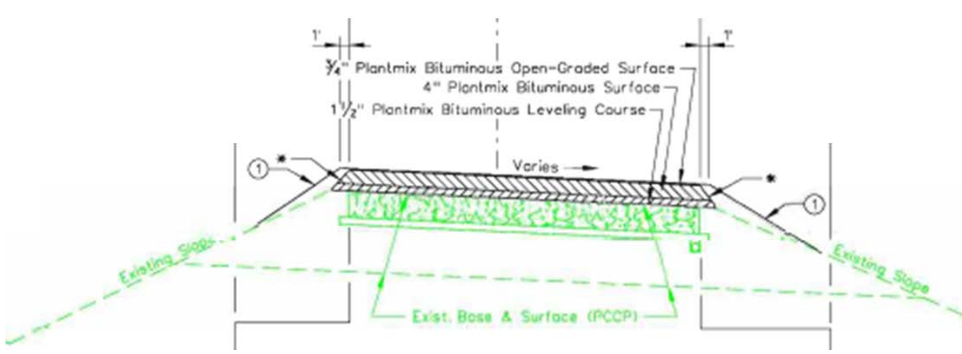


Figure 7. Diagram. Typical section of (a) existing and (b) proposed tunnel and pavement structures.



(a)



(b)

Figure 8. Diagram. Typical section of (a) existing and (b) proposed pavement structure with PBS.

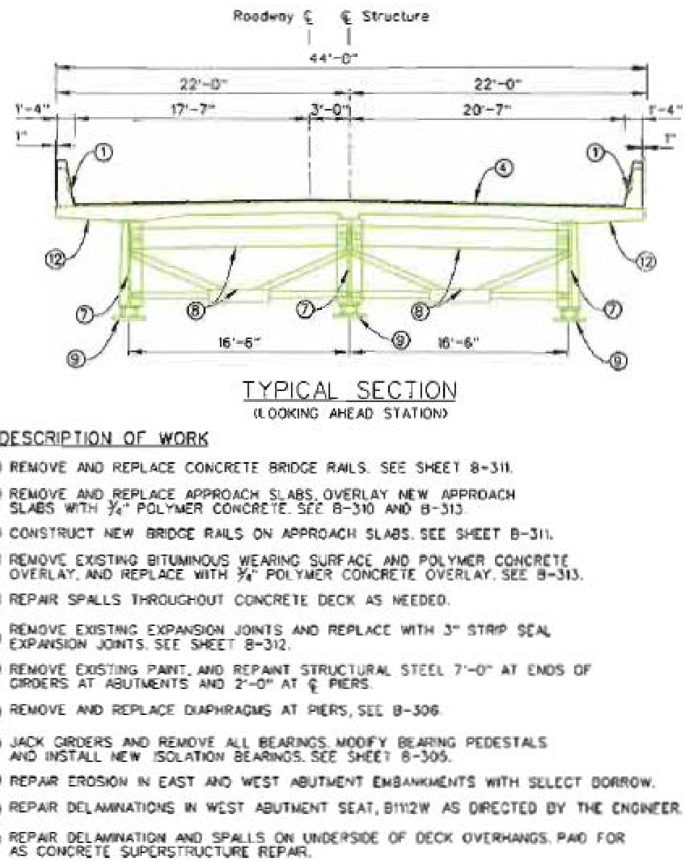


Figure 9. Diagram. Typical section of B-1112 E&W bridge structures.

Figure 10. Photo. Bird’s eye view of Carlin Tunnels project and detoured traffic.

Figure 11. Photo. Reconstruction of rigid pavement structure within Carlin Tunnels.

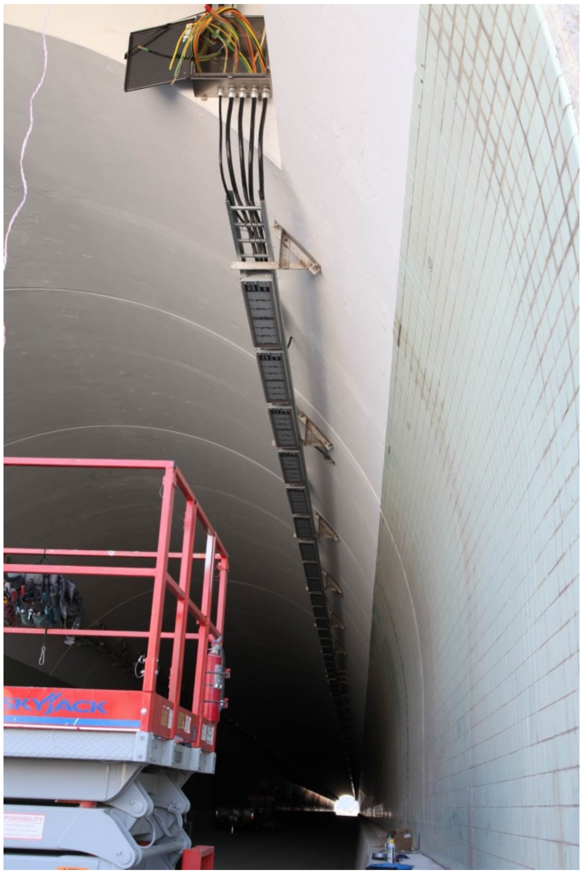


Figure 12. Photo. Installation of LED lighting system.

Figure 13. Photo. Bridge rehabilitation.

Figure 14. Photo. New LED lighting system.

PROJECT INNOVATIONS

A key innovation of this project was the qualifications-based CMAR method of delivery for construction (also frequently referred to as CM-at-risk). In the traditional design-bid-build (DBB) method of contracting, the selection of the construction contractor takes place after completion of the design process. In contrast, in the CMAR delivery method, a construction manager (CM) is selected before or during the preconstruction design phase. During the design phase, the CM provides input and feedback regarding scheduling, pricing, phasing, and constructability of the design. After substantial completion of the design phase (typically 60 to 90 percent), the cost of construction in terms of the guaranteed maximum price (GMP) is negotiated between the CM and the owner agency. Provided that the GMP is acceptable to both parties, a contract is executed so that the CM becomes the contractor for construction committed to deliver the project within the set GMP.

Although CMAR has been employed successfully throughout the U.S. and in Nevada by local agencies, this delivery method is not a standard practice used by NDOT. During the 2011 Nevada legislative session, NDOT was authorized to use CMAR on a 2-year experimental basis. Subsequently, and as part of NDOT's efforts towards the Special Experimental Project Number 14 (SEP-14) initiative for evaluating alternative contracting methods, CMAR was selected as the delivery method for the I-80 project, making this project into NDOT's third and largest construction project to be delivered using this delivery method.

NDOT estimated that implementation of CMAR for this project had a significant impact on the construction schedule when compared to the traditional DBB delivery method. It was estimated that, with the DBB method, the construction would have begun in August 2013, whereas the actual construction was initiated in May 2013 with the CMAR method. With such a late start and considering the construction shutdown during the winter, it was projected that the DBB method would have extended the construction contract to 2015, impacting highway users for a total of 24 months. The CMAR method allowed the construction to be completed in two construction seasons with 16 months of impact to highway users. In the end, the DBB delivery method would have taken 50 percent more time than the innovative CMAR delivery method.

Another important element of this project was to completely renovate the lighting system within the Carlin Tunnels. The existing tunnel lighting (shown in figure 3) is a one-dimensional high-pressure sodium (HPS) system and does not provide the lighting requirements established by American Association of State Highway and Transportation Officials' (AASHTO) Roadway Lighting Design Guide (GL-6) and Illuminating Engineering Society of North America's (IES) Tunnel Lighting Recommended Practices Manual #22 (RP-22-11).

The Carlin Tunnel lighting work consisted of removing all existing luminaires and the non-working lighting control system, upgrading the existing conduit system, replacing all existing power conductors, and installing new LED luminaires with a new control system. The use of a state-of-the-art LED luminaire system within the Carlin Tunnels is another innovation of this project for improving safety, quality, and user satisfaction. This technology has never been used in Nevada and, in fact, this is the first project in North America that uses an LED lighting system for a highway tunnel.

The selection of the LED lighting system for the Carlin Tunnels was based on NDOT's internal evaluation of four main light sources used in tunnel applications: HPS that was previously used in the tunnels, metal halide, induction lighting, and LED. The features considered for the evaluation included the fixture performance and efficiency data from the manufacturers, lamp source, photometric patterns, lumen output, maintenance, and life cycle cost. The LED luminaires were selected due to their long life, ease of control and maintenance, construction durability, great cold temperature operation, instant-on and dimming capabilities, and negligible infrared and ultraviolet emissions, in addition to the lowest life cycle cost as shown in Table 1.

Table 1. NDOT's life cycle cost analysis for various luminaire systems.

Luminaire	20-Year Life Cycle Cost	Annual Life Cycle Cost	Annual Energy Cost
HPS	$13,282,369	$664,118	$336,862
Metal Halide	$21,010,400	$1,050,520	$475,317
Induction Lighting	$9,997,655	$499,882	$296,856
LED	$5,444,707	$272,235	$103,819

It is expected that the LED luminaires selected for the project will prolong the life of the infrastructure and improve quality and functionality. The current lighting devices and other non-LED light sources will fail over their life cycle. The steps to replace the devices are difficult and vary by each respective luminaire. The more difficult the replacement steps are, the more costly the luminaire will be over time due to the labor hours required to maintain them. LEDs have a long life—greater than 100,000 hours. The proposed LED life cycle is 20 years with a 10-year maintenance frequency. In addition, the LED luminaires are field maintainable and would not need to be sent back to the factory for repairs.

NDOT's Selection of CMAR

The request for proposals (RFP) for the selection of the CMAR was issued on August 28, 2012, with a due date of September 27, 2012, for the proposals. Five pre-qualified firms responded to NDOT's RFP by submitting technical proposals and their proposed pricing fees for construction management in separate sealed envelopes. The technical proposals were evaluated first, by a project panel consisting of NDOT staff, to determine the initial short-listed firms for interview and final selection. The proposals were evaluated based on four major factors with different weights and a total possible score of 100. Figure 15 shows the proposal scoring sheet with these evaluation factors (and sub-factors) and the breakdown of the scores.

Proposal Score **100 Points Maximum**

		(1 – 100 points)		Weight		Score
Evaluation Factor 1	**Proposer Team/Organization (40 Points Maximum)**					
Sub-factor 1	**Organization**		X	0.05	=	
Sub-factor 2	**Qualifications and experience of Proposer firm**		X	0.15	=	
Sub-factor 3	**Qualifications and experience of Key Personnel**		X	0.20	=	
					Subtotal	
Evaluation Factor 2	**Project Approach (30 Points Maximum)**					
Sub-factor 1	**Pre-Construction**			0.15	=	
Sub-factor 2	**Construction**			0.15		
					Subtotal	
Evaluation Factor 3	**Past Project Innovation (15 Points Maximum)**		X	0.15	=	
					Subtotal	
Evaluation Factor 4	**Approach to Schedule (15 Points Maximum)**		X	0.15	=	
					Subtotal	

TOTAL PROPOSAL SCORE: (100 Points Maximum)

Figure 15. Illustration. Scoring sheet used for proposal evaluation.

Three short-listed contractors were contacted for further interview. These contractors were interviewed on October 24 and 25, 2012. The final ranking of the proposers was determined based on the interview scores and their proposed construction management fee. Figure 16 shows the interview scoring sheet with three evaluation criteria and the score breakdown.

Q&D Construction received the highest interview score and became the CMAR for this project.

Interview Score **100 Points Maximum**

Interview Scoring Criteria	(1 – 100 points)		Weight		Score
Presentation (10 Points Maximum)		X	0.10	=	
Interview (75 Points Maximum) *(The interview may be evaluated by way of questions and answers and/or a team challenge.)*		X	0.75	=	
Construction Management Fee (15 Points Maximum)			0.15		
				Interview Score	

TOTAL INTERVIEW SCORE: (100 Points Maximum)

Figure 16. Illustration. Interview scoring sheet.

SAFETY ASPECTS OF NDOT'S CARLIN TUNNELS PROJECT

Prior to the rehabilitation of this rural stretch of I-80, there were approximately 70 crashes with 33 injuries and zero fatalities. Ninety percent of accidents were non-collision, and the majority of the crashes were due to the failure to maintain the proper lane or driving too fast for conditions.

To achieve user safety through the Carlin Tunnels, the tunnel environment must be visible and comfortable 24 hours a day. The LED luminaire system provides the driving public with increased visibility when entering the tunnel and throughout the entire length of the tunnel, as the lighting levels can be changed as necessary. The new lighting control system also allows the lighting levels to ramp up and dim down between 0 percent and 100 percent of light output over extensive periods of time. For the Carlin Tunnels, the time period will be approximately 30 minutes to ramp light levels up or down, which will be unnoticeable to drivers. NDOT believes that the improved tunnel lighting with the LED system will enhance the safety of the Carlin Tunnels and reduce the number of incidents, especially the non-collision crashes.

To enhance the work zone safety, NDOT's Traffic Management Plan proposed innovative ideas to eliminate conflict points for the traveling public. NDOT examined the possibility of directing opposing traffic through a single tunnel. Although this option would have saved $1.5 million of project cost and 2 months of construction schedule, NDOT felt having the two-way interstate traffic travel through an enclosed tunnel with an 11-foot lane and 1-foot shoulder would increase work zone crashes. To mitigate this safety risk, NDOT decided to build crossovers for the eastbound traffic and use the old highway (US-40) to detour westbound traffic during construction. The proposed traffic detour is shown in Figure 17. The proposed traffic maintenance plan allows the construction crews to work on the entire westbound or eastbound road while traffic is diverted onto the opposite side of the roadway and the detour road.

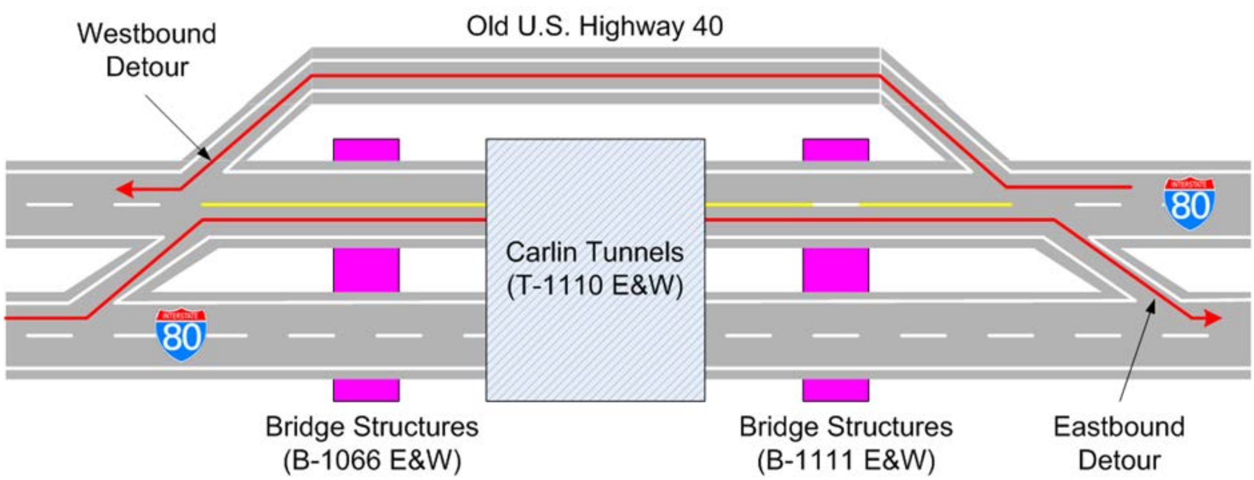


Figure 17. Diagram. NDOT's traffic maintenance schematic.

SUMMARY

The overall objective of this project was to improve the structural condition of I-80 through Carlin Canyon and provide operational and safety improvements. Using the CMAR project delivery method was expected to extend the service life of the highway structures while significantly reducing the duration of construction. In addition, this project is the first project in North America that used an LED lighting system for highway tunnels. It is expected that the LED lighting system will provide improved safety, quality, and user satisfaction.

ACKNOWLEDGMENTS

The project team acknowledges the invaluable insights and guidance of Highways for LIFE Team Leader Byron Lord and Program Coordinator Ewa Flom, who served as the technical panel on this demonstration project. Their vast knowledge and experience with the various aspects of construction, technology deployment, and technology transfer helped immensely in developing both the approach and the technical matter for this document. The team also is indebted to NDOT Engineers Dale Keller, Tom Moore, and Nick Senrud and FHWA Engineers Jin Zhen, Andrew Soderberg, Iyad Alattar, and Paul Schneider for their advice and assistance during this project.