Iowa Demonstration Project: Improvements to the 24th Street–I-29/80 Interchange in Council Bluffs

Final Report
November 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 Iowa Department of Transportation (DOT) was awarded a $1 million grant to demonstrate the use of proven, innovative technologies for accelerated bridge construction. This report documents the use of these innovations, such as cost-plus-time (A+B) bidding and prefabricated full-depth bridge panels used to accelerate the construction of the 24th Street–Interstate 29/80 diamond interchange in Council Bluffs in one construction season.

This report details the innovation used to reconstruct the 24th Street bridge with precast bridge deck panels, high-performance materials, and innovative construction and contracting techniques. Innovations in this project increased safety, enhanced quality, and allowed the contractor to replace the 24th Street bridge in one construction season instead of two as would have been required for traditional construction methods.

Using prefabricated deck panels and high-performance materials increased the initial construction cost by 12 percent over traditional construction. However, a more comprehensive economic analysis including user cost savings shows that the project saved road users about $1 million (or about 8 percent of the $12.7 million project costs). The experience gained on this successful project will help the Iowa DOT implement these innovations more routinely on future projects.

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SI* (MODERN METRIC) CONVERSION FACTORS

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mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
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yd^2	square yard	0.836	square meters	m^2	m^2	square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
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gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	cubic meters	35.71	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1000 shall be shown in m^3									
		MASS					**MASS**		
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fc	foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
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lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3	kg/m^3	pounds per cubic foot	0.062	kilograms per cubic meter	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 Iowa Department of Transportation Engineers John Carns, Ahmad Hawash, and Orest Lechnowsky and FHWA Engineers Andrew Wilson, Joe Jurasic, and Curtis Monk 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
A+B	cost-plus-time bidding
AADT	annual average daily traffic
CBIS	Council Bluffs Interstate System
dB(A)	A-weighted decibels
DOT	department of transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
HMVMT	hundred million vehicle-miles traveled
HPC	high-performance concrete
HPS	high-performance steel
Hz	hertz
IRI	International Roughness Index
ITS	intelligent transportation system
LTAP	Local Technical Assistance Program
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SI	sound intensity
SRTT	standard reference test tire
VOC	vehicle operational costs
vpd	vehicles per day

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration's (FHWA) 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 1 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 (in/mi).

- 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 Iowa Department of Transportation's HfL demonstration project, which involved innovative bridge reconstruction and improvements to the 24th Street–Interstate 29/80 interchange. The report presents project details relevant to the HfL program, including innovative contracting, bridge replacement and construction highlights, 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 Iowa DOT, Nebraska Department of Roads, and FHWA, in coordination with the city of Council Bluffs and the Metropolitan Area Planning Agency, proposed improvements to the Council Bluffs Interstate System (CBIS) around Council Bluffs, IA, with improvements extending across the Missouri River on I-80 into Omaha, NE. The proposed improvements were intended to upgrade mobility through the I-80, I-29, and I-480 corridors; improve the condition of the roadways; reduce traffic congestion and crashes; strengthen system linkages by making transitions between interstates easier; correct functional design issues; and accommodate planned development. These improvements, once implemented, were designed to bring the interstate segments up to current engineering standards and modernize the existing roadway to accommodate future traffic needs.

The 24th Street interchange reconstruction was an initial component of the CBIS. The interchange serves major businesses, such as a large outdoor retailer, a convention and event center, and several casinos, hotels, and semitruck service centers. Access to these businesses and attractions was a major concern during the construction period when access from the interstate to 24th Street was restricted.

The primary component of this project was to replace the existing four-span concrete bridge with a wider and longer two-span steel girder bridge. The city of Council Bluffs recently completed roadway improvements on 24th Street south of the bridge consisting of a five-lane roadway with a raised median. Similar improvements to the north of this interchange were built concurrent with the bridge reconstruction.

As part of the 24th Street interchange improvement project, the existing bridge was replaced in two phases. Each construction phase included one through lane in each direction and a third lane to accommodate left turns. The project widened westbound I-29/80 to the median side in preparation for the ultimate CBIS 12-lane reconstruction project scheduled for 2011. Traffic was shifted onto this widened section to allow the new single bridge pier to be constructed. The new vertical profile on 24th Street was raised about 5 feet (ft) to gain the necessary vertical clearance over the interstate. This grade raise required reconstruction of about 1,340 ft of 24th Street and portions of all four ramps of this rural diamond interchange. New interchange signals and lighting were incorporated to handle the design geometry and anticipated traffic volumes.

Normally, construction time for a project of this magnitude would span two consecutive construction seasons. This project was completed in only one season under an accelerated construction schedule using contract and construction innovations that included the following:

- Use of cost-plus-time bidding to reduce the time required to deliver the project
- Use of full-depth, precast bridge deck panels made with self-consolidating, high-performance concrete (HPC) to ensure quality, increase speed of construction, and improve safety

- Use of HPC throughout the bridge and high-performance steel (HPS) welded plate girders to increase quality of the completed bridge
- Incorporation of a structural health monitoring system to evaluate and document the performance of the in-service materials after project completion
- Fully contained flooded granular backfill installed behind the abutments to mitigate settlement that inevitably occurs with conventionally compacted backfill
- Use of intelligent transportation system (ITS) technology to optimize traffic control during construction

A key innovation was reconstructing the bridge with full-depth precast bridge deck panels. The Iowa DOT uses partial-depth panels for low-volume bridges, but full-depth panels are still a new concept for high-volume corridors. These panels are cast offsite in a controlled environment, steam cured, and made with an innovative self-consolidating HPC to improve consolidation around the complicated arrangement of reinforcing bars and post-tension ducts. The use of prefabricated precast deck panels not only shortened construction time, but is also expected to improve long-term performance of the bridge because the panels were produced under controlled conditions in strict compliance with quality control measures.

HfL Performance Goals

Safety, construction congestion, quality, and user satisfaction data were collected before, during, and after construction to demonstrate that innovations can be deployed while simultaneously meeting the HfL performance goals in these areas.

- **Safety**
  - Work zone safety during construction—No motorist incidents were reported during construction, which means the Iowa DOT exceeded the HfL requirements for worker safety. A key feature of this project was accelerating the construction schedule to only one April-to-October construction season, eliminating hazardous winter driving conditions through the work zone.
  - Worker safety during construction—No worker injuries occurred during construction, which exceeded the goal of less than a 4.0 rating on the OSHA 300 form. Postconstruction facility safety will be checked in future years.

- **Construction Congestion**
  - Faster construction—Conventional construction methods would have negatively impacted both 24th Street and the interstate with construction-related congestion for an estimated 16 months. Shortened construction time limited construction impact on traffic flow to less than 6 months, surpassing the goal of reducing construction time by half.
  - Trip time—A 2-day study was undertaken to measure actual travel times to assess the additional time required to traverse both I-29/80 and 24th Street in the vicinity of the project. The travel time study also included the exiting maneuvers from I-29/80 onto 24th Street. It was found that travel speeds along I-29/80 averaged near or above the posted speed limit in both the eastbound and westbound directions. Neither exit ramp to 24th Street queued back onto the freeway

mainline lanes during any of the travel time runs. Consequently, construction had no measurable impact on I-29/80 traffic, which satisfied the goal of no more than a 10 percent increase in travel time. However, traffic on the exit ramps and crossing over the 24th Street bridge experienced 40 percent or more delay time from lane reduction. Researchers calculated a total of 607 vehicle-hours of delay per day while the traffic management plan for the project was in place. This value also represents the daily benefits achieved for motorists from the steps taken to accelerate construction and reduce overall project duration.
    - Queue length during construction—Queue lengths on the interstate lanes were nonexistent. Queues on the exit ramps were less than the 0.5-mile maximum goal and were prevented from spilling out onto the interstate mainline through signalization and the use of queue detection with ITS. Travel speed across the bridge dropped to more than 20 mi/h less than the posted speed, resulting in queue lengths that were absorbed onto local roads.

- **Quality**
    - Smoothness and noise—Smoothness across the 24th Street bridge was dramatically increased. IRI dropped from a preconstruction value of 199 in/mi to a postconstruction 86 in/mi. Although the HfL goal for IRI of 48 in/mi—reasonably attainable on long, open stretches of pavement—was not met on this project, the 113 in/mi drop in IRI value is a reflection of the high quality of construction.
    - Noise—Quality was measured in terms of noise (OBSI) and smoothness (IRI) both before and after construction. The sound intensity data showed a substantial 4.8 dB(A) reduction in noise from a preconstruction level of 99.2 to a 94.4 dB(A) postconstruction level, meeting the HfL requirement of 96.0 dB(A) or less.
    - User satisfaction—The traveling public and businesses gave the project high marks for overall satisfaction and recognized the importance of keeping traffic flowing during construction. Satisfaction with the finished product is high and meets the HfL user satisfaction criteria of 4-plus on a 7-point Likert scale.

ECONOMIC ANALYSIS

The costs and benefits of this innovative project approach were compared with those of a project of similar size and scope delivered using a more traditional approach. The economic analysis revealed that the Iowa DOT's approach realized a cost savings of about $1 million or 8 percent of the total project over conventional construction practices. A significant amount of the cost savings was from reduced construction time.

LESSONS LEARNED

Through this project, the Iowa DOT gained valuable insights on the innovative processes deployed—both those that were successful and those that need improvement in future project deliveries.

- It is important to provide plenty of lead time (early letting) for projects of this type with nonstandard details. This project had the extra lead time needed to process submittals on the innovative construction techniques and materials.
- The Iowa DOT implemented a successful preconstruction testing program to evaluate construction details unique to the full-depth panels, such as the shear joint transfer for different roughened surfaces between the panels, the shear stud pocket size for welding the stud to the bridge girders, and the stud bend testing. Also, a mockup of the haunch area behind the abutments was built to study the effectiveness of the fully contained flooded backfill. This program was invaluable in finalizing the bridge design and incorporating innovation.
- Collaboration with the industry to address details related to the innovations before design was very important to the success of this project.
- For projects such as this with new construction techniques, it is advantageous to reduce critical path steps in the construction schedule.
- Consider having a designated design engineer on call for quick resolution of design issues on the critical path.
- Considerable experience was gained with the many innovations introduced.
- Consider using a Web-based project communication system to communicate project information and streamline shop drawings and requests for information.

CONCLUSIONS

The Iowa DOT gained considerable experience with the innovations used on this project and, because of the success, is encouraged to include these innovations in future projects. Success was measured in increased safety, quality, and the reality of bringing the project to completion in far less time than with traditional contracting and construction.

PROJECT DETAILS

BACKGROUND

The focus of this project was to replace the existing 24th Street bridge as part of overall improvements to 24th Street and the diamond interchange. The existing four-span 215-ft by 53-ft pretensioned, prestressed concrete beam bridge was replaced with a two-span 350-ft by 105-ft steel welded girder bridge. The new bridge has an 82-ft roadway width, a 10-ft multiuse trail on the west side, and an 8-ft sidewalk on the east side. The 24th Street 2004 annual average daily traffic (AADT) across the bridge was 12,400 vehicles per day (vpd), and the estimated 2030 AADT is 27,700 vpd with 14 percent truck volume. For I-29/80, the 2004 AADT was 81,900 vpd and the estimated 2030 AADT is 124,400 vpd with 11 percent truck volume. Traffic was maintained on I-29/80 except during placement of the bridge girders and deck panels directly over the interstate, when traffic was routed onto the 24th Street ramps. Figure 1 shows the general project location.

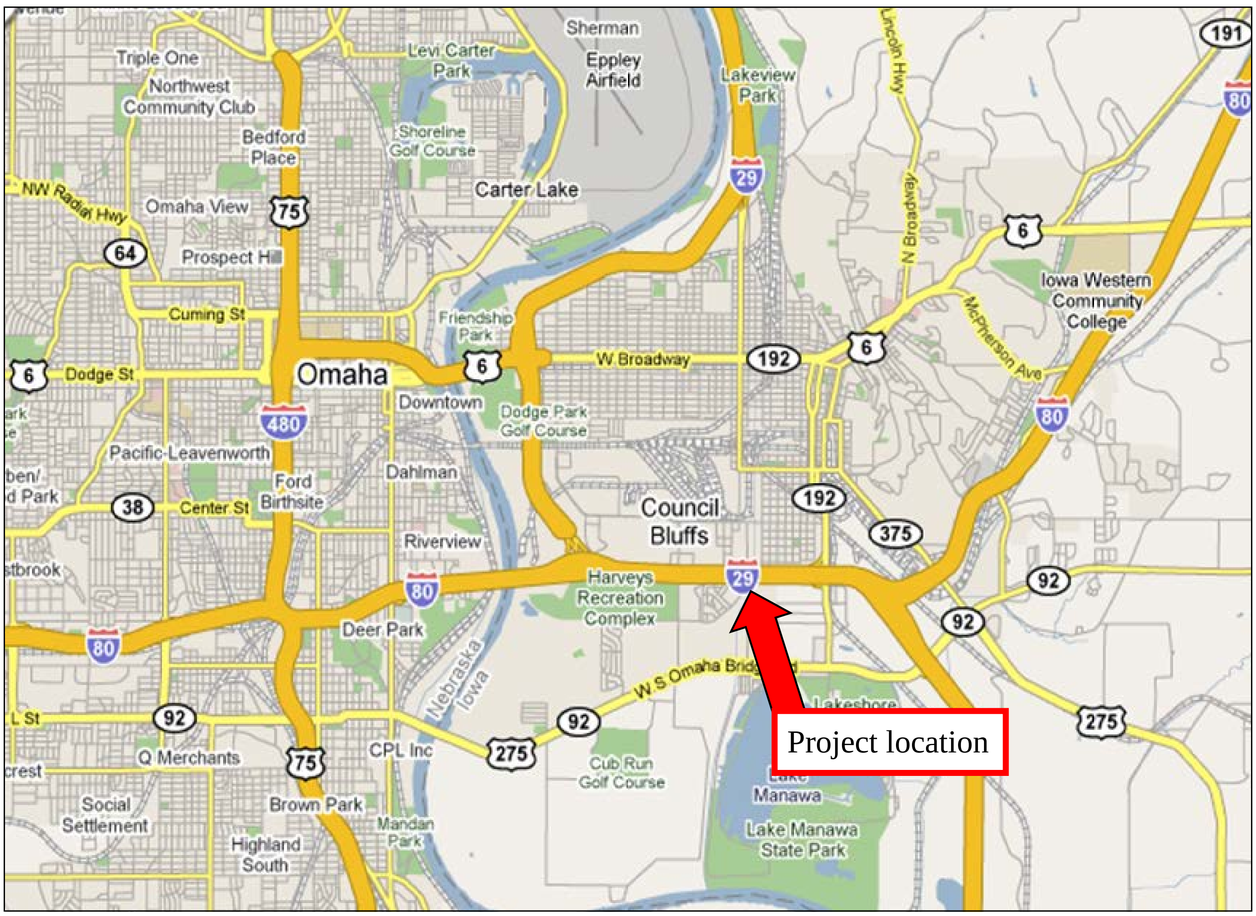


Figure 1. General project location.

PROJECT DESCRIPTION

The new 24th Street bridge is wider than the old bridge to match the city's planned 24th Street improvements. The old bridge is shown in figure 2 and the new bridge, almost complete, is shown in figure 3.

Figure 2. Existing four-span bridge.

Figure 3. New 24th Street bridge near completion.

The superstructure of the new double-span bridge is comprised of 12 composite steel girders with a deck of 70 precast, post-tensioned panels and a 2-inch concrete overlay. Two construction phases were needed to build the superstructure and maintain traffic across the bridge. The bridge deck plan shown in figure 4 illustrates the phased construction.

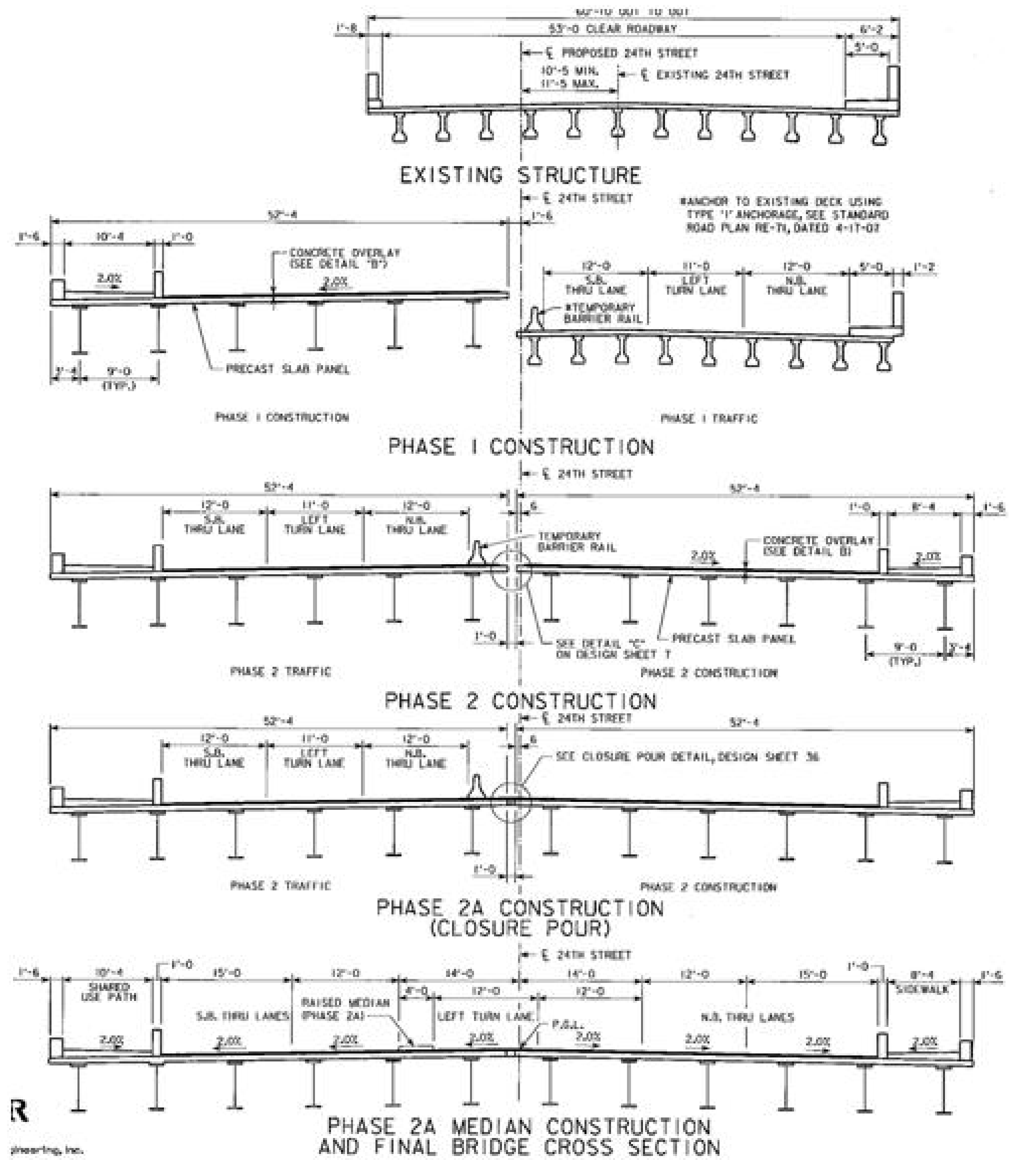


Figure 4. Bridge deck plan.

The bridge was constructed via the use of phased construction, maintaining at least one lane of traffic in each direction and left-turn lanes at all times on 24th Street. The interchange ramps, approach pavements, and westbound I-29/80 were reconstructed to the extent required to accommodate the proposed bridge location, roadway width, length, and grade. New interchange signals and lighting were incorporated to handle the new design geometry and traffic volumes.

The project widens westbound I-29/80 to the median side in preparation for the CBIS 12-lane reconstruction project scheduled for 2011. Traffic was shifted onto this widened section to allow the new single pier to be constructed. The new vertical profile on 24th Street was raised about 5 ft to gain the necessary vertical clearance over I-29/80. This grade raise required about 1,340 ft of 24th Street and portions of all four ramps in the diamond interchange to be reconstructed.

Innovative construction and contracting techniques used to bring this project to fruition are described in the following sections.

Cost-Plus-Time (A+B) Contract Bidding

Because of the size and scope of this project, it would have required at least two construction seasons to complete it using traditional methods. To reduce the project delivery time and open all lanes on the new bridge within one construction season (April through October), the Iowa DOT selected the A+B contract bidding process. This procedure selects the low bidder based on a monetary combination of the contract bid items (A) and the time (B) needed to complete the critical portion of the project. This method favors contractors that explore innovative construction methods to reduce cost and motivates contractors through incentives to minimize the delivery time.

During the planning stage, it was deemed impractical to impose additional constraints by further reducing construction time. As with any construction project, the additional cost for further reduction in construction time requires justification. Under these circumstances, the goal of construction acceleration by 50 percent was considered appropriate, given the need to maintain traffic during construction and the use of many innovations. From I-29/80, 24th Street provides vital access to several regional attractions and businesses in the area. These attractions include a casino, a convention and event center, and a large outdoor retailer. Both the city and the State made a commitment to provide access to these businesses during construction.

The decision to choose a maximum of one full construction season for this project was made after consulting with local contractors. All contractors at the constructability review meeting held to discuss accelerated construction methods for the project were in favor of a staged construction for one full construction season.

The accelerated project schedule was as follows:

- The project was let in October 2007.
- Steel was ordered in November 2007. It was anticipated that most of the steel would be fabricated before the start of construction and traffic restriction.
- Construction and traffic restriction began in April 2008.
- The area was open to traffic in October 2008.
- Traffic restriction was expected to last a maximum of 215 days. The actual contract was awarded to a contractor that limited construction of the bridge to 175 days.

Full-Depth Deck Panels and Self-Consolidating Concrete

The Iowa DOT uses partial-depth panels for low-volume bridges, but full-depth panels are still a new concept for high-volume corridors. The precast panels were transversely prestressed during casting and post-tensioned longitudinally after being placed on the bridge. These panels were cast offsite in a controlled environment, steam cured, and made with an innovative self-consolidating concrete to improve consolidation around the complicated arrangement of reinforcing and post-tension ducts. Figure 5 shows self-consolidating concrete flowing around the reinforcing steel in a panel form and three completed panels stacked after curing. Figure 6 shows panels in position at the job site.

Figure 5. Self-consolidating concrete being placed and three panels ready for delivery.

Figure 6. Panel being placed and several panels installed on the new bridge girders.

The deck panels span about half the width of the bridge and accommodated the two phases of construction traffic. Where the panels met near the bridge centerline, concrete was cast to join the two halves of the bridge deck (figure 7).

Figure 7. Longitudinal panel connection.

After the panels were placed, they were secured to the girders with shear stud connectors welded to the top flange of the girders. The shear stud pockets were then filled with grout and allowed to cure before the surface overlay was placed. This method gave the contractor flexibility to make field adjustments to the panels to ensure proper alignment.

Laboratory and field testing was undertaken by researchers at the Iowa State University Bridge Engineering Center[1] to investigate constructability issues related to the panels and to evaluate the bridge during and after construction. Preconstruction laboratory testing on the full-depth panels is discussed in this section, and the field testing is described in the structural health monitoring section of this report.

Laboratory mockups of the stud pockets as specified in the bridge plans (figure 8) were built and investigated to determine the ability to test the shear studs once they are welded to the top flange of the girder and how to get adequate flow of grout into the haunch between the panel and top flange. The contractor was involved in the process and determined that the shear stud pocket as designed would work in the field.

[1] Iowa State University Bridge Engineering Center, *Laboratory Testing and Evaluation Report, 24th Street Bridge over I80/I29, Council Bluffs, Iowa*, February 28, 2008.

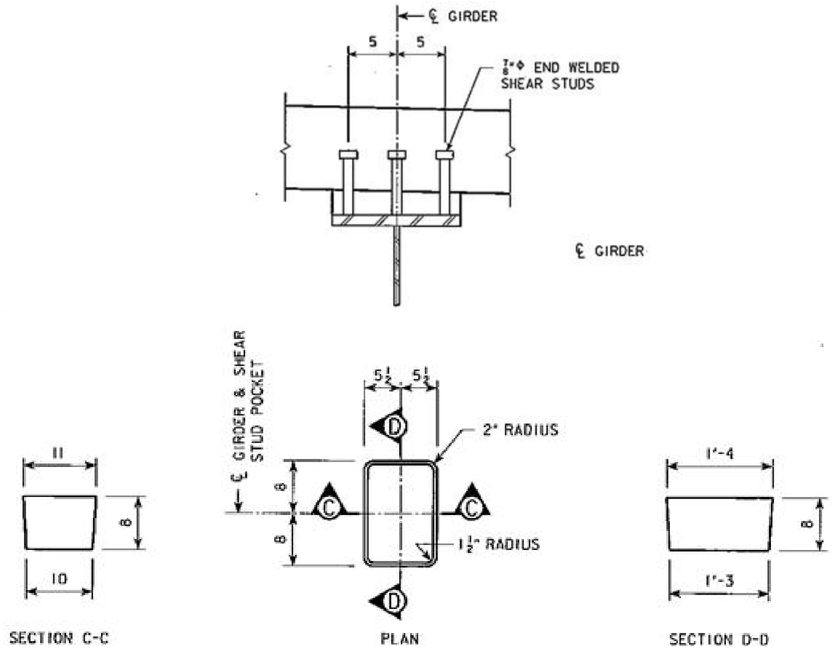


Figure 8. Shear stud pocket detail.

Plans called for the transverse joints between the panels to be filled with grout before the surface overlay was placed. Researchers examined methods to splice the longitudinal post-tension ducts at the transverse joint to keep moisture or grout from infiltrating the ducts. The result of the investigation indicated that sealing the post-tension duct connections with waterproof duct tape or a combination of waterproof duct tape and butyl rubber would be adequate.

The influence of surface treatment on the transverse joint shear transfer between panels was also examined in the laboratory. Precast diamond plate texturing, chemical etching, and sandblasting were evaluated as possible surface treatments to promote bonding at the panel transverse shear key (figure 9). Sandblasting was found to deliver the highest shear bond of the three treatments.

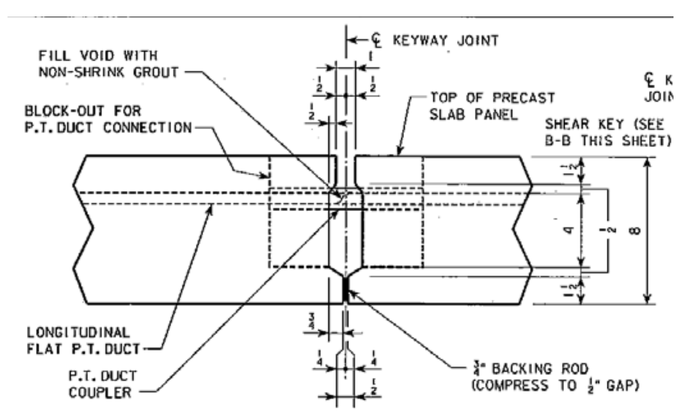


Figure 9. Shear key detail.

High-Performance Steel

HPS was used for the continuously welded plate composite girders (figure 10). Special low alloy 70 kilo-pound per square inch (ksi) steel gives these girders better corrosion resistance and increased fracture toughness over conventional steel. The expected benefit is longer service life with less maintenance during the life of the bridge. The Iowa DOT developmental specification DS-01065 sets standards for the materials as well as fabrication of the steel components that make up the girders.

Figure 10. High-performance bridge girders.

High-Performance Concrete

HPC is new to western Iowa due in large part to availability of materials. Iowa DOT developmental specification DS-01092 requires HPC to have 28-day compressive strength of 4,500 pounds per square inch (psi) and 5,000 psi for bridge deck and substructure, respectively. Permeability levels are specified to enhance the concrete’s resistance to chloride-related distresses. HPC was placed for all bridge components, including the prefabricated bridge panels, overlay, pier, and abutments (figure 11).

Figure 11. Casting HPC at the bridge abutments.

Fully Contained Flooded Backfill

A frequent problem in any bridge construction is development of differential settlement between the bridge and the adjacent pavement, which motorists commonly experience as a bump or dip just before the abutment joint. This project provided the opportunity for Iowa DOT engineers to mitigate this problem by using fully contained flooded backfill behind the abutments. This involves placing a granular wedge behind the abutment backwall, applying conventional compactive effort with a plate tamper (figure 12), and flooding the backfill with water (figure 13) to achieve consolidation. This method, designed to be superior to traditional compaction methods, minimizes settlement.

Figure 12. Granular material behind the abutment.

Figure 13. Flooding the self-contained backfill with water to achieve consolidation.

Intelligent Transportation System

The original ITS plan was to have five permanently mounted cameras and sensors positioned at the 24th Street interchange and on I-80/29. Because of funding difficulties, that system was not used. Instead, two portable cameras and two portable sensors were stationed on I-80 on either side of the interchange. Figure 14 shows the ITS equipment in service at a similar project on I-80 west of Council Bluffs.

The system had an automated feature to notify authorities in case of traffic-flow irregularities. If the sensors detected the traffic speed dropping below an expected rate, an e-mail was automatically sent via wireless cellular technology to officials, who could then determine the appropriate action. If sensors detected unusual congestion, a larger list of officials would be notified and the proper response assets activated to alleviate the cause of the congestion.

Figure 14. ITS portable camera (left) and the ITS portable sensor (right).

Data were collected in both directions from each location on I-80. The sensors and cameras were bidirectional and were positioned about 1 mile east and west of the bridge, which allowed monitoring of traffic conditions from the vantage point of overlooking the interstate as traffic approached from both directions. A sample of the sensor data, shown in table 1, includes the traffic volume, lane occupancy, vehicle speed, and time of recording.

Table 1. ITS sensor data sample.

Traffic Volume	Lane Occupancy	Vehicle Speed mi/h (km/h)	Record Time (date/hour)
313	1.43	45.9 (73.9)	8/10/2008 / 2
95	0.98	44.9 (72.3)	8/10/2008 / 3
91	0.90	43.0 (69.2)	8/10/2008 / 4
84	0.88	44.9 (72.3)	8/10/2008 / 5
98	0.84	42.2 (67.9)	8/10/2008 / 6
134	1.02	48.6 (78.2)	8/10/2008 / 7
213	1.56	49.8 (80.1)	8/10/2008 / 8

A late merge system was proposed that would have coordinated the cameras, sensors, and dynamic message boards to direct traffic merging maneuvers while lane closures on I-29/80 were in effect. This system provides the most benefit for moderate volume levels of mostly passenger vehicles. Consequently, the system was not deployed because of the few nighttime lane closures that did occur; the traffic was light and contained a relatively large percentage of trucks. Traffic conditions did not warrant the additional cost of using the system. Dynamic message boards were used, not as part of this proposed late merge system, but as a traditional nonautomated application to inform the traveling public of work zone conditions.

Structural Health Monitoring System

A structural health monitoring system was implemented through the coordination and expertise of the Iowa State University Bridge Engineering Center. Field data were collected during panel placement and after the bridge was completed, but the final results of this research effort have not been published. The innovative system involves corrosion monitoring of steel pre- and post-tension strands, monitoring of the panels during handling, and live load testing of the bridge.

Figure 15 shows corrosion sensor wiring for monitoring the long-term integrity of prestressed steel tensioning strands in the panels. Six pretensioned strands were instrumented during panel fabrication and six sacrificial post-tensioning strands were instrumented in the field.

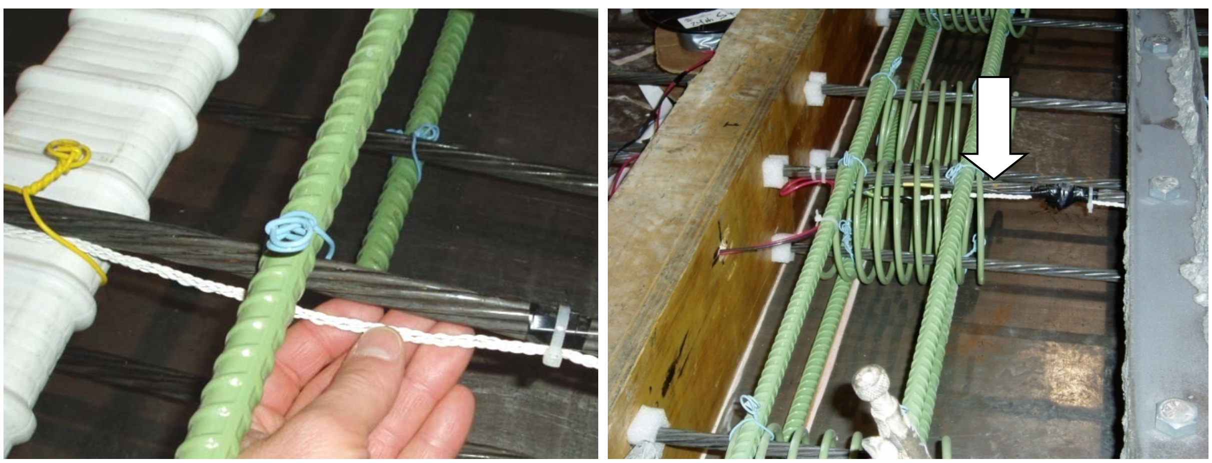


Figure 15. Corrosion sensors installed in a panel before casting.

Two panels were instrumented with externally mounted strain gauges to document the performance of the panels from the point of shipping from the casting plant until the panels were placed on the bridge girders.

A series of strain gauges and deflection transducers were installed at critical locations on the steel girders of the completed bridge to test the performance of the bridge under semicontrolled live loads. These instruments collected time-history data from the bridge as it reacted to a fully loaded dump truck being driven across the bridge. The results will allow researchers to compare actual bridge performance to the expected design performance. The results from this Iowa State University research[2] are expected to be completed by June 2010.

[2] *Evaluation of the 24th Street Bridge, Interstate 80/29, Council Bluffs, Iowa*, (expected June 2010), Iowa State University Bridge Engineering Center.

Public Outreach

Public meetings were held during construction to gain input from the public and provide updates on the progress of the interchange and the concurrent CBIS project. Newsletters were distributed at key events throughout the development of the project. Meetings were held with area businesses impacted by the reconstruction to discuss the project. An advisory committee of local officials was used before and during construction as part of the CBIS project to keep local agencies abreast of the construction schedule and possible impacts on commerce.

A Web site was developed (www.iowadot.gov/cbinterstate.com) to provide background on the project as well as to notify the public about construction activities, road closures, detour routes, and schedules (figure 16). The Iowa DOT also covered the project in the *Insight* newsletter posted on its Web site to provide information to the public about construction progress and announcements for public meetings.

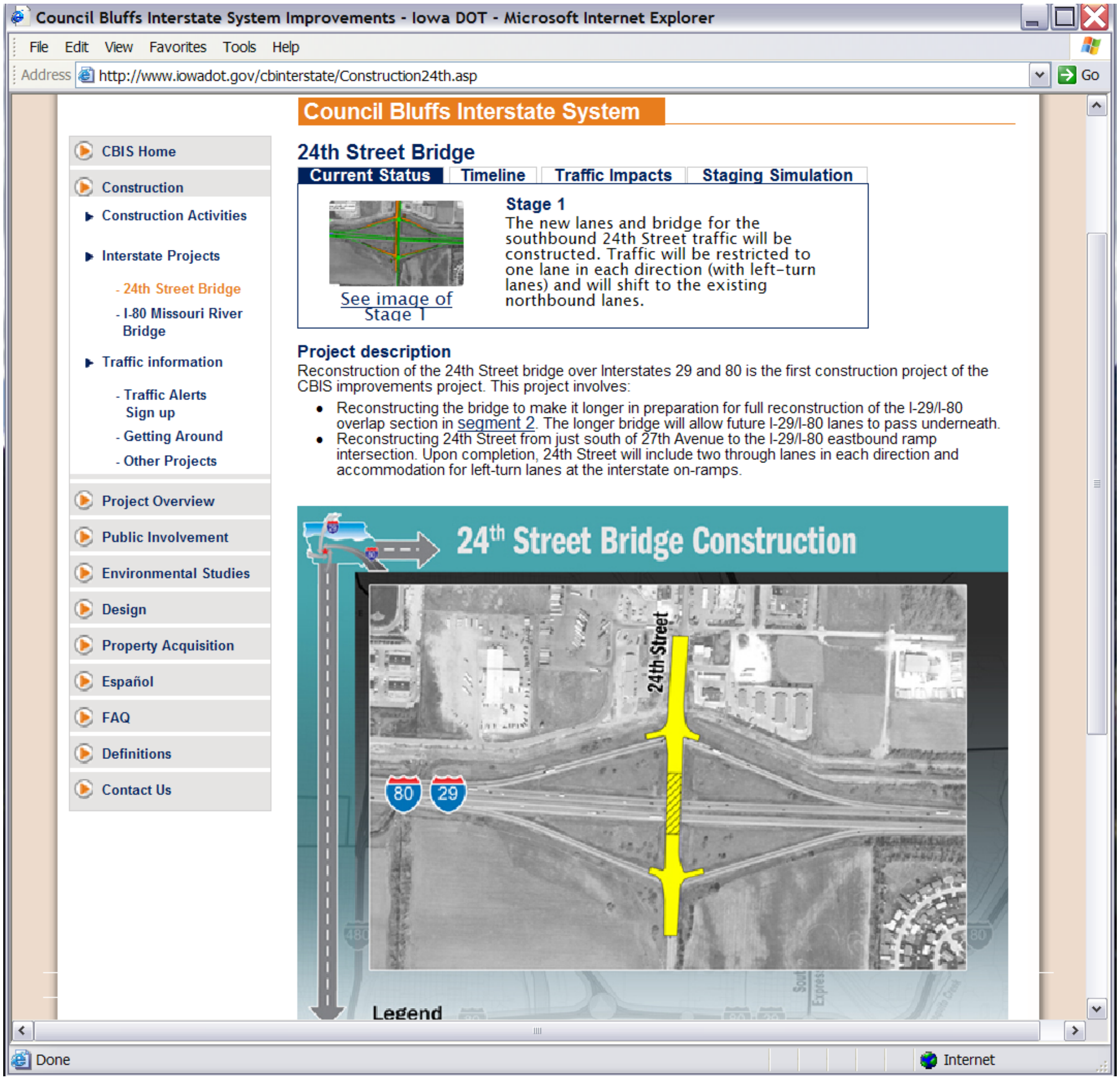


Figure 16. Iowa DOT 24th Street bridge construction information Web site.

DATA ACQUISITION AND ANALYSIS

Data on safety, traffic flow, quality, and user satisfaction were collected before, during, and after construction to determine compliance with the HfL performance goals. The primary objective of acquiring these types of data was to quantify the project performance, provide an objective basis on which to determine the feasibility of the project innovations, and demonstrate that the innovations 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 a high-quality project and gain user satisfaction.

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

SAFETY

Work zone safety for the workers and traveling public during construction was improved through the use of prefabricated bridge components and the A+B bidding method. Both features were intended to accelerate construction and reduce the construction time from two construction seasons to one. A key component of this project was that traffic was not impacted over the winter, when inclement weather would increase the driving hazard through the construction zone. Consistent with this concept, the fall 2007 letting date was selected to allow early ordering of the steel girders for spring delivery and restrict traffic impact to the April-through-October construction season.

Furthermore, placing precast deck panels over interstate traffic minimized the public's exposure to overhead construction hazards, compared to traditional cast-in-place construction in which concrete form work and casting are done directly over live interstate traffic lanes.

During construction, no worker injuries were reported, which means the Iowa DOT exceeded the HfL goal for worker safety (incident rate of less than 4.0 based on the OSHA Form 300 rate). No motorist incidents were reported in the construction zone on the 24th Street bridge or on the interstate below. In contrast, the existing interchange area had an above-average crash rate in the past. Crash data from 2001 to 2005 show the following statistics:

- Total crashes: 146 (47 involved personal injury (fatal and nonfatal) and the remainder are assumed to be noninjury (property damage only))
- Interchange crash rate: 146.2 crashes per hundred million vehicle-miles traveled (HMVMT)

Most crashes occurred on the ramps and at the ramp terminals and appeared to be the result of minimal storage for vehicles on the ramp. The new bridge project added more turn lane storage and storage capacity. The result is more efficient signal cycles that clear the arriving vehicles in short, efficient platoons, promoting shorter queues and less exposure to opposing traffic.

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 two full construction seasons (16 months).With the use of accelerated construction techniques and contracting, the impact was reduced to one construction season. The innovations reduced congestion several ways:

- The use of precast deck panels reduced congestion:
  - By improving traffic flow during construction and reducing motorist impact because of the shortened construction period.
  - By reducing materials deliveries such as fresh concrete and concrete forms and therefore construction traffic because the deck panels were fabricated offsite.
  - By requiring less onsite storage area.
- A+B bidding shortened the duration of construction congestion by allowing the Iowa DOT to select the most efficient bid in terms of construction cost and duration of traffic impact.
- Installation of an intelligent transportation system was specifically targeted at reducing construction congestion. The system had automated components to detect travel speed and queuing lengths and helped the contractor regulate traffic flow.

The longer life of the structure from the use of HPS, HPC, and flooded backfill is expected to reduce congestion because of reduced future maintenance activities. Both the reduction in total construction time and in the impacts on motorists compared to conventional construction methods for this project far exceeded the HfL performance goals.

TRAFFIC STUDY

To assess the impacts of the construction project on motorists, researchers conducted a series of travel time runs to determine the additional travel time required to traverse both I-29/80 and 24th Street in the vicinity of the project. The travel time studies included exiting maneuvers from I-29/80 onto 24th Street. Studies were conducted midway through the construction schedule.

Researchers used the floating vehicle methodology to collect travel times, attempting to mimic the typical driving speed of other vehicles along the various roadway segments of the construction zone. Data were collected on weekdays during daytime hours (7 a.m. to 7 p.m.) when traffic demand was high and the work zone would have the greatest impact. Over a 2-day period, researchers collected a total of 17 travel times on I-29/80 and 34 times on 24th Street.

Overall, travel speeds along I-29/80 averaged 60 mi/h in the eastbound direction and 59 mi/h in the westbound direction. Neither exit ramp to 24th Street queued back onto the freeway mainline lanes during any of the travel time runs. Consequently, there were no measurable impacts of construction on I-29/80 traffic.

Traffic congestion data include the computed impacts on traffic exiting to 24th Street from either direction on I-29/80 and on traffic on 24th Street itself. Travel times along the 1.5-mile length of

24th Street over 2 days of data collection averaged 5.8 minutes in the northbound direction and 6.5 minutes in the southbound direction. For eastbound I-29/80 traffic exiting at 24th Street and then turning left, travel times to the northern terminus of 24th Street averaged 4.0 minutes over the 0.9-mile distance. For westbound I-29/80 traffic exiting and then turning left, the travel time for the 1.4-mile journey to the southern terminus of 24th Street averaged 4.5 minutes.

Iowa DOT officials indicated that the same traffic management plan would have been used for this project regardless of whether accelerated construction techniques were used. Therefore, the benefits to the public from accelerated construction can be computed by determining the extent to which conditions during construction increased travel times over normal nonconstruction conditions, and then determining how many fewer days of construction were required by using these accelerated construction techniques.

Unfortunately, actual travel times under normal conditions (before the start of construction) were not available for this analysis. Therefore, researchers estimated what travel times may have been on the roadway under typical conditions before construction. Chapter 15 of the 2000 *Highway Capacity Manual* was used to estimate an average running time of 119 seconds per mile on 24th Street.

Added to this arterial segment running time was the additional delay expected to have existed at the interchange with 24th Street. For this estimate, researchers relied on guidance developed by the Texas Transportation Institute for the Texas Department of Transportation in *Recommended Ramp Design Procedures for Facilities Without Frontage Roads*. Assuming a fairly well-timed and operating diamond interchange, this guidance estimates the delay through a standard diamond interchange at about 21 seconds per vehicle.

Summing the running travel time along the 1.5-mile length of 24th Street with the additional 21 seconds required to traverse through the interchange at I-29/80 yielded a total expected travel time on 24th Street of 3.3 minutes in each direction. For the I-29/80 exiting traffic, researchers estimated normal travel times of 1.9 minutes and 1.4 minutes for the eastbound-to-northbound and westbound-to-southbound maneuvers, respectively. Using these numbers, table 2 presents the per-vehicle delays estimated to have been generated by the traffic management plan used for this project. For simplicity purposes, it appears reasonable to use a 2.6-minute delay per vehicle for all movement types within the interchange (for both through and exiting traffic).

Table 2. Per-vehicle delay estimates.

	Travel time, minutes per vehicle		
Movement	Estimated normal travel times	Travel times during construction	Additional delay
24th Street northbound	3.3	5.8	2.3
24th Street southbound	3.3	6.5	3.2
I-29/80 eastbound to 24th Street northbound	1.4	4.0	2.6
I-29/80 westbound to 24th Street southbound	1.9	4.5	2.6

In the HfL application the Iowa DOT submitted, traffic volumes at the site were provided for 2004 and 2030 estimates of traffic demands north, south, and across the 24^{th} Street bridge. For simplicity purposes, researchers used the bridge volume and extrapolated the count to 2008 values. This was estimated at 14,000 vehicles per day. Multiplying the daily traffic demands by the 2.6-minute-per-vehicle delay estimate from above, researchers calculated a total of 607 vehicle-hours of delay per day while the traffic management plan for the project was in place.

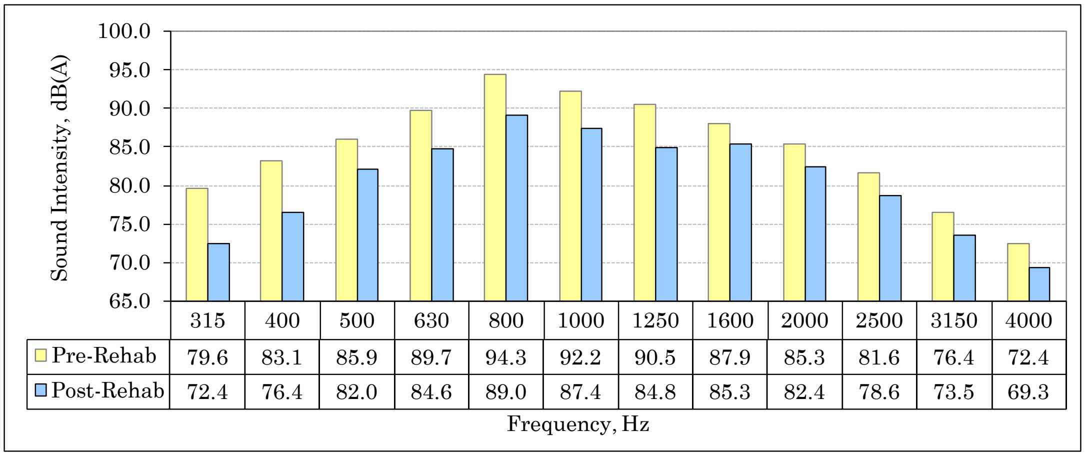
QUALITY

Sound Testing

Sound intensity (SI) measurements were made using the current accepted onboard sound intensity (OBSI) technique AASHTO TP 76-08, which include dual vertical sound intensity probes and an ASTM standard reference test tire (SRTT). Sound testing was done before construction and on the new bridge surface shortly after it was opened to traffic. OBSI measurements were obtained from the bridge at the posted speed limit of 35 mi/h. A minimum of three runs were made in the right wheelpath with the two phase-matched microphone probes simultaneously capturing noise data from the leading and trailing tire-pavement contact areas. Figure 17 shows the dual probe instrumentation and the tread pattern of the SRTT.

Figure 17. OBSI dual probe system and the SRTT.

The average of the front and rear OBSI values was computed over the full length of the bridge deck to produce sound intensity values. Raw noise data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean sound intensity levels were A-weighted to produce the noise-frequency spectra in one-third octave bands, as shown in figure 18. This chart shows that the new bridge surface was quieter at every band in the spectrum and particularly for the low frequencies, which means that noise from the new bridge will tend to not travel as far as noise from the old bridge.



	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
Pre-Rehab	79.6	83.1	85.9	89.7	94.3	92.2	90.5	87.9	85.3	81.6	76.4	72.4
Post-Rehab	72.4	76.4	82.0	84.6	89.0	87.4	84.8	85.3	82.4	78.6	73.5	69.3

Figure 18. Mean A-weighted sound intensity frequency spectra.

Global noise levels were calculated by using logarithmic addition of the one-third octave band frequencies between 315 and 4,000 hertz (Hz). The global noise levels were 99.2 and 94.4 dB(A) for the old and new bridge, respectively. For reference, a 3.0 decibel difference in noise is considered noticeable to the human ear. The original portland cement concrete bridge deck surface had multiple patches and distresses and was 4.8 decibels louder than the newly constructed bridge surface. Moreover, the HfL target value of less than 96.0 dB(A) was met.

Smoothness Measurement

Smoothness testing was done in conjunction with noise testing using a high-speed inertial profiler integrated into the noise test vehicle. Figure 19 shows the test vehicle with the profiler positioned in line with the right rear wheel. Figure 20 graphically shows the test results.

Figure 19. High-speed inertial profiler mounted behind the test vehicle.

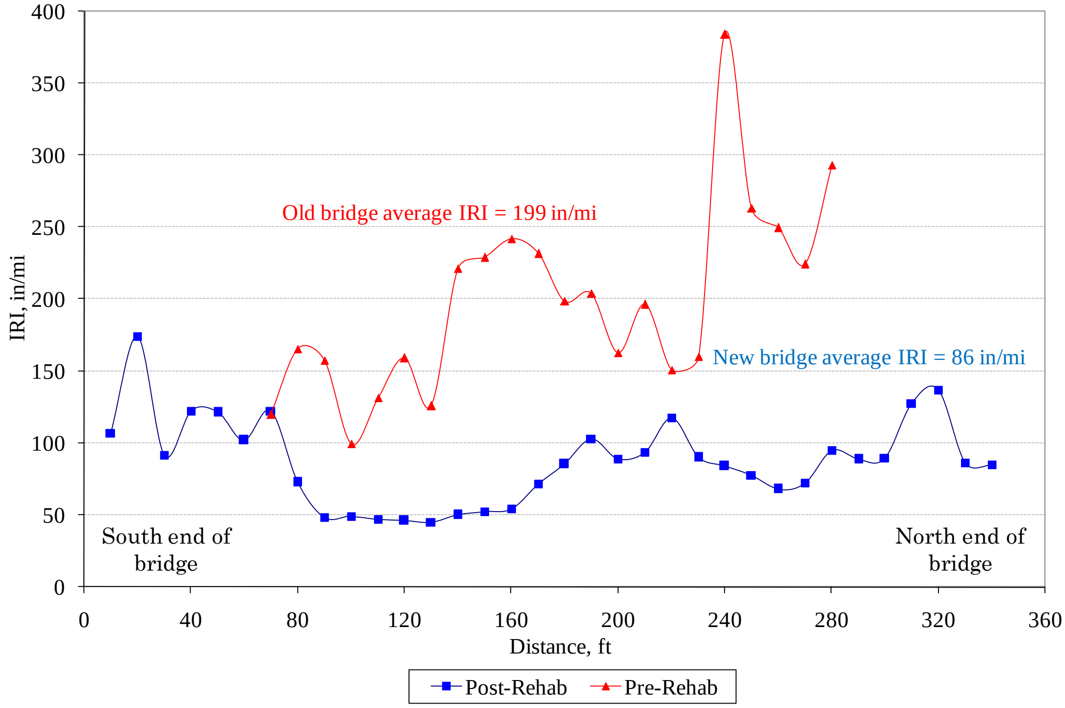


Figure 20. Mean IRI values for the old and new bridges.

The overall IRI values are 199 and 86 in/mi for pre- and postconstruction, respectively. Postconstruction IRI is more than 40 percent lower and is a direct result of quality construction. Figure 20 shows large peak values near the north end of the existing bridge, whereas the new construction has eliminated all but a few minor spikes in roughness.

The HfL goal for IRI of 48 in/mi, 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. Nonetheless, the new construction is a vast improvement over the existing bridge.

USER SATISFACTION

The HfL requirement for user satisfaction included a performance goal of 4-plus on a Likert scale of 1 to 7 for the following two questions:

- How satisfied are you with the new facility?
- How satisfied are you with the approach the Iowa DOT used (keeping 24th Street open) to construct the new facility in terms of minimizing disruption?

The Iowa DOT conducted a stakeholder survey in which nearby residents and businesses were encouraged to complete electronic survey forms (pdf format) indicating their approval of a wide variety of issues ranging from the most effective means of communication to construction details.

Instead of a 7-point scale, a 4-point scale was used to determine the level of project satisfaction. On either scale the targeted level of satisfaction needed to be at least 57 percent to meet HfL goals. The overall response indicates that the level of satisfaction exceeded the HfL goals; 97 percent of users gave high scores to the importance of the approach used on this project and 89 percent gave good to very good marks to the way the project was carried out. The Appendix contains the complete results of the survey.

TECHNOLOGY TRANSFER

To promote the innovations—prefabricated bridge panels, high-performance materials, construction methods, and the bidding process—the Iowa DOT in conjunction with FHWA and the Utah Local Technical Assistance Program (LTAP) sponsored a 1-day showcase. The showcase was held September 25, 2008, at the nearby Mid-America Center in Council Bluffs, IA. The event featured presentations by representatives of FHWA, the Iowa DOT, and the contractor, followed by a field trip to the project site to observe the second phase of bridge construction. Participants were able to observe traffic using the completed first phase of the project (figure 21). Figure 22 shows participants discussing bridge details onsite.

Figure 21. Phase one of the bridge construction open to traffic.

Figure 22. Showcase participants examining the new bridge construction.

More than 20 people from the Iowa DOT, FHWA, local agencies, the construction industry, and academia attended the showcase. The Appendix contains the workshop agenda and speakers list. During the showcase, John Carns of the Iowa DOT provided opening comments. He explained the need to keep the 24th Street bridge open to traffic to accommodate the surrounding community and forgo alternate designs that would have involved completely closing the bridge during construction. Joe Jurasic of FHWA gave an overview of the HfL program detailing the performance goals for this project and how the project will advance the use of new technologies for future bridge construction.

Norm McDonald of the Iowa DOT discussed the HfL project application process and how the 24th Street bridge project was selected based on the Iowa DOT's willingness to embrace innovation to bring about a better way of building public sector projects. George Feazell of the Iowa DOT gave an overview of the HfL goals on safety, congestion, and quality as they applied to this project. Feazell detailed the long-range development plan of the region to facilitate local growth while improving the overall mobility and aesthetics of the transportation corridor. Technical features of the specific innovations were presented by James Nelson of the Iowa DOT. Nelson also addressed the need to allow adequate lead time to fabricate the innovative deck panels and to review each new technology before it is incorporated into design.

Robert Cramer, the president of the contracting firm, gave the contractor’s perspective on construction of the project. He underscored the need for adequate planning and thinking outside of the box when it comes to scheduling and using new materials and techniques, such as full-depth deck panels and fully contained flooded backfill.

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 this economic analysis.

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

CONSTRUCTION TIME

It is likely that standard phase construction methods would have been used to build the bridge to insure that two or three lanes were kept open to 24th Street traffic. Completely closing the bridge to 24th Street traffic and reconstructing the entire bridge would have been the least expensive option in terms of construction costs, but it would have been unacceptable to the surrounding businesses that rely heavily on the interchange. Nevertheless, the phased construction method with traditional cast-in-place construction techniques serves as an appropriate baseline for comparison with the as-built phased construction method using innovative contracting and construction materials and techniques.

Conventional construction methods would have negatively impacted the 24th Street interchange with construction-related congestion for an estimated 16 months. Shortened construction time limited the impact on traffic flow to less than 6 months.

CONSTRUCTION COSTS

Table 3 presents the differences in construction costs between the baseline and the as-built alternatives. All of the as-built costs were taken from the actual contract bid provided by the Iowa DOT. Baseline costs were determined on the basis of a study of bridge replacement options for this interchange by HDR Engineering, Inc. and in consultation with the Iowa DOT engineering staff by noting whether the itemized as-built costs would have applied to the baseline case. Adjustments were made to the cost categories as necessary. 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.

It can be estimated from table 3 that the adoption of the HfL innovations (as-built scenario) to build the 24th Street interchange bridge resulted in an increased construction cost (less incentives) of $1,377,398 (12 percent) when compared with the baseline scenario.

Table 3. Capital cost calculation table.

Cost Category	Baseline Case	As-Built (A+B bid)
Design and Engineering[1]	$ 304,380	$ 516,032
Bridge Construction	$ 5,073,000	$ 6,450,398
Roadway Improvements	$ 4,807,721	$ 4,807,721
Traffic Control	$ 272,521	$ 272,521
Construction Inspection[2]	$ 50,730	$ 70,954
Other	$ 620,512	$ 388,636
Contract Incentives[3]	--	$ 232,494
Total Cost	**$ 11,128,864**	**$ 12,738,756**

Notes:
[1] Six percent baseline case and 8 percent as-built case of the bridge construction cost, according to the Iowa DOT.
[2] Assumed to include quality assurance program costs of 1 percent of the bridge construction cost. As-built inspection costs were about 10 percent higher than average.
[3] Incentives were collected almost exclusively from value engineering.

USER COSTS

Generally, three categories of user costs are used in an economic/life-cycle cost analysis: vehicle operating costs (VOC), delay costs, and safety-related costs. The cost differential in delay costs and safety costs were considered different enough to be included in a comparative analysis of cost differences between the baseline and as-built alternatives.

Delay Costs

The impact on traffic for the baseline case is based on using traditional contracting methods and cast-in-place construction. It is estimated that $1,560,135 was saved as a direct result of accelerating the construction to only a single season. The following provides a basis for this conclusion:

- The volume of trucks using the 24th Street bridge is 14 percent of the total AADT crossing the bridge; the remaining 86 percent is private vehicles.
- As concluded in the "Traffic Study" section of this report, 607 vehicle-hours of delay per day occurred while the traffic management plan was in place.
- The Iowa DOT contracting office estimates the cost to the public at $8 an hour per private vehicle and $24 an hour per single and multiple-unit commercial truck.
- Total time savings is one construction season (one whole season is 213 days) plus 38 days saved during actual construction, totaling 251 days.
- Estimated daily user cost is the sum of the cost of private and commercial vehicle use:
    - Vehicle hours of delay/day * percent private vehicles * vehicle costs/day * total time savings = 607 * 0.86 * $8.00 * 251= $1,048,216
    - Vehicle hours of delay/day * percent commercial trucks * vehicle costs/day * total time savings = 607 * 0.14 * $24.00 * 251 = $511,919
    - Total delay cost savings is $ 1,048,216 + $ 511,919 = $1,560,135

Safety Costs

As discussed earlier in this report, this interchange has experienced above-average occurrences of crashes over the past several years. Costs associated with the crashes that could have occurred during the project construction are detailed below.

Assumptions and data supporting the cost analysis are as follows:

- The 24th Street and I-29/80 2008 AADT are estimated at 14,000 and 88,438, respectively, as extrapolated from the Iowa DOT 2004 and estimated 2030 AADT.
- The interchange area is estimated to include the 24th Street bridge across I-29/80 and the portion of I-29/80 interstate between the closest interchanges immediately to the east and west of the 24th Street bridge interchange. This totals about 6.8 lane-miles of affected area.
- According to the Iowa DOT, this affected area has experienced 146 crashes on average (based on data from 2001 to 2005) per hundred million vehicle-miles traveled (HMVMT). This results in an overall crash rate of 0.215 (146 crashes/100 million vehicles/6.8 miles).
- The crash rate is further defined as crashes that result in personal injury and nonpersonal injury:
    - According to the Iowa DOT, 47 of the 146 crashes/HMVMT involved personal injury (injuries and fatalities), for which the crash rate is 0.069 (47 crashes/100 million vehicles/6.8 miles).
    - The nonpersonal injury-causing crash rate is 0.146 (146-47 crashes/100 million vehicles/6.8 miles).

Ullman et al[3] investigated the safety of work zones for various scenarios: (1) crashes during daytime and nighttime work periods when lanes were closed and work was ongoing, (2) crashes when work was ongoing but no closures were required, and (3) crashes when no work was ongoing (the work zone was inactive). They concluded that crashes increased 60 to 66 percent (an average of 63 percent) when a traffic lane was closed day or night. Given this information and considering the traffic volumes and hourly traffic variations on this highway and the expected construction schedules, table 4 presents the number of vehicles that would have passed through the work zone for the as-built and baseline projects.

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[3] Ullman, G.L., M.D. Finley, J.E. Bryden, R. Srinivasan, and F.M. Council, *Traffic Safety Evaluation of Nighttime and Daytime Work Zones* (NCHRP Report 627), National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, 2008.

Table 4. Estimated total traffic for the intersection used to compute safety impacts for baseline and as-built scenarios.

	Baseline Case		As-Built Case	
	I-29/80	**24th Street**	**I-29/80**	**24th Street**
Two-way 2008 (estimated) AADT, vehicles/day	88,348	14,000	88,348	14,000
Total number of construction days	496 (assumed)	496 (assumed)	175	175
Total Traffic Volume (millions) (2-way AADT * Construction days)	**43.82**	**6.94**	**15.46**	**2.45**

Table 4 shows that the total volume of traffic exposed to crash risk was much lower for the as-built case than the baseline case. The estimated increase in crashes for the baseline case can be computed as the product of (1) the historical crash rate for each type of crash (number of crashes per million vehicles), (2) the total volume of traffic exposed to the risk, and (3) the risk escalation factor associated with work zones (= 0.63, as discussed earlier). This is computed for the baseline case as follows:

- Estimated personal injury-causing crashes due to work zone on I-29/80:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (43.82) * 0.069 * (1.0 + 0.63) = 4.93 crashes

- Estimated personal injury-causing crashes due to work zone on 24th Street:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (6.94) * 0.069 * (1.0 + 0.63) = 0.78 crashes

- Estimated nonpersonal injury-causing crashes due to work zone on I-29/80:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (43.82) * 0.146 * (1.0+0.63) = 10.43 crashes

- Estimated nonpersonal injury-causing crashes due to work zone on 24th Street:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (6.94) * 0.146 * (1.0+0.63) = 1.65 crashes

The elevated risk noted above was monetized by assuming unit costs from Council et al[4] for the various types of historical crashes reported by the Iowa DOT. The following mean comprehensive costs per crash for a rural highway with a posted traffic speed greater than or

---

[4] These costs were based on F. Council, E. Zaloshnja, T. Miller, and B. Persaud, *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (FHWA-HRT-05-051), Federal Highway Administration, Washington, DC, October 2005.

equal to 50 mi/h (80.4 km/h) and an arterial highway with a posted traffic speed less than 45 mi/h (72.4 km/h) were used in the analysis:

- I-29/80 (rural highway with a posted traffic speed greater than or equal to 50 mi/h (80.4 km/h))
  - Injury-causing crash—$95,368 (injured, severity unknown, Level 5)
  - Noninjury crash—$25,735 (nature of crash unknown, Level 5)
- 24th Street (arterial highway with a posted traffic speed less than 45 mi/h (72.4 km/h))
  - Injury-causing crash—$72,002 (injured, severity unknown, Level 5)
  - Noninjury crash—$23,993 (nature of crash unknown, Level 5)

Table 5 presents the difference in safety costs for the baseline and as-built cases. It can be computed from the table that the total expected safety costs for the baseline case would have been $834,329 ($738,580 + 95,749) as opposed to no costs for the as-built case. The $834,329 total is essentially the safety benefit of the as-built case.

Table 5. Comparison of safety costs—baseline versus as-built.

	Baseline Case		**As-Built Case**	
	I-29/80	**24th Street**	**I-29/80**	**24th Street**
Personal injury-causing crashes (= Crash cost ($/crash) X Number of crashes)	$470,164 (= $95,368*4.93)	$56,161 (= $72.002*0.78)	$0 (No crashes)	$0 (No crashes)
Nonpersonal injury crashes	$268,416 (= $25,735*10.43)	$39,588 (= $23,993*1.65)	$0 (No crashes)	$0 (No crashes)
Total	**$738,580**	**$95,749**	**$0**	**$0**

COST SUMMARY

Construction costs (less incentives) for the 24th Street bridge would have likely placed the as-built construction at $1,377,398 (12 percent) more than the traditional delivery and construction methods. However, delivering the project in only one season saved users $1,560,135 in delay costs and $834,329 in safety costs. Using the innovative HfL project delivery approach saved an estimated $1,017,066. In other words, the innovative approach to this $12.7 million project had an 8 percent cost benefit over traditional methods.

APPENDIX

The figures and tables in this appendix document the results of the user satisfaction survey conducted by the Iowa Department of Transportation.

A postconstruction survey was sent to residences and businesses near the 24th Street interchange via electronic format. The survey not only addressed user satisfaction, but also sought to determine the best methods for communicating project information, such as lane configuration and project updates.

Table 6. Level of use of the 24th Street bridge during construction.

Rate your level of use of the 24th Street bridge during construction.		
Answer Options	**Response Percent**	**Response Count**
All the time	12.5%	3
Frequent	29.2%	7
Moderate	25.0%	6
Occasional	33.3%	8
Never	0.0%	0
Answered question		**24**
Skipped question		**3**

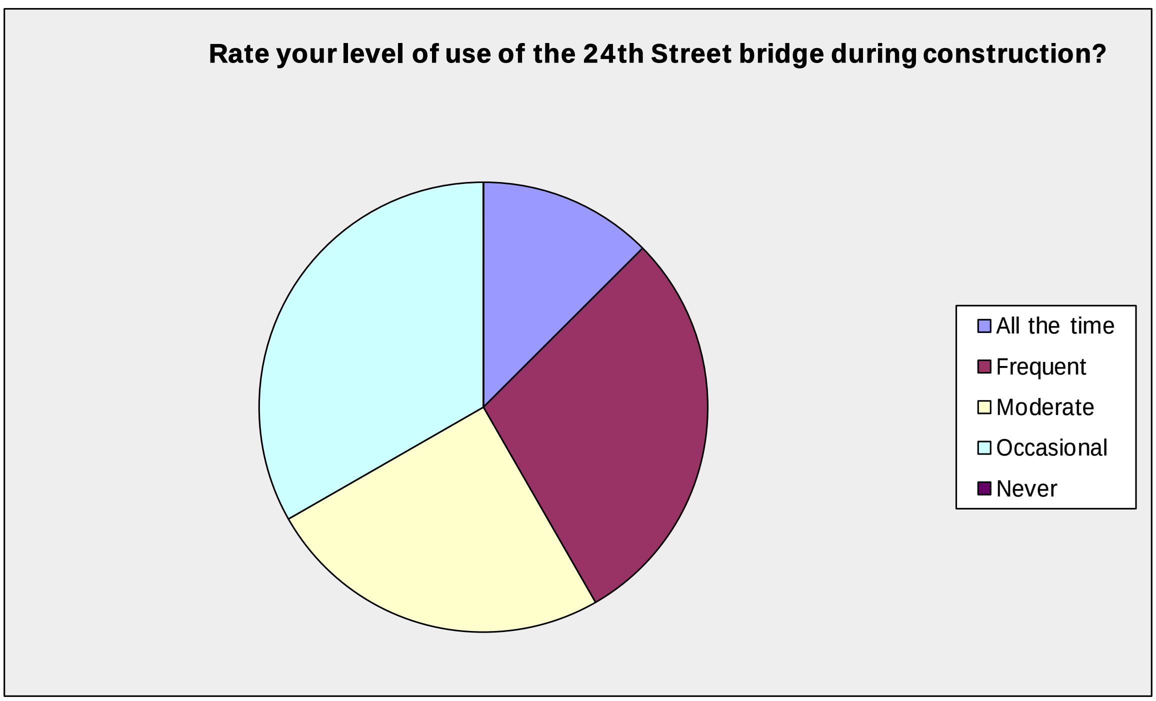

Figure 23. Level of use of the 24th Street bridge during construction.

Table 7. User demographics.

How would you best describe yourself? (Check all that apply.)		
Answer Options	**Response Percent**	**Response Count**
I own a business close to the project.	0.0%	0
I work at a business close to the project.	11.1%	3
I live close to the project.	25.9%	7
I regularly visit a business near the project.	37.0%	10
I often travel close to or visit areas near the project.	70.4%	19
I typically use 24th Street to get somewhere else.	29.6%	8
I don't typically drive near the 24th Street project.	3.7%	1
Answered question		**27**
Skipped question		**0**

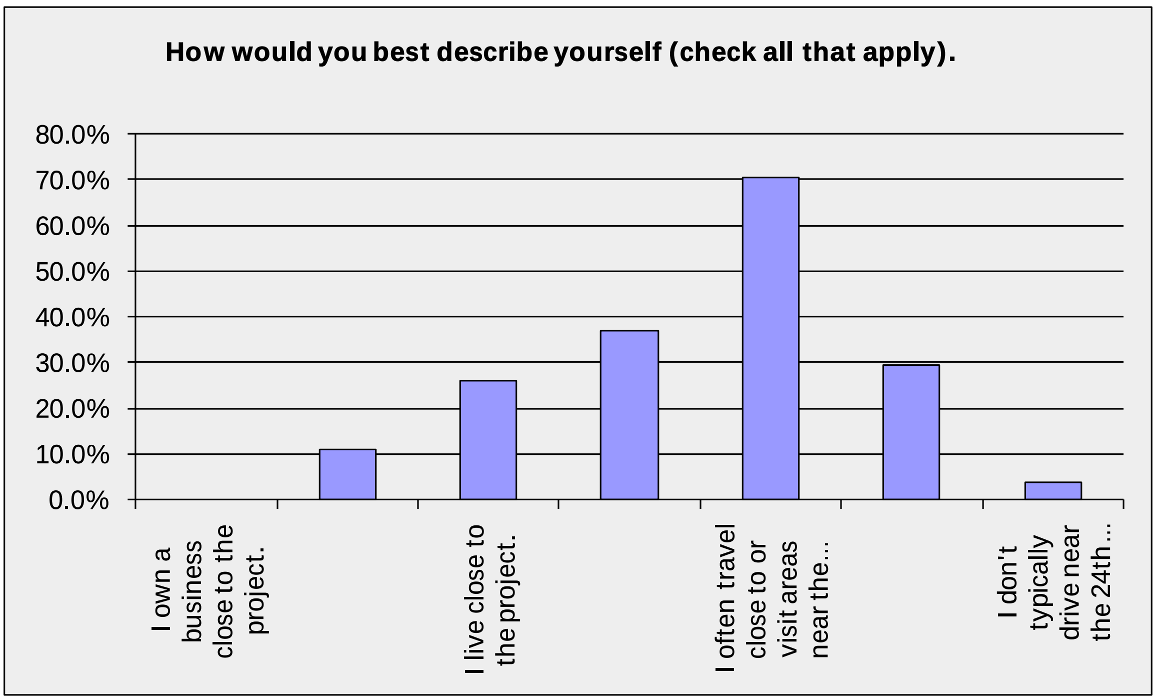

Figure 24. User demographics.

Table 8. User response to the importance of the project and how well it was executed.

Rate how important you believe each approach is and how well it was carried out on this project.					
Importance					
Answer Options	**Important**	**Somewhat Important**	**Somewhat Unimportant**	**Unimportant**	**Response Count**
–Keeping 24th Street open during construction	15	5	0	1	21
–Providing signage for businesses in the area	13	7	2	0	22
–Condensing project from 2 years down to 1	21	1	0	0	22
–Using stronger materials to extend bridge life and reduce future disruptions for maintenance	21	1	0	0	22
–Using prefabricated components to speed construction	18	4	0	0	22
–Using multiple methods (message signs, radio, texts, etc.) to advise motorists of construction and alternative routes	20	1	1	0	22
How well					
Answer Options	**Very Good**	**Good**	**Poor**	**Very Poor**	**Response Count**
–Keeping 24th Street open during construction	6	13	2	0	21
–Providing signage for businesses in the area	4	14	4	0	22
–Condensing project from 2 years down to 1	13	9	0	0	22
–Using stronger materials to extend bridge life and reduce future disruptions for maintenance	12	8	0	0	20
–Using prefabricated components to speed construction	8	11	1	0	20
–Using multiple methods (message signs, radio, texts, etc.) to advise motorists of construction and alternative routes	7	8	4	3	22
					Question Totals
Comments					2
				Answered question	**22**
				Skipped question	**5**

Table 9. User response to keeping 24th Street open to traffic.

Knowing it would mean traffic delays and driving through construction areas, how important was it to keep 24th Street open during construction?		
Answer Options	**Response Percent**	**Response Count**
Important	66.7%	14
Somewhat important	23.8%	5
Somewhat unimportant	4.8%	1
Unimportant	4.8%	1
Answered question		**21**
Skipped question		**6**

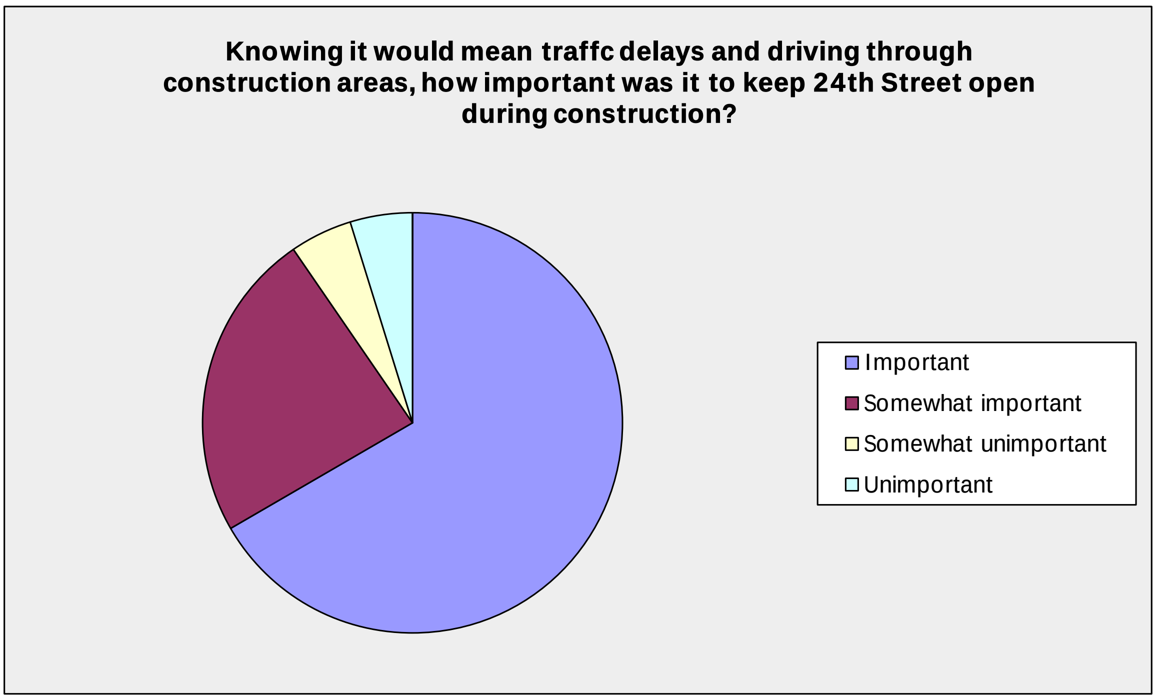

Figure 25. User response to keeping 24th Street open to traffic.

Table 10. Response to how well the Iowa DOT kept users informed about construction work.

How satisfied are you with the way the Iowa DOT kept you informed about the construction work?		
Answer Options	**Response Percent**	**Response Count**
Satisfied	50.0%	11
Somewhat satisfied	31.8%	7
Somewhat dissatisfied	18.2%	4
Dissatisfied	0.0%	0
Answered question		**22**
Skipped question		**5**

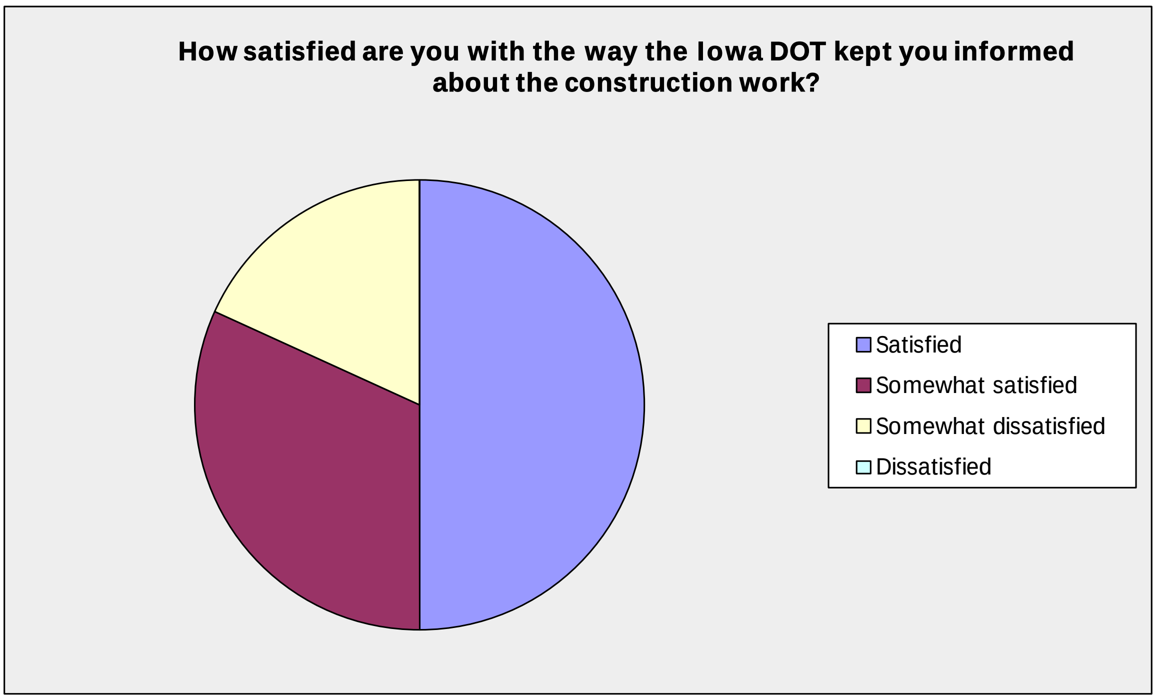

Figure 26. Response to how well the Iowa DOT kept users informed about construction work.

Table 11. Forms of communication used most often.

What means of communication do you USE MOST OFTEN to learn about traffic issues/road information?		
Answer Options	**Response Percent**	**Response Count**
Radio	57.1%	12
Web sites	52.4%	11
Text messages	9.5%	2
E-Alerts	52.4%	11
Changeable message signs	57.1%	12
Other (please specify)		5
	Answered question	**21**
	Skipped question	**6**

Number	**Response Date**	**Other (please specify)**
1	**Sept. 24, 2009 8:32 p.m.**	Word of mouth
2	**Sept. 25, 2009 1:02 a.m.**	Local newspapers
3	**Sept. 25, 2009 1:47 a.m.**	Television newscasts
4	**Oct. 2, 2009 8:30 p.m.**	TV
5	**Oct. 5, 2009 8:43 p.m.**	If there are changeable message signs, they should have Web site info for more details. Alternatively, just a regular sign with the Web site (to sign up for e-mail updates) would be great!

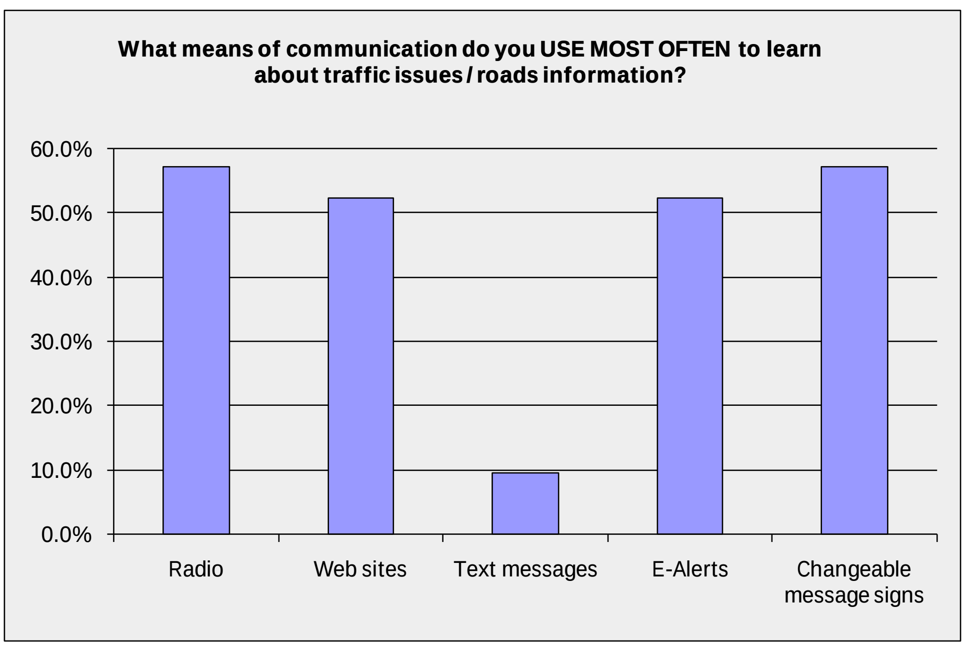

Figure 27. Forms of communication used most often.

Table 12. Best methods to keep users informed about traffic and construction issues.

What are the BEST METHODS to keep you informed regarding traffic issues/road construction?			
Answer Options		**Response Percent**	**Response Count**
Radio		59.1%	13
Web sites		36.4%	8
Text messages		22.7%	5
E-Alerts		59.1%	13
Changeable message signs		63.6%	14
Other (please specify)			3
		Answered question	**22**
		Skipped question	**5**
Number	**Response Date**	**Other (please specify)**	
1	**Sept. 25, 2009 1:47 a.m.**	Television newscasts and alerts	
2	**Oct. 2, 2009 8:30 p.m.**	TV helps	
3	**Oct. 5, 2009 8:43 p.m.**	If there are changeable message signs, they should have Web site info for more details. Alternatively, just a regular sign with the Web site (to sign up for e-mail updates) would be great!	

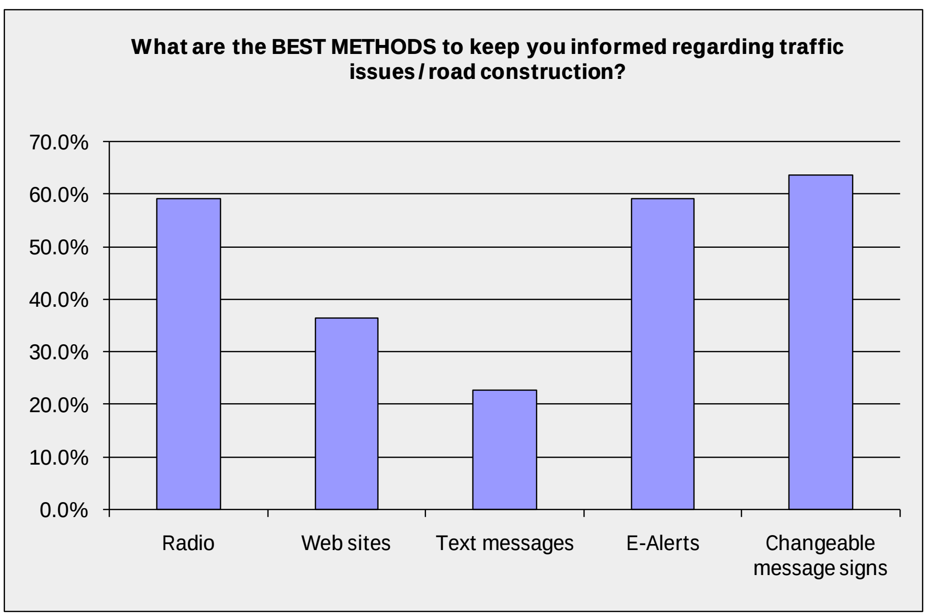

Figure 28. Best methods to keep users informed about traffic and construction issues.

Table 13. User rating of the finished project.

Rate the following aspects of the new 24th Street bridge and surrounding areas as compared to its previous condition.						
Answer Options	**Much Better**	**Better**	**Unchanged**	**Worse**	**Much Worse**	**Response Count**
Lane width	17	5	0	0	0	22
Visibility	13	9	0	0	0	22
Signage	4	13	5	0	0	22
Lighting	8	12	2	0	0	22
Turn lanes	14	8	0	0	0	22
Aesthetics (appearance)	14	5	2	0	0	21
Other (please specify)						3
					Answered question	**22**
					Skipped question	**5**

Number	**Response Date**	**Other (please specify)**
1	**Sept. 24, 2009 6:19 p.m.**	The middle lane where I-29 and I-80 merge is not set up very well. Two lanes moving into one with people going 60 miles per hour is probably going to create an accident at some point.
2	**Sept. 24, 2009 8:12 p.m.**	The project is still quite unkempt underneath the 24th Street bridge adjacent to the traffic lanes, very unattractive, presents negative image of the state and area for through-traffic visitors. Aesthetic lighting on bridge still needs work.
3	**Oct. 5, 2009 8:47 p.m.**	The I-80 west bound offramp to southbound on 24th Street needs the dotted lines for turn lanes. It is common for the left-most vehicle to get "pinched off" at median of 24th Street. The dotted lines would help keep the #2 lane vehicles from doing this.

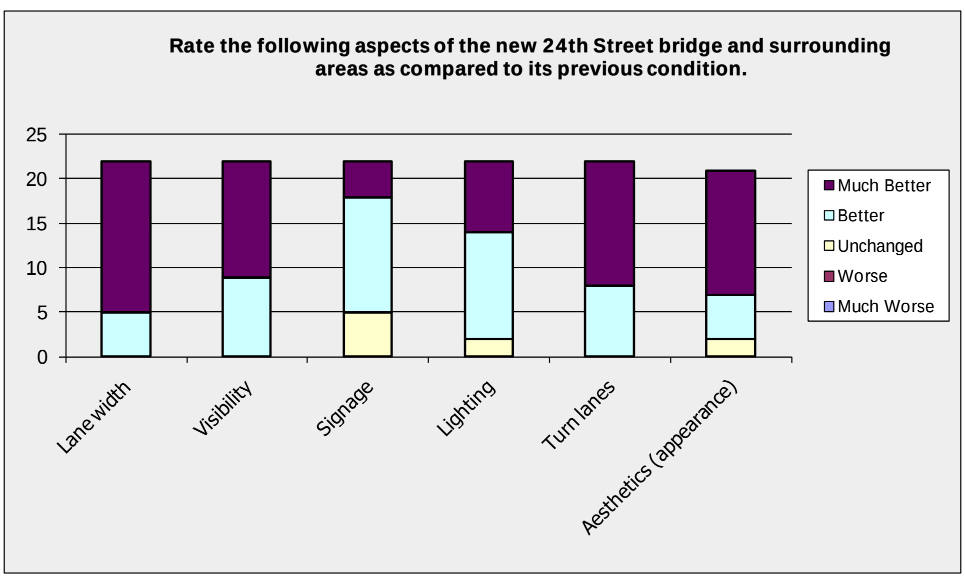

Figure 29. User rating of the finished project.

Table 14. User rating of the project amenities.

The 24th Street bridge project was designed to increase safety and improve mobility. Which of the following changes do you believe were most important in achieving these goals?					
Answer Options	**Important**	**Somewhat important**	**Somewhat unimportant**	**Unimportant**	**Response Count**
–Additional turn lanes	20	2	0	0	22
–Bike/pedestrian path on both sides of the bridge	13	6	2	1	22
–Additional through lanes	19	2	0	0	21
–Aesthetic features	5	14	2	1	22
–Other (please specify)					1
				Answered question	**22**
				Skipped question	**5**

Number	**Response Date**	**Other (please specify)**
1	**Oct. 5, 2009 8:47 p.m.**	The I-80 westbound offramp to southbound on 24th Street needs the dotted lines in the intersection for turn lanes. It is common for the left-most vehicle to get "pinched off" at the 24th Street median. The dotted lines would help keep the #2 lane vehicles from doing this.

Figure 30. User rating of the project amenities.

Table 15. Level of inconvenience experienced by the user.

Rate the level of inconvenience you experienced as a user of the 24th Street bridge during its construction.		
Answer Options	**Response Percent**	**Response Count**
Minimal	28.6%	6
Moderate	66.7%	14
Serious	4.8%	1
	Answered question	**21**
	Skipped question	**6**

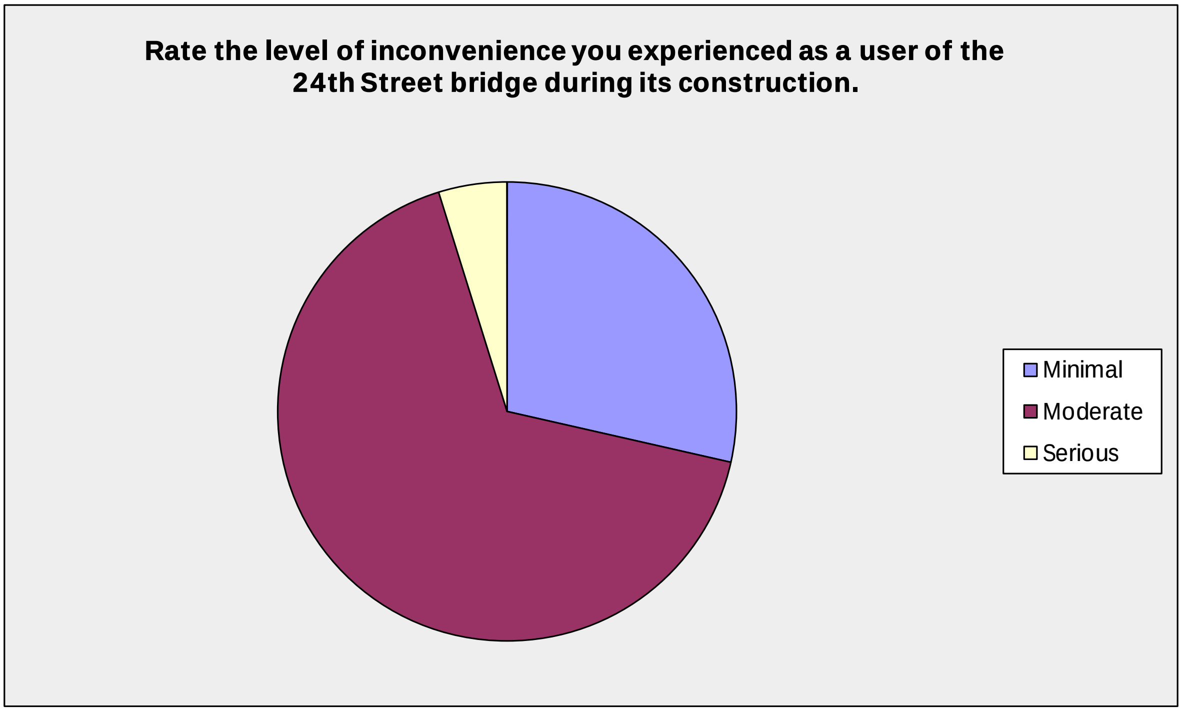

Figure 31. Level of inconvenience experienced by the user.

Table 16. Impact on local businesses.

Did construction on the 24th Street bridge deter you from visiting local businesses in the area?			
Answer Options		**Response Percent**	**Response Count**
Yes		27.3%	6
No		72.7%	16
If yes, please specify.			4
		Answered question	**22**
		Skipped question	**5**
Number	**Response Date**	**If yes, please specify.**	
1	**Sept. 24, 2009 6:09 p.m.**	I frequently used an alternate route to visit the Star Cinema and Bass Pro Shop. I did choose not to use the Camping World location as it would have required driving through the site with a large travel trailer in tow.	
2	**Sept. 24, 2009 8:13 p.m.**	I would take an alternate route to avoid the construction area.	
3	**Sept. 25, 2009 4:19 p.m.**	I would not visit those areas if I didn't have to go to work and I avoided the businesses that were there as I found other solutions for fuel, etc., due to the lane changes and making turns through construction zones.	
4	**Sept. 30, 2009 12:50 a.m.**	Congestion on the exit ramps from interstate affected decision for visiting businesses in the area. Now that it is done, I have nothing but praise for the results of the construction.	

Figure 32. Impact on local businesses.

Table 17. Safety issues.

Were there any safety issues/concerns raised during the 24th Street project?		
Answer Options	**Response Percent**	**Response Count**
Yes	9.5%	2
No	90.5%	19
If yes, were they dealt with appropriately? How could they be handled better in the future?		2
	Answered question	**21**
	Skipped question	**6**

Number	**Response Date**	**If yes, were they dealt with appropriately? How could they be handled better in the future?**
1	**Sept. 25, 2009 1:50 a.m.**	Giving all the semi's room for traveling, light timing was terrible.
2	**Oct. 5, 2009 8:48 p.m.**	Backups into the intersections due to poor stoplight timing/design. (described in other response)

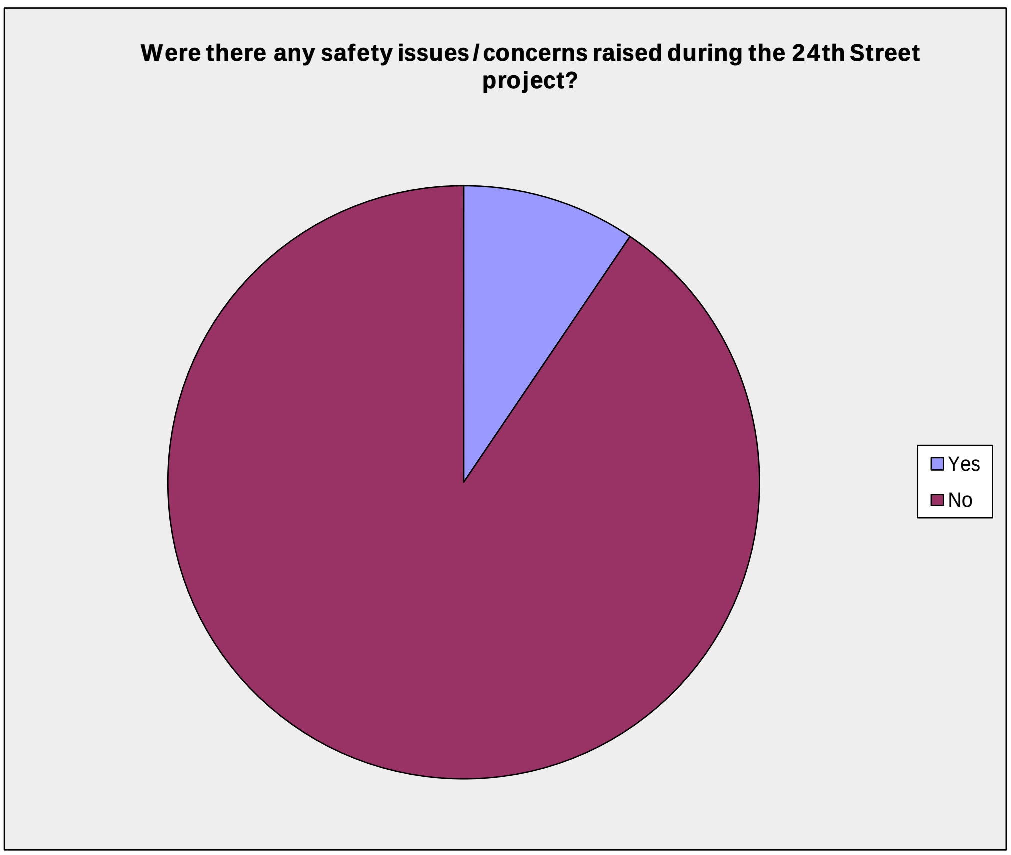

Figure 33. Safety issues.

Table 18. User-perceived importance of design and scheduling.

Rate the importance in regard to designing and scheduling projects.					
Answer Options	**Very important**	**Important**	**Unimportant**	**Very unimportant**	**Response Count**
–Keeping a road/bridge open–allow restricted traffic, increase cost and time	7	8	4	1	20
–Closing a road/bridge–no traffic, reduce cost and time	4	10	5	1	20
–Extending the life of the road/bridge–more initial cost but less life cycle cost	17	4	0	0	21
–Reducing future maintenance needs–more initial cost but fewer disruptions	16	4	0	0	20
–Reducing time to complete a project through the use of incentives to contractors	12	5	0	1	18
–Reducing time to complete a project through design/material selection	15	4	0	0	19
–Creation of alternative routes while project is underway	12	5	3	0	20
–Use of multiple methods (technology) to inform the public of work zone conditions	17	2	1	0	20
–Other (please specify)					1
				Answered question	**21**
				Skipped question	**6**

Number	**Re-sponse Date**	**Other (please specify)**
1	**Oct. 5, 2009 8:50 p.m.**	A sign with a Web site to sign up for e-mail updates would be extremely helpful for those that often use an intersection or roadway that is under construction.

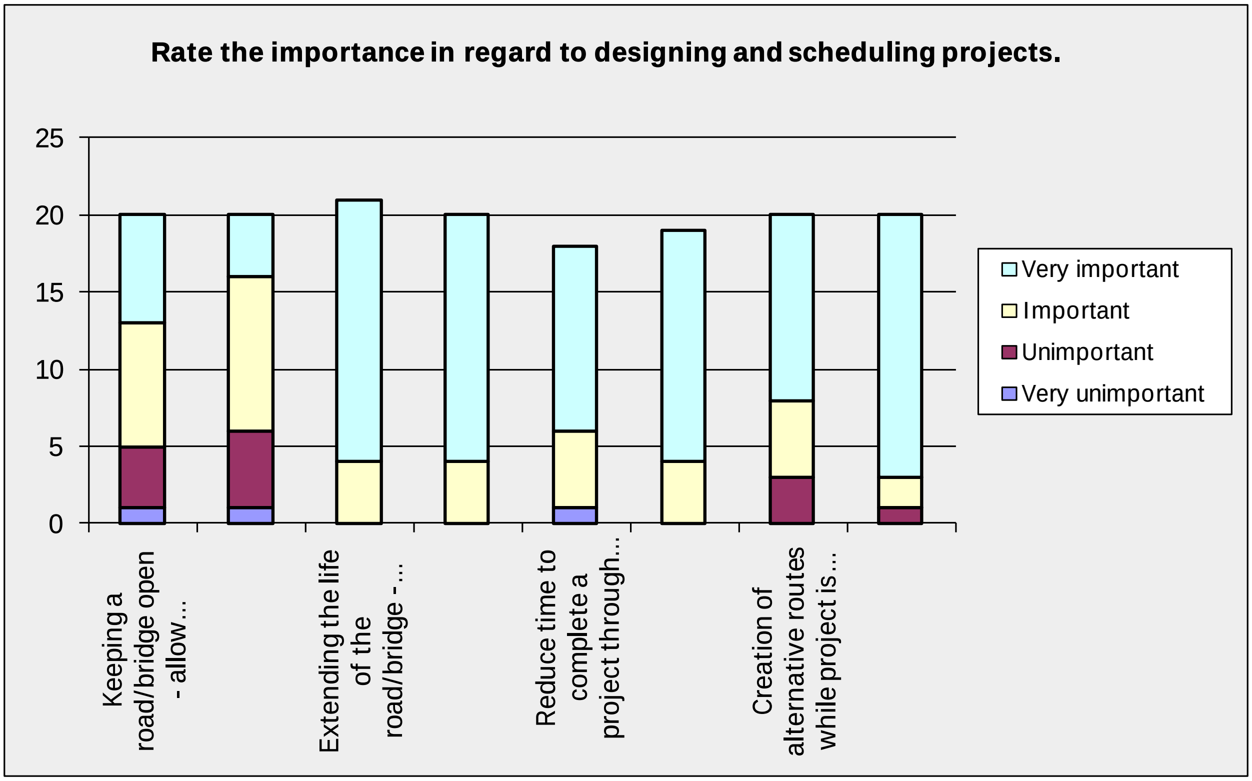

Figure 34. User-perceived importance of design and scheduling.

Co-sponsored by:

U.S. Department of Transportation
Federal Highway Administration

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

Iowa Department of Transportation

Utah LTAP

IOWA 24th Street Bridge

Highways for LIFE Project Showcase

September 25, 2008
Mid-America Center
One Arena Way
Council Bluffs, IA

This project will improve the interstate system around the City of Council Bluffs, Iowa, with improvements extending across the Missouri River on I-80 into Omaha, Nebraska.

The proposed improvements to the Council Bluffs Interstate System (CBIS) are intended to upgrade the mobility through the I-80, I-29, and I-480 corridors, to improve the condition of the roadways, reduce traffic congestion and crashes, strengthen system linkages by making transitions between interstates easier, correct functional design issues, and accommodate planned development. The 24th St. interchange is an initial component of the CBIS project.

Iowa DOT Innovations for the 24th St. Interchange

- Precast, full depth deck panel units
- A + B bidding
- ITS tools
- High performance materials such as HPS, HPC, and SCC
- Two-course deck
- Structural Health Monitoring System

Innovative features improve safety, reduce risk, liability

- Precast deck panels improves traffic flow, public satisfaction
- HPS, HPC, and Flooded Backfill aids in future maintenance activities
- A+B Bidding shortens duration of traffic impact
- ITS system detects travel speed and advises traffic through automated messages

Driving Experience Improved for Consumer

- Precast deck panels will improve quality and long term performance of the bridge. The overlay will improve the quality of the driving surface and reduce tire/pavement noise.
- Curing methods associated with the use of HPC will reduce deck cracking.
- The Structural HMS installed during construction, will remain in place and will allow the precast superstructure elements to be monitored during construction. Also, monitored after completion of the bridge to determine the bridge performance.
- Improved consolidation resulting from the proposed fully contained flooded backfill treatment will improve the problem with settlement that results in bumps at the bridge.

Figure 35. Showcase brochure.

Table 19. Showcase agenda: September 25, 2008.

Time	*Session/Topic*	*Speakers*
8:30–9:00 a.m.	**Registration**	
9:00–9:15 a.m.	**Welcome and Introductions**	John Selmer, District 4 Engineer
9:15–9:45 a.m.	**Highways for LIFE Program Overview**	Joe Jurasic, FHWA IA Construction/Transportation Engineer
9:45–10:00 a.m.	**IDOT's Project Management Team Process/HfL Steering Committee– "Seeking Best Solutions"**	Sandra Larson, IDOT
10:00–10:30 a.m.	**IDOT's HfL Project Overview** • Project Goals • Project Development Process • Innovative Contracting (A+B bidding) • Public Communications/Outreach	George Feazell, IDOT
10:30–10:45 a.m.	**BREAK**	
10:45–11:30 a.m.	**IDOT's Project Overview and Perspective** • Project Description Details • Full-Depth Precast Panels and SCC • HPS/HPC • Structural Health Monitoring • Flooded Backfill	Jim Nelson, IDOT
11:30–11:50 a.m.	**Contractor's Project Perspective**	Robert Cramer
11:50 a.m.–12:10 p.m.	**Q&A for Panel**	
12:10–1:00 p.m.	**LUNCH**	
1:00–1:15 p.m.	**Project Tour**	
1:15–2:30 p.m.	**View Project**	
2:30–2:45 p.m.	**Trip to Conference Center**	
2:45–3:15 p.m.	**Q&A to Panel and Wrapup**	

Showcase Speakers List

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