Utah Demonstration Project: Rapid Removal and Replacement of the 4500 South Bridge over I-215 in Salt Lake City

Final Report
April 2009

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. "Innovations" is an inclusive term used by HfL to 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 decisionmakers 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.

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16. Abstract

As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Utah Department of Transportation (UDOT) was awarded a $1 million grant to demonstrate the use of proven, innovative technologies for accelerated bridge removal and replacement. This report documents accelerated bridge construction (ABC) techniques used to remove and replace the 4500 South Bridge on State Route 266 over Interstate 215 in Salt Lake City over a weekend.

This report includes construction details of the bridge superstructure built offsite on temporary abutments and prefabricated and cast-in-place bridge components and substructure built under the existing bridge without interfering with traffic flow. It also discusses use of a self-propelled modular transporter (SPMT) to remove the old bridge and to replace it with a new one. Under conventional construction, the impact of this project on the traveling public was estimated at 120 days, but with the use of accelerated construction techniques, the impact was reduced to a single weekend for I-215 and 10 days for SR 266.

Using an SPMT and other ABC techniques added approximately $0.81 million to the initial construction cost of the project. However, a more comprehensive economic analysis including user cost savings shows that the project saved road users about $3.24 million (or approximately 36 percent of the total project costs). Because of the success of this project, UDOT has decided to use ABC techniques more routinely on future projects and has set a goal of making ABC standard practice for all bridges by 2010.

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Unclassified	Unclassified	60	

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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 yard	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	milliliters	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 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 (metric tons)	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/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	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

APPROXIMATE CONVERSIONS FROM SI UNITS

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	35.71	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 (metric tons)	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	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
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)
		DENSITY		
kg/m^3	kilograms per cubic meter	0.062	pounds per cubic foot	lb/ft^3 (pcf)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised September 1993)

ACKNOWLEDGMENTS

The project team would like to acknowledge the invaluable insights and guidance of Federal Highway Administration (FHWA) Highways for LIFE Team Leader Byron Lord and Program Coordinators Mary Huie and Kathleen Bergeron, 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 Utah Department of Transportation engineers Jim McMinimee, Shana Lindsey, Lisa Wilson and Daniel Hsiao and FHWA Division Administrator Butch Waidelich and ITS and Structural Engineer Russ Robertson for their tireless advice, assistance, and coordination during this project.

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ABC	accelerated bridge construction
ADT	average daily traffic
CIP	cast-in-place
CMGC	construction manager general contracting
dB(A)	A-weighted decibels
DOT	department of transportation
FHWA	Federal Highway Administration
FY	fiscal year
HfL	Highways for LIFE
Hz	hertz
IRI	International Roughness Index
OBSI	on-board sound intensity
OSHA	Occupational Safety and Health Administration
PIC	public involvement coordinator
PIM	public information manager
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SI	sound intensity
SPMT	self-propelled modular transporter
SR	State Route
SRTT	standard reference test tire
UDOT	Utah Department of Transportation
VOC	vehicle operational costs

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration's (FHWA's) initiative to accelerate innovation in the highway community, provides incentive funding for demonstration construction projects. Through these projects, the HfL program promotes and documents improvements in safety, construction-related congestion, and quality that can be achieved by setting performance goals and adopting innovations.

The HfL program—described in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—may provide incentives to a maximum of 15 demonstration projects a year. The funding amount may total up to 20 percent of the project cost, but not more than $5 million. Also, the Federal share for a HfL project may be up to 100 percent, thus waiving the typical State-match portion. At the State's request, a combination of funding and waived match may be applied to a project.

To be considered for HfL funding, a project must involve constructing, reconstructing, or rehabilitating a route or connection on an eligible Federal-aid highway. It must use innovative technologies, manufacturing processes, financing, or contracting methods that improve safety, reduce construction congestion, and enhance quality and user satisfaction. To provide a target for each of these areas, HfL has established demonstration project performance goals.

The performance goals emphasize the needs of highway users and reinforce the importance of addressing safety, congestion, user satisfaction, and quality in every project. The goals define the desired result while encouraging innovative solutions, raising the bar in highway transportation service and safety. User-based performance goals also serve as a new business model for how highway agencies can manage the highway project delivery process.

HfL project promotion involves showing the highway community and the public how demonstration projects are designed and built and how they perform. Broadly promoting successes encourages more widespread application of performance goals and innovations in the future.

Project Solicitation, Evaluation, and Selection

FHWA issued open solicitations for HfL project applications in fiscal years 2006, 2007, 2008, and 2009. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, and contacted applicants to discuss technical issues and obtain commitments on project issues. Documentation of these questions and comments was sent to applicants, who responded in writing.

The project selection panel consisted of representatives of the FHWA offices of Infrastructure, Safety and Operations; the Resource Center Construction and Project Management Team; the Division offices; and the HfL team. After evaluating and rating the applications and supplemental information, panel members convened to reach a consensus on the projects to recommend for approval. The panel gave priority to projects that accomplish the following:

- Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
- 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.
- Include innovations that will change administration of the State's highway program to more quickly build long-lasting, high-quality, cost-effective projects that improve safety and reduce congestion.
- Will be ready for construction within one year of approval of the project application. For the HfL program, FHWA considers a project ready for construction when the FHWA Division authorizes it.
- Demonstrate the willingness of the applicant department of transportation (DOT) to participate in technology transfer and information dissemination activities associated with the project.

HfL Project Performance Goals

The HfL performance goals 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. States are encouraged to use all applicable goals on a project:

- **Safety**
    - Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
    - Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported via Occupational Safety and Health Administration (OSHA) Form 300.
    - Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.

- **Construction Congestion**
    - Faster construction—Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
    - Trip time during construction—Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
    - Queue length during construction—A moving queue length of less than 0.5 mile (mi) (0.8 kilometer (km)) in a rural area or less than 1.5 mi (2.4 km) in an urban area (in both cases at a travel speed 20 percent less than the posted speed).

- **Quality**
    - Smoothness—International Roughness Index (IRI) measurement of less than 48 inches per mile.

- Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test method.
- User satisfaction—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-plus on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This report documents the award-winning Utah Department of Transportation's (UDOT) HfL demonstration project, which involved accelerated removal and replacement of a bridge over an urban Interstate highway. The report presents project details relevant to the HfL program, including innovative contracting, superstructure and substructure design and construction highlights, rapid bridge removal and replacement, HfL performance metrics measurement, and economic analysis. Technology transfer activities that took place during the project and lessons learned are also discussed.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The 4500 South Bridge on State Route (SR) 266 in Salt Lake City, UT, was built in 1971. The four-span bridge crossed Interstate 215 and served as an important access point for local businesses and residents. The bridge was in very poor condition, with delaminated, distressed concrete columns, pier caps, girders, and decks, as well as badly exposed and corroded reinforcing steel. On a scale of 0 to 100, the overall sufficiency rating for the structure was 40.3. The condition of the bridge prompted UDOT to expedite the removal and replacement of the bridge. After exploring alternatives and evaluating project and user costs, UDOT selected innovative accelerated bridge construction (ABC) and project delivery strategies to remove and replace the bridge. These strategies include the following:

- Use of the construction manager general contractor (CMGC) project delivery strategy, which allowed fast-tracking of the project.
- Offsite construction of the entire superstructure, including girders, deck, curb, gutter, side railings, etc. The single-span deck was 172 feet (ft) (52.4 meters (m)) long.
- Offsite construction of other bridge components, such as sleeper slabs and approach panels.
- Construction of substructures beneath the 4500 South Bridge and outside the bounds of I-215 with little to no impact on I-215 traffic. The construction of the substructure consisted of building the abutments with aesthetic murals on cast-in-place (CIP) spread footing foundations with extended wing walls.
- Dramatic reduction in user costs and increase in motorist and worker safety and user satisfaction through the use of a revolutionary construction engineering aid—the self-propelled modular transporter (SPMT). This tool made it possible to remove the old bridge and replace it with the new bridge over a weekend.
- Employment of a short-term full lane closure on I-215 to reduce construction time and user impact and improve safety.
- Implementation of an effective public information campaign involving both outreach and communication efforts.

The innovations employed on the project represented many firsts for UDOT, including the use of an SPMT and several of the substructure elements. The biggest innovation was the removal and replacement of the bridge using an SPMT. The entire operation took a mere 53 hours and has significantly raised customers' future expectations of UDOT on highway project delivery methods and time frames.

Equipped with 256 wheels and operated remotely by a single operator using a joystick control, the SPMT made two trips to complete the removal of the existing two-span superstructure (one trip per span). The entire removal took about 4 hours on Saturday, October 26, 2007. After moving both parts of the existing superstructure to the demolition area, work on rubblizing the existing columns and bent caps began over I-215. The remaining time on Saturday was spent removing the rubblized materials and preparing the abutments for placement of the new superstructure

On Sunday, October 28, the SPMT moved the new single-span superstructure to its final destination supported by the newly built abutments. The new 172-ft-long (52.4-m-long) superstructure, which weighed about 16,000 tons (14,514 metric tons), was the longest bridge ever moved by an SPMT in the United States. Many local residents and professionals from UDOT and other highway agencies observed the process. Local and national news outlets, including CNN, were also at the site. I-215 reopened to traffic on Monday, October 29, at 1 a.m. The 4500 South Bridge reopened to traffic about 10 days later, after the precast approach slabs and bridge detail work were completed. UDOT estimated that under conventional construction, which would have employed partial lane closures, the user impact would have been felt for 120 days over a 4- to 6-month period.

DATA COLLECTION

Safety, construction congestion, quality, and user satisfaction data were collected before, during, and after construction to demonstrate that accelerated bridge technologies can be used to achieve the HfL performance goals in these areas.

No worker injuries or motorist incidents were reported during construction, which means UDOT exceeded the HfL requirements for worker safety. A segment of I-215 that included the 4500 South Bridge on SR 266 and part of the pavement on either side of this structure was selected to determine the operational safety of the structure before construction. The 3-year crash histories revealed numerous crashes, but none that could be attributed directly to the structure that was replaced. Finally, no motorist incidents have been reported since the construction of the new bridge structure.

Under conventional construction, the impact on both roads from construction-related congestion was estimated at 40 to 50 weeks. With the use of ABC techniques, the impact was reduced to a weekend for I-215 and 10 days for SR 266. There was minor impact on I-215 for 8 weeks during construction of the spread footing (foundation for the abutments), abutments, and wingwalls. During the removal and replacement of the 4500 South Bridge, I-215 was closed to all traffic for 48 hours. Essentially, the major impact on I-215 was for only a weekend.

Quality was measured in terms of noise (OBSI) and smoothness (IRI) both before and after construction. The sound intensity data suggest that pre- and postconstruction noise levels did not differ significantly. Both were excellent and exceeded the HfL target values. Preconstruction IRI was 223 inches per mile for the existing bridge deck, and postconstruction IRI was 265 inches per mile. However, the final riding surface had not been placed before postconstruction IRI data collection. Although the thin riding surface is not expected to decrease the IRI dramatically, it is expected to provide a better match between the pre- and postconstruction test results. Nevertheless, the HfL goal for IRI of 48 inches per mile, while reasonably attainable on long, open stretches of pavement, was not met on this project. It is difficult to attain this level of average ride quality on a short-span bridge because the inevitable bumps at each end of the bridge have so much influence on the average.

During the planning and construction of the 4500 South Bridge, UDOT implemented an aggressive, comprehensive communication effort with residents and businesses in the affected zones. Through fliers, newsletters, e-mails, and a dedicated hotline, the public was kept aware of key project schedules and milestones on a weekly or as-needed basis. In addition, a project summary page posted on the UDOT Web site was updated periodically to reflect project progress. A postconstruction survey indicated that residents and businesses were extremely satisfied with the construction approach and the final product. As a result, UDOT exceeded the HfL customer satisfaction expectation by a large margin.

ECONOMIC ANALYSIS

The benefits and costs of this innovative project approach were compared with those of a project of similar size and scope with a more traditional delivery approach. UDOT supplied most of the cost figures for the as-built project, and the cost assumptions for the traditional approach were determined from discussions with UDOT and FHWA Utah Division staff and national literature.

The economic analysis revealed that UDOT's approach realized a cost savings of about $3.24 million or 36 percent over conventional construction practices.[1] A significant amount of the cost savings was from reduced delay costs.

LESSONS LEARNED

Through this project, UDOT gained valuable insights on the innovative processes deployed, both those that were successful and those that need improvement in future project deliveries. These were published in a UDOT report[2] and are excerpted below.

Contracting Process

Benefits of the CMGC contracting method used for this project include the following:

- The contractor was involved in the project early.
- Input and coordination on the schedule and cost were constant.
- The design considers contractor's inputs thereby improving constructability.
- All the answers were not required up front; they were developed throughout the project.
- The prime contractor was able to coordinate with subcontractors up front.
- The contractor was able to coordinate with utility companies early in the project.
- Flexibility allowed early action items and early release packages (structural steel procurement and temporary site construction) to be provided.
- The project was delivered on a tight schedule and was estimated to have been completed approximately 12 months earlier than the traditional (design-bid-build) approach to bridge construction.

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[1] These costs were estimated in consultation with UDOT engineers and FHWA Utah Division staff.

[2] HDR, *Lesson Learned Report, I-215; 4500 South Structure Project, Project Number F-I215 (126) 13, Structure NO. C-953*, January 2008.

Areas needing improvement include the following:

- Provide more design time to investigate alternatives, optimize design, and improve constructability.
- Define clearly the roles and responsibilities of the design engineer and the construction engineer.
- Determine a method for improving construction cost estimates early in the design process, since the cost of the project is determined as the design progresses.

Design

Benefits of the design process used on this project include the following:

- The designer and contractor worked as a team.
- The designer was able to visit the site constantly to ensure that the design requirements were met and the design schedule was maintained.
- Early communication and coordination occurred among the designer, contractor, and mover.

Areas needing improvement include the following:

- Know the design direction for the project up front with owner-defined goals.
- Plan up front for more design associated with temporary works.
- Obtain the contractor and subcontractor earlier in the process.

Construction

Benefits of the construction process adopted include the following:

- The designer and contractor worked as a team.
- A contingency plan was in place for unforeseen complications.
- Multiple pre-event meetings were held with the entire team to examine every step.

Areas needing improvement include the following:

- Limit the number of nonproject personnel on the job site to limit exposure, risk, and liability from the contractor. Coordinate more effectively between the owner and contractor on site access, and develop a protocol for site visitation for all individuals. Schedule tour times if necessary.
- Investigate cheaper alternatives for temporary work.
- Schedule adequate time for curing requirements of concrete work.
- Plan for adequate space at the staging area for the significant amount of SPMT equipment delivered to the site.
- Develop a checklist for items to evaluate during construction.

- Provide a more detailed plan for tasks to be done after the bridge move (grading plans, landscaping, staging area, and nonstructural items).

SPMT

Benefits of the SPMT process include the following:

- The designer, contractor, and subcontractor worked together as a team.
- UDOT gained experience with the use of SPMTs.
- The new bridge was erected quickly and traffic disruption was minimized.

Areas needing improvement include the following:

- Provide additional contingency in the conceptual cost estimate when a new technology is being implemented.
- Write specifications to promote ABC and the use of SPMTs.

Public Involvement

Benefits of the public involvement process include the following:

- Printed information was available to the public early in the project.
- The media and public were informed throughout the project.

Areas needing improvement include the following:

- Define project expectations and the timeline of the bridge move to the public more clearly.
- Provide more information in the public viewing area during the bridge move.
- Provide facilities for all public viewers.

In addition to the benedtis noted, the off-site construction enhanced motorist and worker safety and minimized traffic disruptions and related congestion.

CONCLUSIONS

From the standpoint of construction speed, motorist and user safety, cost, and quality, this project was an unqualified success and embodied the ideals of the HfL program. UDOT received AASHTO's *Innovative* Management award in the Small Project category for this project. More importantly, UDOT learned that careful planning—coupled with an aggressive public outreach and the use of innovative ABC technologies—can result in projects that serve as watershed events in the way they are delivered to the public. A postconstruction stakeholder survey conducted by UDOT clearly indicated that local residents and businesses were extremely satisfied with the construction approach and the final product.

Because of the success of this project, UDOT has taken several significant steps toward making ABC an integral part of its bridge construction projects and has set a goal of making ABC standard practice for all bridges by 2010. They are well and truly underway in their endeavor in becoming the first US highway agency to do so.

PROJECT DETAILS

BACKGROUND

The 4500 South Bridge on SR 266 over I-215 in Salt Lake City, designated as structure F-156 in UDOT's bridge management system, is the focus of this infrastructure renewal project. The four-span structure, originally built in 1971, was 244 ft (74.3 m) long and 77.2 ft (23.5 m) wide, including a driving lane, turn lane, shoulders, curbs, gutters, and sidewalks.
Figure 1 shows the typical section for the existing bridge.

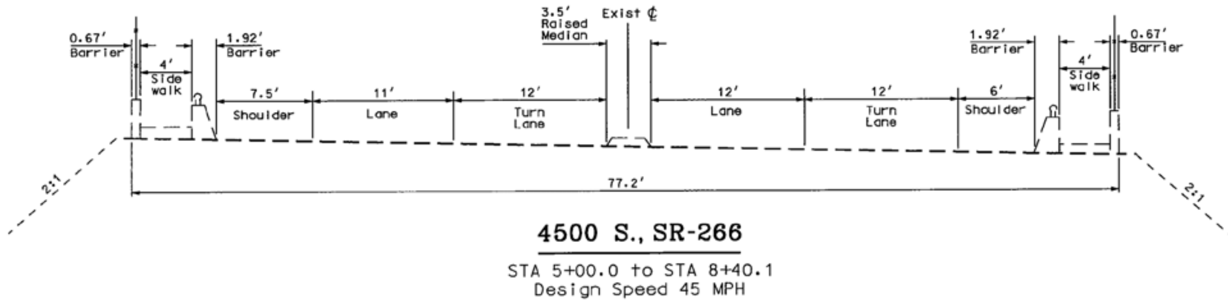

Figure 1. Existing typical section.

The average daily traffic (ADT) for I-215 and SR 266 is 66,085 and 14,815 vehicles, respectively.

By 2007, the structure was in poor condition, with delaminated, distressed concrete columns, pier caps, girders, and decks, as well as badly exposed and corroded reinforcing steel. On a scale of 0 to 100, the overall sufficiency rating for this structure was 40.3, indicating an unsafe condition requiring immediate mitigation. The deck, superstructure, and substructure were rated at 4, 4, and 3 on a 0-to-10 scale, respectively, causing it to be categorized as "structurally deficient." Some of the columns of the bridge were in such poor condition that UDOT had to shore up the bent caps for extra support (see Figure 2 and Figure 3). The poor overall condition of the bridge prompted UDOT to expedite the removal and replacement of the bridge.

Figure 2. Delaminated column.

Figure 3. Shoring the bent caps.

PROJECT DESCRIPTION

Using a combination of innovative bidding and construction approaches centered on ABC methods, UDOT replaced the existing 4500 South Bridge with a new single-span structure. The main goal was to reduce traffic impacts on I-215 and minimize impacts on residents who use the 4500 South Bridge. The selected reconstruction approach represents the core principles of the HfL program and UDOT's modern approach to bridge construction: to deliver projects expeditiously, safely, economically, and with minimal impact on the environment and highway users.

A plan view of the proposed new structure is shown in Figure 4. The innovative elements of the project include the following:

- Use of construction manager general contracting (CMGC).
- Construction of the superstructure offsite, supported by temporary abutments.
- Construction of the substructure without interfering with traffic flow.
- Use of prefabricated bridge components.
- Use of free-draining backfill materials to minimize compaction efforts.
- Use of a self-propelled modular transporter (SPMT) for bridge removal and replacement.

These innovative elements are described in the following subsections.

Construction Manager General Contacting

CMGC is a construction delivery method in which the construction manager acts as a general contractor, bringing the contractor and designer together to meet the owner's goals for the project. In general, the CMGC method uses an integrated team approach, applying modern management techniques that allow the designer and contractor to collaborate during the design

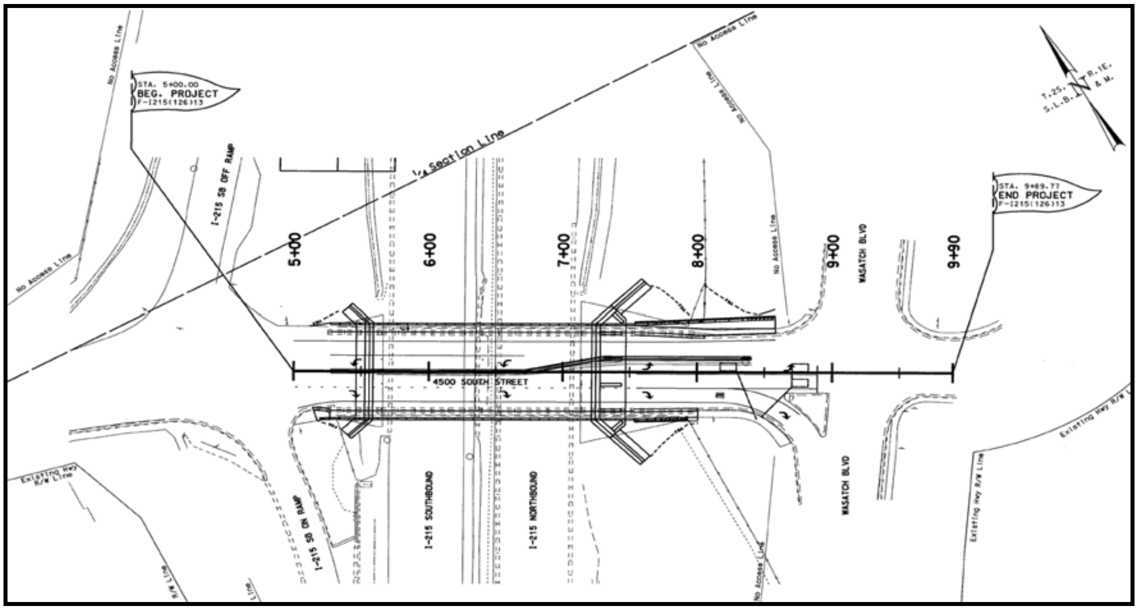

Figure 4. Plan view of the new 4500 South Bridge.

process to control time, cost, and quality. This process was used effectively on this project, and some major design and construction decisions were processed together by the teams. This ultimately saved time and expensive change orders on the project. In terms of time savings, UDOT noted that the traditional design-bid-build approach would have taken 12 months longer from preliminary design to construction completion than the CMGC approach adopted.

Superstructure Construction

One of the major decisions made to accelerate the replacement of the existing structure was to construct the superstructure offsite, next to the existing bridge. The girders were assembled on a 9 percent slope[3] over temporary abutments (see Figure 5). After assembling the girders, the deck was cast in place over the girders and painted. Figure 6 shows the built superstructure resting on the temporary abutments about 50 ft (15.3 m) from the existing bridge on a specially constructed staging area. The benefits of constructing the superstructure offsite include the following:

- Minimized traffic disruptions over the structure and on I-215 and maintained normal traffic flow without altering the present roadway configuration.
- Provided a safer environment for the traveling public and workers by drastically reducing exposure to traffic and construction activities.
- Potentially improved quality because bridge elements were fabricated in a more protected environment.

[3] At the time of bridge placement, the superstructure was inclined longitudinally by another 3 percent to a final position of 12 percent grade.

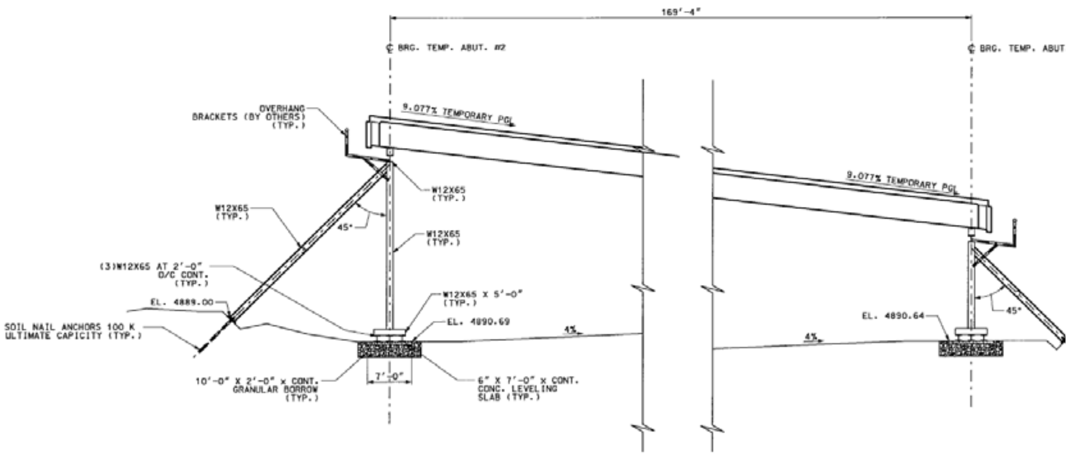

Figure 5. Schematic view of temporary abutments.

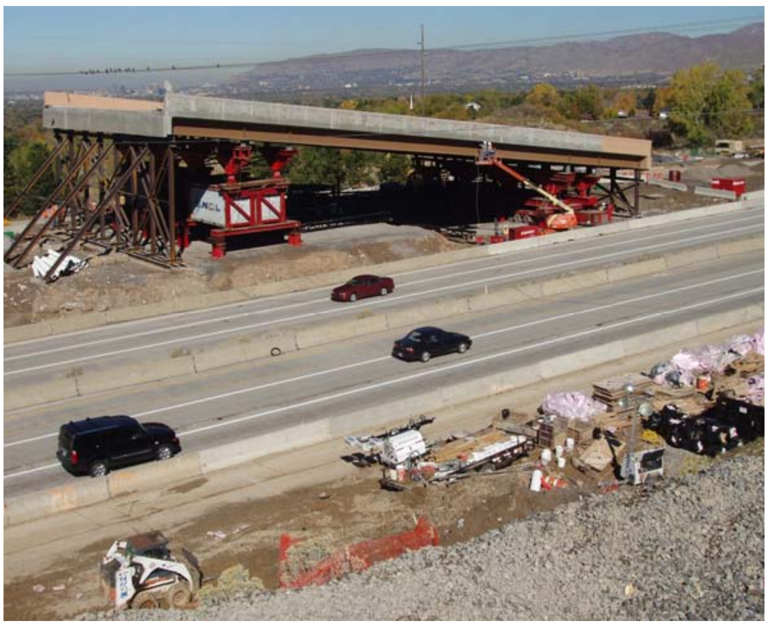

Figure 6. Side view of the new superstructure in the staging area.

Substructure Construction

Concurrent with the superstructure construction, substructures were constructed below the bridge with little or no impact on I-215 traffic. Portions of the I-215 shoulders were used during construction of the substructures, but the shoulder and traffic lane were separated using Jersey barriers. The substructure construction consisted of building abutments with aesthetic murals on CIP spread footing foundations with extended wingwalls (see Figure 7, Figure 8, and Figure 9). Abutments were cast in place by pouring concrete through the holes drilled into the existing bridge deck.

Figure 7. View of the east spread footing.

Figure 8. View of the CIP abutment.

Figure 9. View of CIP wingwall.

To facilitate construction of the abutments and wingwalls, the approach embankments were stabilized by inserting tiebacks ranging from 27 to 37 ft (8.2 to 11.2 m) long in a grid system of 5 by 7 ft (1.5 by 2.1 m) using a technique called soil nailing. After the tiebacks were inserted, shotcrete was applied to the entire exposed face of the approach embankments (Figure 10).

Figure 10. Soil nailing of the approach embankment.

Use of Free-Draining Backfill Materials

Free-draining backfill material conforming to American Association of State Highway and Transportation Officials (AASHTO) No. 57 stone was placed behind the abutments to minimize the need for compaction and to expedite the construction, as shown in
Figure 11 and
Figure 12. AASHTO 57 stone requires very little compactive effort and is a highly drainable aggregate with a coefficient of permeability, k, greater than 10,000 feet per day. A small hand-operated vibratory plate compactor was used to seat the aggregate (Figure 13).

Prefabricated Bridge Components

Interlocking bridge approach panels (weighing 40,000 pounds (lb) (18,143 kilograms (kg)) and measuring 25 by 12 ft (7.6 by 3.6 m)) and sleeper slabs were precast next to the bridge, as shown in Figure 14 and Figure 15
.

Removal and Replacement of 4500 South Bridge Using an SPMT

The 4500 South Bridge was removed and replaced successfully in a 53-hour time span during and immediately before the weekend of October 27 and 28, 2007. To make such a rapid removal and replacement possible, UDOT used an SPMT for the first time in its history. The SPMT greatly reduced construction time, minimized inconvenience to the traveling public, improved worker and motorist safety, and maintained a normal workweek traffic flow.

Figure 11. Backfill aggregate.

Figure 12. Placement of backfill material.

Figure 13. Seating the backfill material.

Figure 14. Precast approach slabs.

Figure 15. Sleeper slab reinforcement assembly.

An SPMT is a computer-controlled platform vehicle with a large array of articulating wheels on the bottom. It is used for transporting massive objects such as bridges, buildings, heavy and oversized equipment, and other objects too large or too heavy for normal trucks. The SPMT deployed on this job was equipped with two sets of 16 axles, each with eight independent, fully articulated, computer-controlled wheels (256 wheels total) and a hydraulic system capable of moving up and down within a vertical range of 24 inches (in) (25.4 millimeters (mm)). It was operated remotely by a single operator using a joystick control.

Although UDOT decided early to use an SPMT to remove and replace the bridge, this project presented unique challenges. One of the most challenging factors was the weight and size of the superstructure, estimated at about 3.2 million lb (1.4 million kg) and 172 ft (52.4 m), respectively. This was the longest bridge ever moved by SPMT in the United States. Another challenge included the various slopes on the project—5- to 7-ft (1.5- to 2.1-m) elevation differential between the north- and southbound lanes, 4 percent roadway longitudinal grade, 2 percent pavement cross slope on I-215, and 12 percent slope of the superstructure longitudinally along SR 266.

On the afternoon of October 26, UDOT closed both I-215 and the 4500 South Bridge and began final preparation for the removal of the existing bridge. To facilitate removal of the superstructure, preliminary work had to be performed on the bridge surface, including sawing and removal of the asphalt overlay, rubblization, and removal of the bridge railings, concrete median, and approach slabs (Figure 16 and Figure 17). On October 27, the SPMT was used to lift and move the two-span superstructure of the 4500 South Bridge to a demolition area alongside I-215 (Figure 18). It took the SPMT two trips (one per span) to complete the removal of the superstructure.

Figure 16. Demolition of railing and median.

Figure 17. Approach panel removal.

Figure 18. Lifting and removing the first span.

The supports for the superstructure at the demolition site were built to mimic the existing alignment, which facilitated the rapid placement of each span (see Figure 19).

Figure 19. Demolition area.

The entire removal process took about 4 hours. After moving both parts of the existing superstructure to the demolition area, work on rubblizing the existing columns and bent caps began over I-215, as shown in Figure 20. The remaining time on Saturday was spent removing the rubblized materials and preparing the abutments (Figure 21) for placement of the new superstructure.

Figure 20. Demolition of the columns and bent caps.

Figure 21.View of abutments and wingwalls with no superstructure.

On Sunday, October 28, the SPMT moved the new superstructure to its final location to rest on the newly built abutments. Because of the considerable length of the superstructure, the SPMT used both the north- and southbound lanes of I-215 to transport the structure (Figure 22 and Figure 23). One glitch was encountered in placing the superstructure on the abutments. As the superstructure approached the abutments it was discovered that the incline at which the superstructure was held by the SPMT (i.e., its cross-slope) did not match the incline of the abutments (see Figure 24). As a consequence, halfway into transporting the superstructure over the abutments, the southeastern corner of the superstructure came close to touching the eastern abutment. To prevent the superstructure from coming into contact with the abutments prematurely and to ensure correct placement, the contractor had to implement a contingency that they had considered for this scenario. The superstructure was jacked up as high as possible using the 16 hydraulic jacks that the SPMT was equipped with. In addition, using the materials on-site, the contractor built a temporary ramp on I-215 that the SPMT could climb over to ensure enough clearance between the superstructure and the highest point of the abutment. The SPMT used the ramp and was able to then precisely install the superstructure. This entire adjustment only added approximately 1 hour to the entire operation and I-215 was opened to traffic on Monday morning as scheduled.

Figure 22. Moving the new superstructure.

Figure 23. Another view of moving the superstructure.

Figure 24. Top view of the deck over the abutments.

Many members of the public, as well as representatives from UDOT and other Federal and State transportation agencies, witnessed the entire removal and replacement process (Figure 25). Local and national news outlets, including CNN, covered the proceedings at the construction site.

Figure 25. Spectators watching the removal and replacement of the 4500 South Bridge.

I-215 reopened to traffic on Monday, October 29, at 1 a.m. The 4500 South Bridge reopened to traffic about 10 days later. Overall, despite the minor glitch associated with the placement of the superstructure, the removal and replacement of the 4500 South Bridge project was a great success. Arguably, the biggest payoff from this project is the change in bridge construction practice in Utah. As a result of the success of this project, UDOT has developed implementation plans to use ABC technologies on all future structural projects in the State.

Figure 26Figure 27 show views of the 4500 South Bridge after it opened to traffic and during postconstruction HfL data collection activities on December 5, 2007.

Figure 26. View of the new 4500 South Bridge.

Figure 27. Another view of the new 4500 South Bridge.

DATA ACQUISITION AND ANALYSIS

Data collection on the UDOT HfL project consisted of acquiring and comparing data on safety, construction congestion, quality, and user satisfaction before, during, and after construction. The primary objective of acquiring these types of data was to provide HfL with sufficient performance information to support the feasibility of the proposed innovations and to demonstrate that ABC technologies can be used to do the following:

- Achieve a safer work environment for the traveling public and workers.
- Reduce construction time and minimize traffic interruptions.
- Produce greater user satisfaction.

This section discusses how well the UDOT project met the specific HfL performance goals related to these areas.

SAFETY

The HfL performance goals for safety include meeting both worker and motorist safety goals during construction. During the construction of the 4500 South Bridge project, no worker injuries or motorist incidents were reported, which means UDOT exceeded the HfL goal for worker safety (incident rate of less than 4.0 based on the OSHA 300 rate).

A 0.38-mi (0.61-km) segment of I-215 was selected for the operational safety reporting before construction. This roadway segment included the 4500 South Bridge on SR 266 and part of the pavement on either side of the structure. The 3-year crash histories (2003–2005) for I-215 and SR 266 in the vicinity of the 4500 South Bridge provided by UDOT are below. According to UDOT, none of the crashes can be attributed directly to the structure that was replaced:

- Sixty-one crashes on I-215 (primarily rear-end collisions with no fatalities)
    - Thirty-two crashes along the main line (52.5 percent).
    - Twenty-nine crashes on the ramps (47.5 percent).
    - None of the crashes were fatal and there was only one incapacitating injury reported within this period.
- Nine crashes on SR 266 (primarily rear-end collisions)

Between the time the HfL project was completed and the date of this report, no motorist crashes were reported, so the goal of reduced motorist crash rates was achieved in the short term. This measure will be tracked for several years.

CONSTRUCTION CONGESTION

The HfL program specifies performance goals for reducing both total construction duration by 50 percent and construction impacts on traffic. Under conventional methods, the construction impact on both roads was estimated at 40 to 50 weeks. With the use of ABC techniques, the impact was reduced to a weekend for I-215 and 10 days for SR 266. There was minor impact on

I-215 for 8 weeks during the construction of the CIP spread footing (foundation for the abutments), abutments, and wingwalls. Jersey barriers were used to separate the shoulders from the outside travel lanes, allowing the contractor to use the shoulder for these construction tasks. I-215 experienced somewhat slower traffic because of the 8-week shoulder elimination. During the removal and replacement of the 4500 South Bridge, I-215 was closed to all traffic for 48 hours. In essence, the major impact on I-215 was for only a weekend.

Both the reduction in total construction time and in impacts on motorists compared to conventional construction methods for this project far exceeded the HfL performance goals.

QUALITY

Sound Intensity Testing

Sound intensity (SI) measurements were taken on October 22, 2007, before reconstruction, at the posted speed limit of 30 miles per hour (mi/h) (48.2 kilometers per hour (km/h)) using the latest industry standard onboard sound intensity (OBSI) technique. This method employs dual vertical sound intensity probes and an ASTM F 2493 standard reference test tire (SRTT). Figure 28 shows the dual probe instrumentation and the tread pattern of the SRTT.

Figure 28. OBSI dual probe system and the SRTT.

Sound measurements were recorded using an onboard computer with the Brüel and Kjær PULSE software and data collection system. A minimum of three test runs were made in the right wheelpath of the inside lane in each direction. The dual sound intensity probes simultaneously collect noise data from the leading and trailing tire-pavement contact areas, and the PULSE software uses Fourier transform to analyze the raw data signals over the full length of each test run to produce SI values.

The values are normalized for environmental effects such as ambient air temperature and barometric pressure at the time of testing. The resulting A-weighted mean SI levels are filtered to produce the noise-frequency spectra in one-third octave bands, as shown in Figure 29.

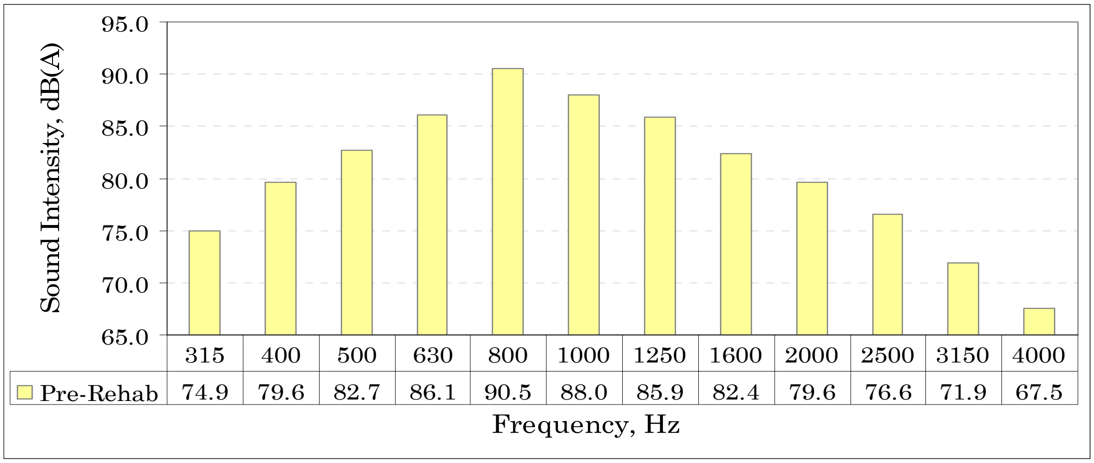

Figure 29. Mean A-weighted sound intensity one-third octave frequency spectra.

The onboard preconstruction SI levels on the 4500 South Bridge in each direction of travel were as follows:

- Eastbound SI = 94.5 dB(A)
- Westbound SI = 95.6 dB(A)

The average preconstruction SI level was 95.1 dB(A), determined using the measurements from the test runs in both directions and logarithmic addition of one-third octave band frequencies between 315 and 4,000 hertz (Hz).

On December 5, 2007, the postconstruction pavement/tire SI levels were acquired at 30 mi/h (48.2 km/h). At this time, the precast superstructure had not been overlaid with the final riding surface. The onboard postconstruction SI levels on the 4500 South Bridge in each direction of travel were as follows:

- Eastbound SI = 94.8 dB(A)
- Westbound SI = 95.7 dB(A)

The average postconstruction SI level determined as described above was 95.3 dB(A).

These data suggest the difference between pre- and postconstruction SI levels was not significant. Both pre- and postconstruction SI levels were excellent and slightly exceeded the HfL target values.

Smoothness Measurement

Smoothness testing was done in conjunction with SI testing using an inertial laser profiler manufactured by International Cybernetics Corp. and built into the noise test vehicle. Figure 30 shows the test vehicle with the laser positioned in line with the right rear wheel.

Figure 30. Laser profiler mounted behind the test vehicle.

At least three test runs were conducted in each wheelpath in each direction and were averaged to produce a singe IRI value with units of inches per mile. Resulting IRI values of the prerehabilitated bridge and approach pavement are plotted in Figure 31 at 10-ft (3-m) intervals.

The average preconstruction IRI value was 223 inches per mile for the existing bridge deck (excluding the pavement before and after the bridge). Figure 31 shows large peak values near the ends of the bridge resulting from rough expansion joints.

Postconstruction smoothness testing performed on December 5, 2007, showed that the IRI value on the precast deck was higher than the preconstruction values at 265 inches per mile. The final riding surface was not placed on this bridge before postconstruction IRI data collection. Although the thin riding surface is not expected to decrease the IRI dramatically, it is expected to provide a better match between the pre- and postconstruction test results.

Nevertheless, the HfL goal for IRI of 48 inches per mile, which reasonably can be met on long, open stretches of pavement, was not met on this project. It is extremely difficult to achieve this mean ride measurement on a short-span bridge of this type because of the influence of the bumps at each end of the structure on the mean.

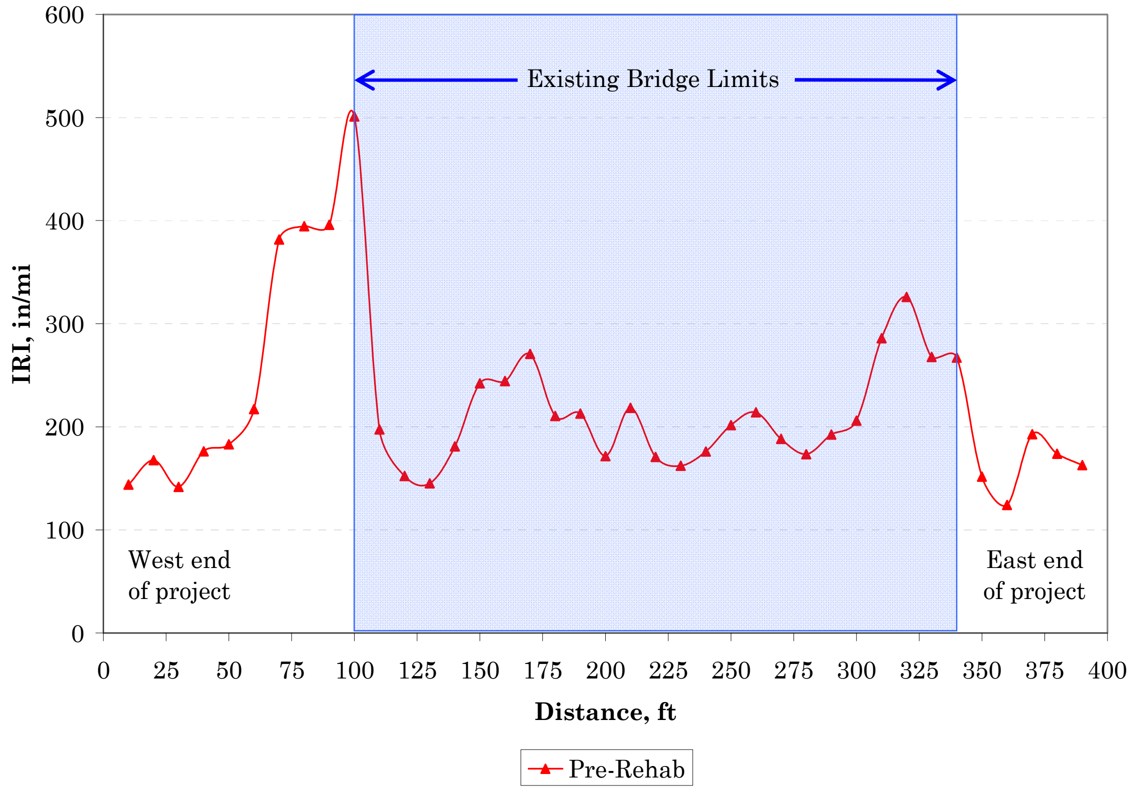

Figure 31. Mean IRI values.

USER SATISFACTION

During the planning and construction of the 4500 South Bridge, UDOT implemented an aggressive, comprehensive communication effort with residents and businesses in the affected zones to keep them informed of all activities. The public information manager (PIM), a private contractor hired by UDOT, was charged with providing information and facilitating communication among the public, the construction contractor, the UDOT resident engineer and the UDOT Region 2 public involvement coordinator (PIC).

The PIM developed and implemented a comprehensive public involvement plan that included an extensive mailing and contact lists. The PIM facilitated an open house-style public hearing and personally met with the neighboring residents and businesses along the corridor to gather comments, receive feedback, and address concerns. Through fliers, newsletters, e-mails, and a dedicated hotline, the public was kept aware of key project schedules and milestones on a weekly or as-needed basis. The PIM also submitted a detailed report on construction updates at each weekly meeting. In addition, the PIM was responsible for preparing a project summary page on the UDOT Web site that included project background, information about upcoming construction activities, and a schedule of key events. The summary page was updated periodically to reflect the project's progress. The HfL requirement for user satisfaction included a performance goal of 4-plus on a Likert scale of 1–7 for the following two questions:

- How satisfied are you with the results of the new bridge compared to the condition of the previous bridge?
- How satisfied are you with the approach UDOT used (accelerated bridge construction) to construct the new bridge in terms of minimizing disruption?

A postconstruction stakeholder survey conducted by UDOT indicated that neighboring residents and businesses were extremely satisfied with the construction approach and the final product. UDOT far exceeded the HfL goal of 4-plus on the Likert scale. Figure 32 illustrates UDOT's and the contractor's overall performance during the project and Figure 33 shows stakeholders' overall satisfaction with the project results. For complete results of UDOT's user satisfaction survey, see Appendix A.

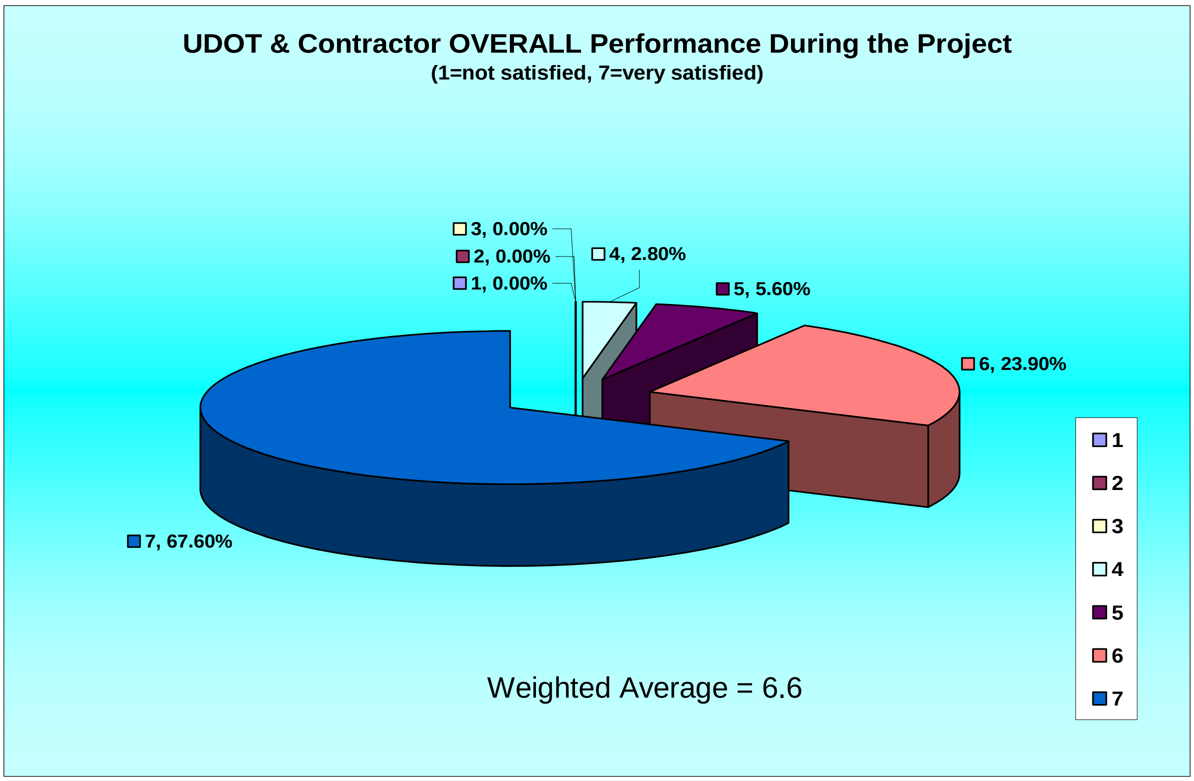

Figure 32. UDOT and contractor overall performance.

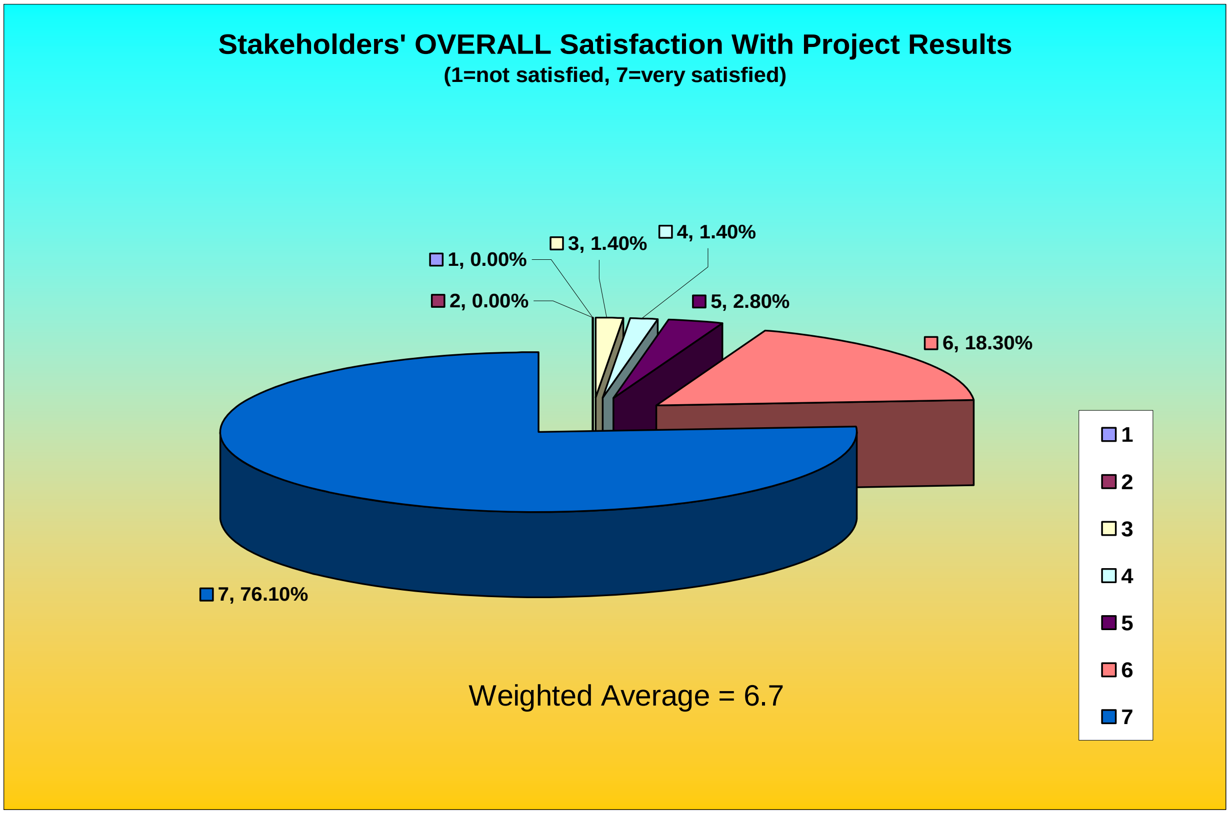

Figure 33. Stakeholders' overall satisfaction.

TECHNOLOGY TRANSFER

By executing a precise, well-coordinated plan, UDOT successfully removed and replaced the 4500 South Bridge in Salt Lake City during one weekend. UDOT proved that ABC is a cost-effective solution, even for structures with challenging geometric constraints. To accelerate nationwide adoption of this proven innovation, a team of representatives from UDOT and FHWA's Utah Division and HfL team developed and implemented a technology transfer plan that included a showcase with a workshop and field demonstration. The showcase was held during the weekend the bridge superstructure was moved into place by SPMT. It began with a Saturday field visit attended by representatives of UDOT and 14 other State DOTs, FHWA, other government agencies and industry.

On Saturday morning, participants observed the new prefabricated bridge superstructure located near the existing bridge. In addition, they witnessed the SPMT lifting and moving the existing two-span superstructure of the 4500 South Bridge to a demolition area alongside I-215. It took the SPMT two trips (one for each span) to complete the removal of the superstructure. The remaining time on Saturday was spent removing the rubblized materials and preparing the abutments for placement of the new superstructure on Sunday morning. At 1 p.m. Saturday, the workshop portion of the showcase began at a nearby location (see workshop agenda in Appendix B). About 150 participants attended the workshop, which consisted of presentations on the design, construction, removal, and replacement of the bridge by representatives of UDOT, FHWA, the design consultant, and the contractor (see Figures 34 and 35).

Figure 34. Workshop participants.

UDOT Executive Director John Njord and the Associate Administrator of FHWA's Office of Infrastructure, King Gee, opened the meeting with comments on their strong support for the project and for implementing innovation in the highway community in general. The participants were provided with an overview of the Highways for LIFE program and national perspectives on the use of ABC techniques. Jim McMinimee of UDOT presented an overview of the design and ABC elements of the 4500 South Bridge and elaborated on UDOT's plan to use this technology on 13 other bridges on I-80 during the 2008 construction season.

Figure 35. Workshop presenters.

Shana Lindsey, Director of Bridge Operations and Research at UDOT moderated the workshop. She talked about the research elements of the project. Kip Wadsworth of Ralph Wadsworth Construction and Bill Halsband of Mammoet discussed construction phasing, innovative features and overall challenges of the project. During a question-and-answer session, participants asked the expert panel questions on all aspects of the project.

On Sunday morning, an SPMT was used to lift and move the new superstructure to its final destination. In addition to showcase participants, many members of the public and representatives from local and national news outlets witnessed the bridge move.

UDOT considered the removal and replacement of the 4500 South Bridge using ABC techniques a great success. By using an SPMT, UDOT was able to remove and replace the 4500 South Bridge in one weekend, reducing construction time, minimizing inconvenience to the traveling public, and improving worker and motorist safety while maintaining normal traffic flow. UDOT undertook an aggressive, comprehensive effort to communicate with residents and businesses near the bridge, keeping them abreast of activities during pre- and postconstruction phases of the project. A user satisfaction survey clearly demonstrated the satisfaction of the neighboring residents and businesses with the project approach and final product.

The workshop was also a tremendous success. Participants from 14 State DOTs took the ABC and SPMT concepts, along with firsthand experience of a successful project, back to their States. The Oregon DOT, for example, used what its workshop participants learned on the UDOT project and applied it their bridge program. In addition, UDOT's project participants received public credit for producing this successful project, inspiring them to similar achievements on upcoming ABC projects in the State.

Shana Lindsey summed up the success of the workshop in her words as follows:

> "Highways for LIFE was not only able to provide the seed money for the implementation of a new technology in our bridge project, but was also able to assist with the sharing of the technology. The workshop made it possible for many of the surrounding states and many

UDOT employees to see the project firsthand. Subsequently, the interest and confidence created by this successful project and workshop helped UDOT construct 12 more ABC projects in 2008. Further, a number of the represented adjacent states asked us to come to their home offices with more detailed follow-up presentations to help them implement ABC in their states."

After the project was completed, UDOT and the HfL program undertook several technology transfer efforts to promote the project's successes and lessons learned and to establish further course of action with regard to ABC. These included the following:

- The 4500 South Bridge was featured prominently in HfL's display booth at major conferences including the Transportation Research Board (TRB) Annual Meeting held in Washington, DC, in January 2008 and 2009 and the International Bridge Conference held in Pittsuburgh, Pennsylvania in June 2008.
- HfL has co-sponsored the first ABC workshop hosted by UDOT titled "Accelerated Bridge Construction Standards." The workshop was held in Salt Lake City, Utah and more than 80 people, many of whom were national authorities on bridge and highway construction, attended it. This workshop was dedicated to making ABC the norm for bridge project delivery in Utah by the year 2010.
- HfL has sponsored the development of a prefabricated bridge element system (PBES) toolkit DVD as well as the PBES connection details manual.
- The 4500 South project was presented and discussed in technical sessions and working committee meetings of the TRB, American Concrete Institute, and individual state highway agencies.

Mr. Walter Waidelich Jr., Utah division administrator for the Federal Highway Administration, was quoted in an AASHTO news article as saying "UDOT's enthusiasm and willingness to openly share experiences has helped advance [accelerated bridge construction] technology nationally." "This was a truly proud moment for UDOT, and I believe a turning point perhaps in public awareness of this technology and expectations for project delivery in the future."

ECONOMIC ANALYSIS

A key aspect of HfL demonstration projects is quantifying, as much as possible, the value of the innovations deployed. This entails comparing the benefits and costs associated with the innovative project delivery approach adopted on an HfL project with those from a more traditional delivery approach on a project of similar size and scope. The latter type of project is referred to as a baseline case and is an important component of the economic analysis.

For this economic analysis, UDOT supplied most of the cost figures for the as-built project. The assumptions for the baseline case costs were determined from discussions with UDOT and FHWA Utah Division staff and national literature.

CONSTRUCTION TIME

UDOT believes that, through the use of innovative construction technologies such as SPMTs and ABC, it was able to dramatically reduce the impact of this project's construction on roadway users. For the as-built case, although the substructure and superstructure took several months to complete, the impact on users was minimal until the 4500 South Bridge was ready to be removed and replaced. During this removal and replacement time, full lane closures were in effect on I-215 and SR 266, on which the 4500 South Bridge is located. As discussed earlier, I-215 was impacted for a weekend. However, 4500 South was affected for 10 days after the bridge was put in place while the contractor finished the project.

If a traditional approach had been used to remove and replace the bridge incrementally while maintaining traffic on I-215, UDOT estimates that it would have taken 6 to 9 months to complete the project and that construction-related user impacts would have been felt over a total of 120 days. In this scenario, the median and the inside two passing lanes of I-215 may have been closed to traffic for construction purposes. Periodic closures of the other lanes also may have been necessary.

DETOUR

As noted earlier, UDOT decided to close I-215 and SR 266 completely during the bridge replacement, which accelerated the removal and replacement process. However, this also required maintaining a detour on local roads. All I-215 traffic was detoured to parallel collector streets and highways. The designated detours did not increase travel time significantly. The 4500 South traffic used the same detour roads.

CONSTRUCTION COSTS

Table 1 presents the differences in construction costs between the baseline and the as-built alternatives. All of the as-built cost estimates were provided by the UDOT project engineer assigned to this job. The baseline cost was determined in consultation with the FHWA Utah Division bridge engineering staff by (1) noting whether the itemized costs in the as-built cost table would have applied to the baseline case, (2) making adjustments to cost categories and costs as necessary, and (3) itemizing other costs associated with the baseline case that may not have been required for the as-built case. The baseline cost estimate is inexact, therefore, and the information presented is a subjective analysis of the likely cost differential rather than a rigorous computation of a cost differential. Several other assumptions were made in selecting significant cost factors and determining some unit costs, as noted in Table 1.

Table 1. 4500 South Bridge capital cost calculation table.

Cost Category	Baseline Case	As Built (ABC)
Preliminary Design and Engineering[1]	$ 728,000	$ 710,929
Bridge Construction		
Structures-Excavation	--	$ 11,510
Staging Area[2]	$ 100,000	$ 529,000
Structures-Materials[3]	$4,500,400	$5,384,576
Roadway-Materials	$ 3,000	$ 23,200
Structures-Cleanup/Removal[4]	$ 600,000	$ 821,737
Structures-Aesthetics[5]	$ 300,000	$ 258,794
Structures-Electrical	$ 4,000	$ 4,000
Construction Engineering[5]	$ 900,000	$1,066,394
Mobilization	$ 500,000	$ 544,914
Traffic Control[7]	$1,200,000	$ 289,973
Utility Relocation	$ 70,000	$ 66,983
Law Enforcement Officer	$ 10,000	$ 9,494
Total Cost	**$8,915,000**	**$9,721,504**

Notes:
[1] Assumed as 10 percent of construction cost for baseline case. For as-built case, the total cost is assumed to include this amount.
[2] For the baseline case this cost related to preparing the site for a construction, e.g., material staging, construction office, etc. For the as-built case, it was for staging materials for precasting the bridge superstructure and demolition area.
[3] A big factor contributing to the cost differential is the SPMT costs to move the new bridge.
[4] A big factor contributing to the cost differential is the cost of removing the existing bridge using the SPMT.
[5] It was assumed that the aesthetics cost for the baseline and as built cases would be the same.
[6] Includes quality assurance program costs. Assumed as 15 percent of the construction cost.
[7] Assumed traffic control costs for baseline over 120 days. Includes costs for Jersey barrier, flaggers, signs, trucks, etc.

USER COSTS

Generally, three categories of user costs are used in an economic/life-cycle cost analysis: vehicle operational costs (VOC), delay costs, and crash and safety-related costs. The cost differential in delay costs was included in this analysis to identify the differences in costs between the baseline and as-built alternatives. Because the anticipated period of user impact during the bridge replacement was relatively short (120 days for traditional versus about 2 days for accelerated) and the site under consideration is in an area with relatively low crashes, it was decided not to compute crash costs. Also, the short detour lengths precluded computation of VOC.

Because SR 266 essentially becomes a local road west of I-215 (toward the Wasatch Mountains), the impact of delay costs on users of SR 266 is not considered significant compared to I-215 below. However, for the sake of completeness, the user delay costs for SR 266 have also been compiled and noted in the following paragraphs.

The following baseline information was available for I-215:

- Based on the data provided by UDOT, the ADT on I-215 was 64,000.
- User impact analysis performed by UDOT on the peak 2 hours of north- and southbound traffic resulted in the following conclusions:
  - Average delay: 11.7 minutes per vehicle
  - Maximum delay: 25.9 minutes per vehicle
  - Average queue length: 2.11 mi (3.39 km)
  - Maximum queue length: 4.8 mi (7.72 km)
- It was assumed that 15 percent of all I-215 traffic would be diverted to detour roads if traditional traffic maintenance techniques were used. However, UDOT decided to not include the delay on detours in the cost analysis.
- UDOT estimates that the delay costs amounted to $31,000 a day. These costs were based on delay costs of $12 an hour per private vehicle and $28 an hour per commercial truck.

The following baseline information was available for SR-266:

- Based on the data provided by UDOT, the ADT on SR-266 is 14,800.
- Most of the residents are expected to take a detour with minimum impact in travel time.
- UDOT estimates that the delay costs amounted to $3,000/day (or about $0.25 per day per vehicle).

Assuming that traditional construction would have impacted traffic for about 120 days and using the average estimated delay cost of $34,000 a day, the additional delay costs for the baseline case would have been $4,080,000 ($34,000/day * 120 days). Based on the user impacts on SR-266 and assuming a total of 10 days of disruption to traffic (2 days for the bridge removal and replacement plus 8 days for approach slab construction and other miscellaneous work to be completed until SR-266 was open to traffic), the delay costs accrued for the as-built case were $30,000 ($3,000/day * 10 days). Several factors ensured that these costs were minimal, including the following:

- The bridge removal and replacement was performed over a weekend. Weekend traffic typically is lower than weekday traffic.
- UDOT's extensive efforts to keep the public informed about the full lane closure on I-215 and SR 266 over the weekend when construction took place resulted in lower traffic levels and congestion.
- The designated detours were sufficient to handle the traffic that had to pass through the affected zone and, based on anecdotal evidence, did not cause excessive queuing.

COST SUMMARY

From a construction cost standpoint, traditional construction methods would have cost UDOT about $806,504 ($9,721,504 - $8,915,000 from table 1) less than accelerated construction.

However, the ABC techniques saved $4,050,000 ($4,080,000 - $30,000) in user costs. Therefore, the net savings on this project totaled $3,243,496 ($4,050,000 - $806,504). Using the estimated total costs for designing and constructing the bridge with traditional practices as a basis, the innovative HfL project delivery approach realized a cost savings of about 36 percent. Moreover, UDOT has noted a downward trend in first costs as ABC use has increased and contractors have become more comfortable with the techniques that embody this project delivery approach. As gathered from recent bridge construction activity in Utah, this trend has provided a greater incentive for increased use of ABC contracting in Utah.

APPENDIX A: USER SATISFACTION SURVEY

The figures and tables presented in this appendix document the user satisfaction surveys conducted and the findings thereof compiled in detail.

A postconstruction survey was sent to residences and businesses around the 4500 South construction area via the U.S. Postal Service on December 28, 2007. Of the 500 surveys sent, about 75 were returned. Some were not fully completed, which accounts for the inconsistency in the number of responses reported here.

The suggestions and recommendations listed below were part of the responses from the gathered data. The Utah Department of Transportation (UDOT) plans to use all of the findings to improve future construction projects and relationships with stakeholders in the area.

Table 2. UDOT survey respondents.

Survey Question: In your current location around the 4500 South/I-215 East Bridge, are you			
		Response Percent	**Response Count**
A resident?		90.9%	60
A business owner/manager?		9.1%	6
An employee?		0.0%	0
	Answered question		**66**
	Skipped question		**0**

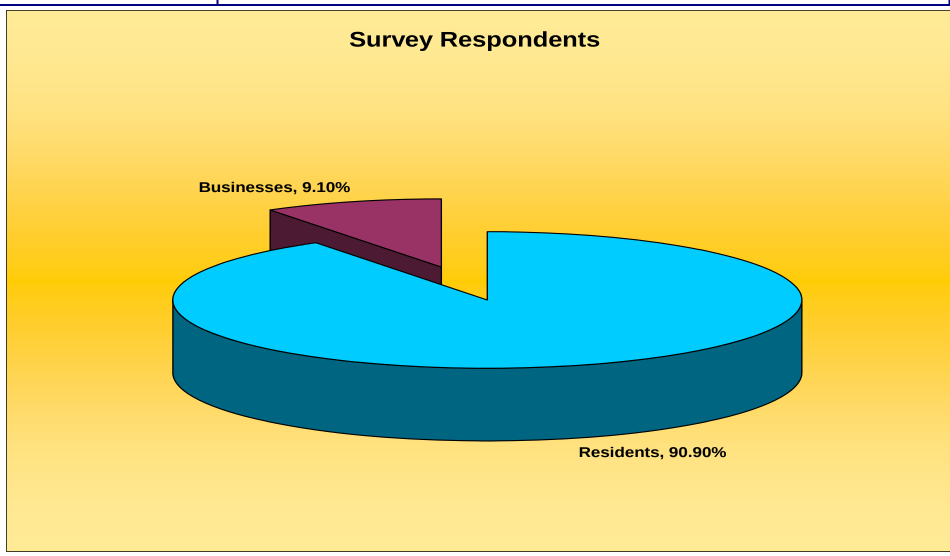

Figure 36. UDOT survey respondents.

Table 3. UDOT and contractor performance.

On a scale of 1–7, please rate UDOT's and the construction contractor's performance in the following areas during the recent roadwork (1 meaning unacceptable and 7 meaning acceptable)**.**

	Rate 1–7							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Response Count**
Safety during construction	1.4% (1)	0.0% (0)	0.0% (0)	2.7% (2)	4.1% (3)	20.5% (15)	71.2% (52)	73
Property/business access during construction	0.0% (0)	1.4% (1)	1.4% (1)	1.4% (1)	8.2% (6)	16.4% (12)	71.2% (52)	73
Detours during construction	0.0% (0)	0.0% (0)	2.8% (2)	5.6% (4)	11.3% (8)	21.1% (15)	59.2% (42)	71
Traffic movement along the roadway during construction	0.0% (0)	0.0% (0)	0.0% (0)	1.4% (1)	5.7% (4)	25.7% (18)	67.1% (47)	70
Noise during construction	0.0% (0)	0.0% (0)	1.4% (1)	2.8% (2)	9.7% (7)	20.8% (15)	65.3% (47)	72
Length of time the bridge was under construction	0.0% (0)	1.4% (1)	1.4% (1)	1.4% (1)	4.3% (3)	8.6% (6)	82.9% (58)	70
							Answered question	**73**
							Skipped question	**2**

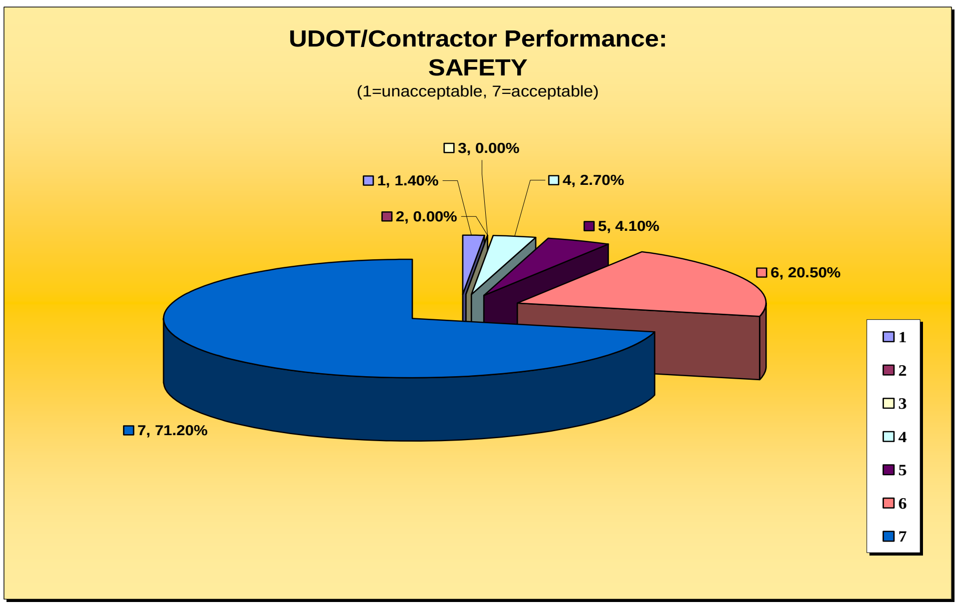

Figure 37. UDOT and contractor safety performance.

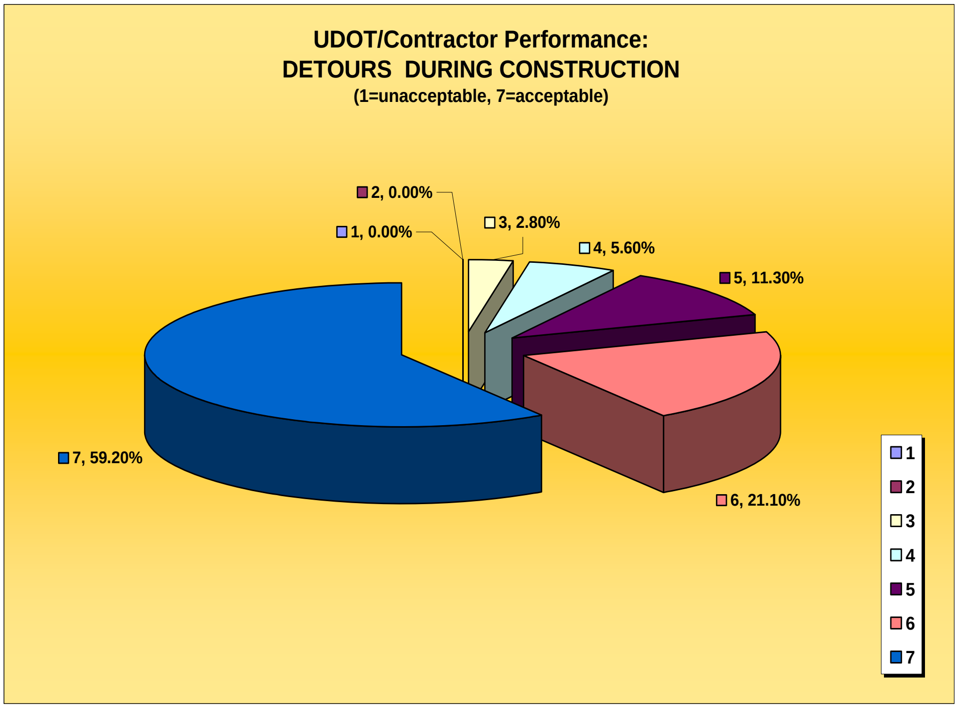

Figure 38. UDOT and contractor performance on detours during construction.

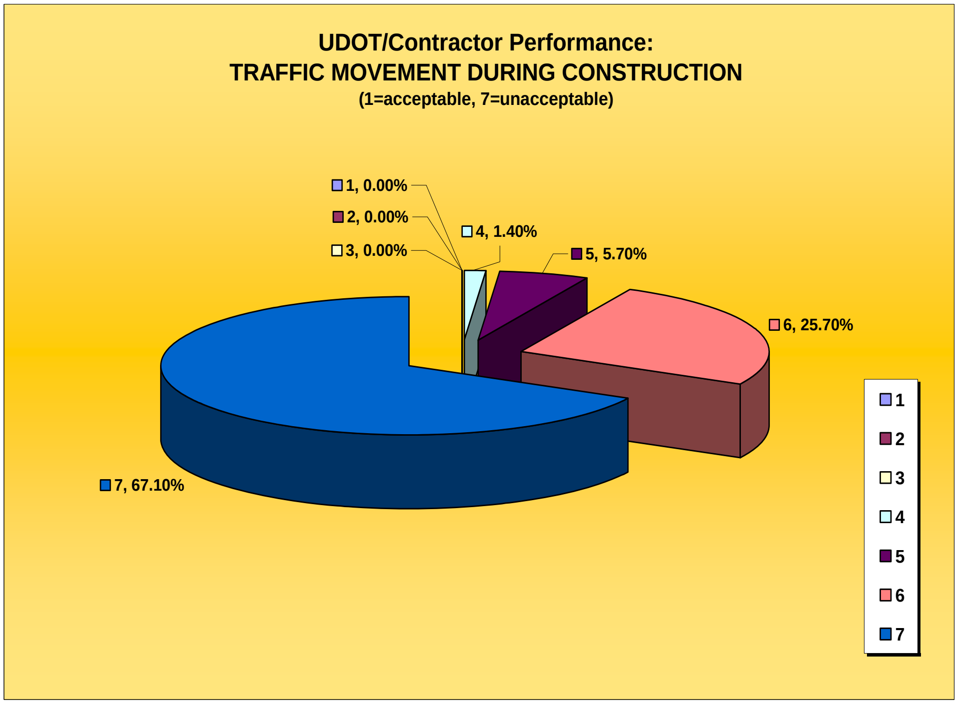

Figure 39. UDOT and contractor performance on traffic movement during construction.

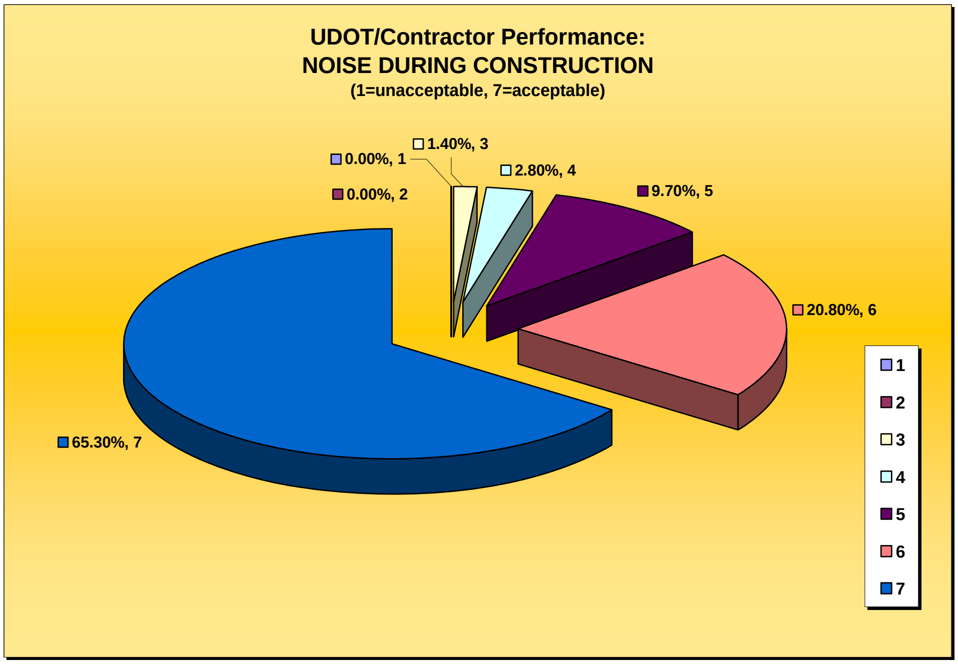

Figure 40. UDOT and contractor performance on noise during construction.

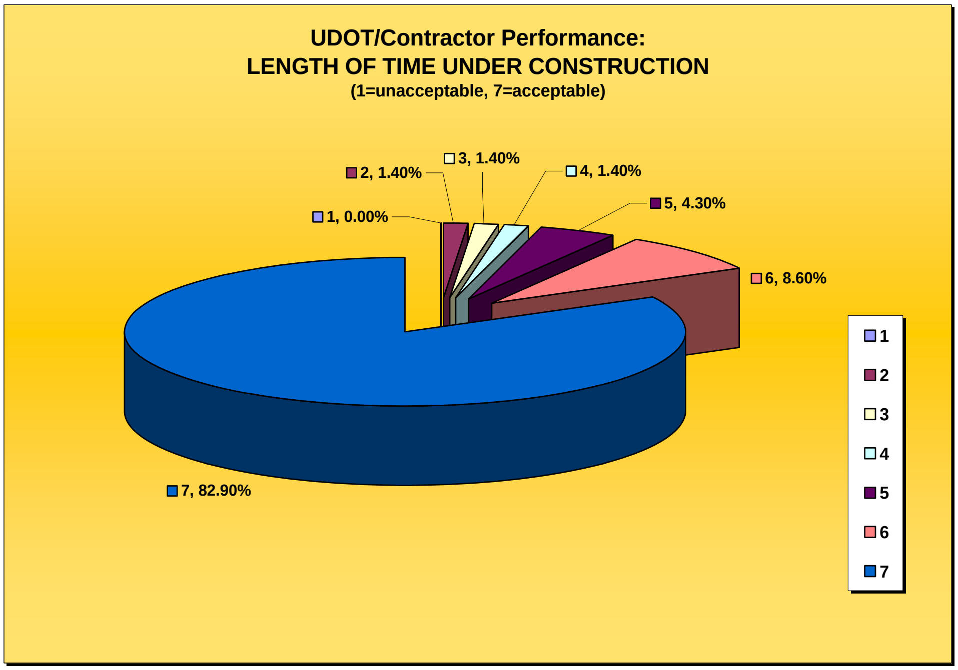

Figure 41. UDOT and contractor performance on construction time.

Table 4. Stakeholder satisfaction level.

On a scale of 1–7, please rate your satisfaction level with the following (1 meaning not satisfied and 7 meaning very satisfied).

Rate 1–7								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Response Count**
UDOT's and the construction contractor's overall performance during this project	0.0% (0)	0.0% (0)	0.0% (0)	2.8% (2)	5.6% (4)	23.9% (17)	67.6% (48)	71
Your overall satisfaction level with the results of the recent roadwork on the 4500 South/ I-215 East Bridge	0.0% (0)	0.0% 0)	1.4% (1)	1.4% (1)	2.8% (2)	18.3% (13)	76.1% (54)	71
Our information efforts, or the ways we provided you information about the recent roadwork activities on the 4500 South/I-215 East Bridge	0.0% (0)	4.2% (3)	1.4% (1)	5.6% (4)	9.7% (7)	22.2% (16)	56.9% (41)	72
Your information level, or how well informed you were during the recent roadwork activities on the 4500 South/ I-215 East Bridge	0.0% (0)	2.8% (2)	2.8% (2)	4.2% (3)	12.5% (9)	25.0% (18)	52.8% (38)	72
							Answered question	**72**
							Skipped question	**3**

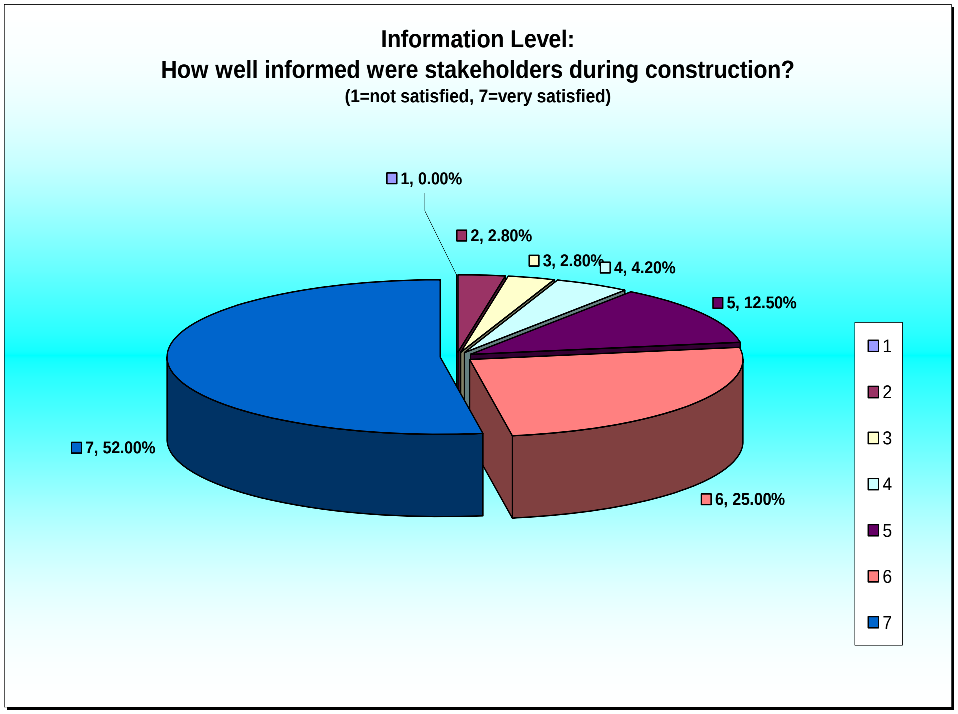

Figure 42. Stakeholder information level during construction.

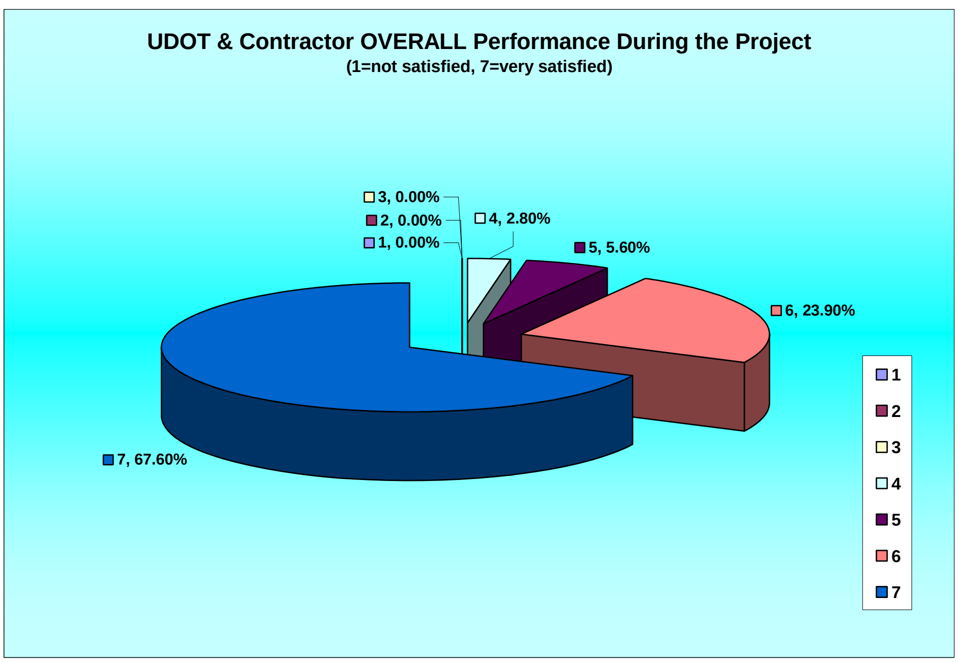

Figure 43. Overall project performance for UDOT and contractor.

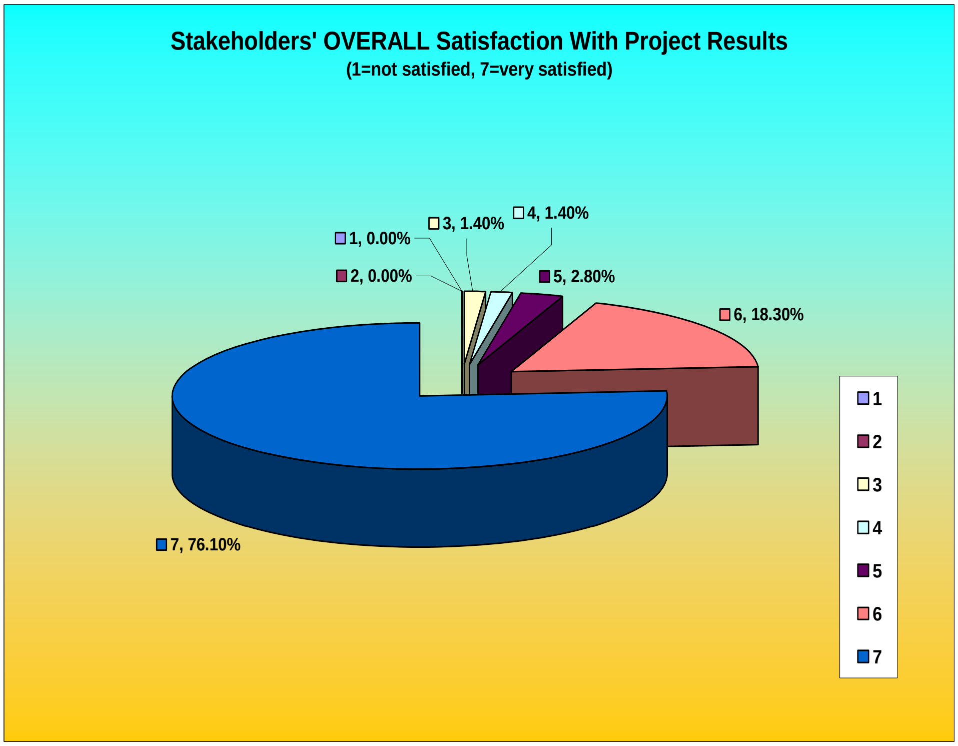

Figure 44. Stakeholders' overall satisfaction with project results.

Table 5. Information sources.

On a scale of 1–7 please rank the materials or methods we used to keep you informed about the activities and schedules during the recent roadwork on the 4500 South/I-215 East Bridge (1 meaning least effective and 7 meaning most effective).

	Rate 1–7							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Response Count**
a. E-mail updates	15.8% (3)	15.8% (3)	15.8% (3)	21.1% (4)	5.3% (1)	5.3% (1)	21.1% (4)	19
b. Road signs	1.6% (1)	0.0% (0)	1.6% (1)	6.5% (4)	12.9% (8)	27.4% (17)	50.0% (31)	62
c. Direct mail	4.2% (2)	8.3% (4)	6.3% (3)	12.5% (6)	8.3% (4)	14.6% (7)	45.8% (22)	48
d. Project hotline (801-891-8340)	6.9% (2)	3.4% (1)	6.9% (2)	24.1% (7)	3.4% (1)	20.7% (6)	34.5% (10)	29
e. Highway advisory radio	5.9% (2)	0.0% (0)	8.8% (3)	17.6% (6)	11.8% (4)	20.6% (7)	35.3% (12)	34
f. UDOT Web site	3.4% (1)	6.9% (2)	3.4% (1)	13.8% (4)	6.9% (2)	24.1% (7)	41.4% (12)	29
g. Fliers delivered to your home or workplace	2.3% (1)	4.7% (2)	4.7% (2)	25.6% (11)	11.6% (5)	16.3% (7)	34.9% (15)	43
h. Local meetings in open house format	3.6% (1)	7.1% (2)	10.7% (3)	32.1% (9)	10.7% (3)	7.1% (2)	28.6% (8)	28
							Other (please specify)	13
							Answered question	**65**
							Skipped question	**10**

Other information sources listed as effective:

- Newspaper (4)
- Highway caution signs [are] the best
- TV and print news
- TV
- Media/newspaper (6)
- News

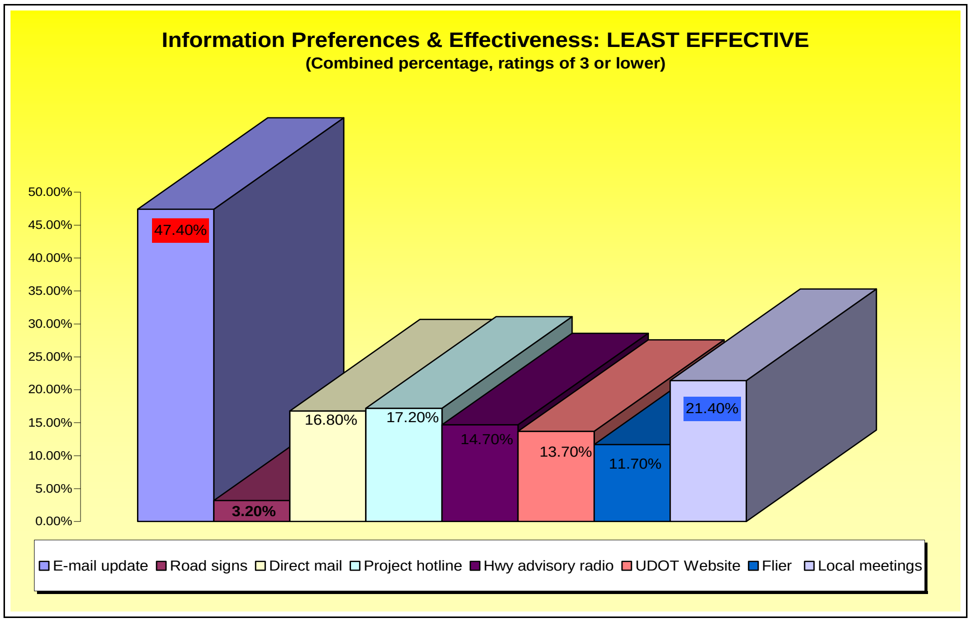

Figure 45. Least effective information sources.

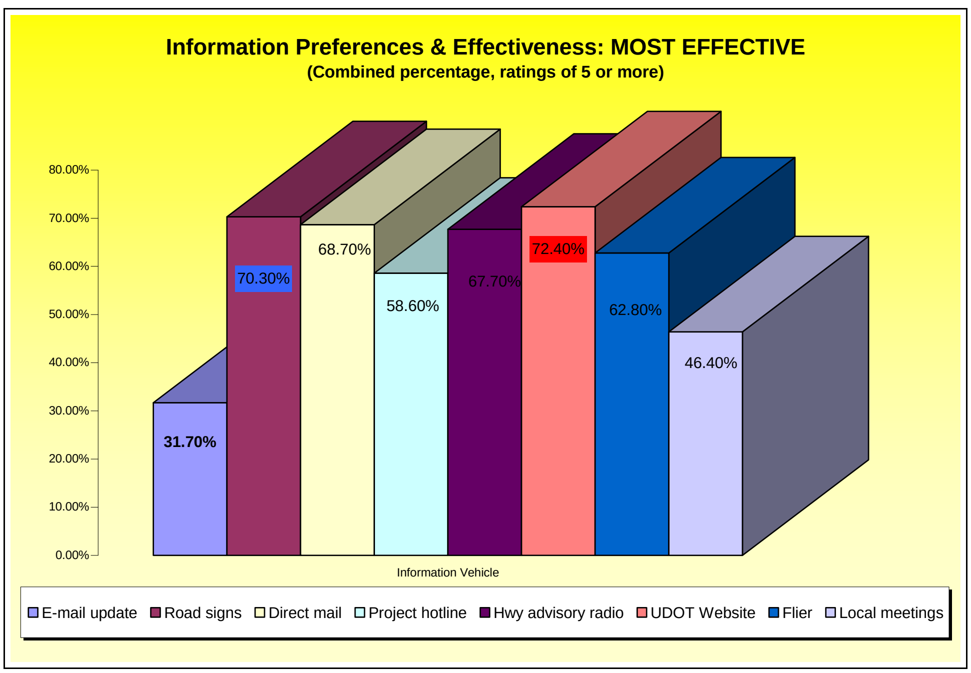

Figure 46. Most effective information sources.

5. What suggestions, comments, or questions do you have concerning the recently completed roadwork on the 4500 South/I-215 East Bridge?

- No design incorporation for increased pedestrian safety. Did not change the incident angle of bridge—still too steep.
- Good job!
- Nothing is said about the extra cost to the taxpayers for this type of construction. This is important to me. The 45th overpass could have been closed for a long time since there is freeway access close by 39th South.
- None. I though things went well.
- Good job!
- I like this new method.
- Certainly did not tie up road traffic very long. Good process for bridge building!
- Satisfied with construction and completion time.
- The stories on the nightly news were very informative and a great way to reach people.
- Direct mail info early helped.
- I thought the project was done very well and efficiently.
- For a first it was great! I'm sure there were things that will speed up the process in the future; keep up the good work.
- I love the rustic colors of the animals and mountains but I don't like the pinkish color of the bridge.
- Thought it was amazingly well orchestrated
- Great job, wonderful men.
- None, this was a job well done.
- We were very pleased in the way this was handled.
- Very well done.
- We were quite pleasantly surprised by how quickly it was completed.
- Planning and execution good, I-80 [will be] more of a challenge.
- The only thing to improve your operations—serve coffee to the hundreds of us that viewed your operations. Congrats on a job well done.
- The project was well managed with minimal problems accessing I-215 when we needed to. A great job and we will enjoy it.
- I was impressed with this job. Very fast, short interruption.
- It was actually a fairly easy process for such a big project.
- The only problem our household encountered was the lack of information on I-215 southbound indicating whether the off ramp to 4500 South was open [after the bridge was placed]. We ended up at 6200 South to get off on more than one occasion when we would have used [the] 3900 South off ramp if the information had been visible from I-215.
- We thought the project was very successful. [If we had known] the off ramp to 4500 South was unavailable from the roadside it would [have helped]. That was also true when the 4500 South off ramp reopened permanently. The information wasn't out there and we had taken a different path to our home at 2400 East, 4500 South when someone caught [a] glimpse [that] it was finally open. In spite of the inconvenience, we felt the bridge project was very successful and appreciate a site to view the old bridge being removed and the new one installed. Good work.

- You did a great job, very quick and efficient.
- Was able to access info after some searching. Most valuable was gained from media (newspaper, TV).

APPENDIX B: WORKSHOP AGENDA

Utah Department of Transportation/Federal Highway Administration
Showcase–Workshop
October 27, 2007

1. Welcome to Utah—John Njord, Executive Director, Utah Department of Transportation (UDOT)

2. Welcome—King Gee, Associate Administrator, Federal Highway Administration (FHWA)

3. National Perspective of Accelerated Bridge Construction (ABC)—Vasant Mistry, Office of Bridge Technology, FHWA

4. Accelerated Bridge Construction Overview— Jim McMinimee, Director of Project Development, UDOT

Break

5. Project Challenges:
    a. Project Team—Randy Park, Region Director, UDOT
    b. Management—Lisa Wilson, Project Manager, UDOT
    c. Design—Michael Arens, Structural Engineer, Baker Inc.
    d. Construction—Kip Wadsworth, Ralph Wadsworth Construction
    e. Self-Propelled Modular Transporter (SPMT)—Bill Halsband, Vice President, Mammoet

Break

6. Project Panel Discussion
    a. Region—Randy Park
    b. Project Manager—Lisa Wilson
    c. Project Designers—Michael Arens
    d. Contractor—Kip Wadsworth
    e. SPMT Operations—Bill Halsband

Break

7. ABC Panel Discussion: What is your plan after the workshop?
    a. Administration—Jim McMinimee
    b. Research—Shana Lindsey
    c. FHWA—Vasant Mistry

Moderator—Shana Lindsey, Director of Research, UDOT