Wisconsin Demonstration Project: Multiple Bridge Reconstruction on WIS 25 Across the Mississippi River

Final Report
June 2013

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

U.S.Department of Transportation
Federal Highway Administration

FOREWORD

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

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

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

NOTICE

1. Report No.

2. Government Accession No

3. Recipient's Catalog No

3. Title and Subtitle

Wisconsin Demonstration Project: Multiple Bridge Reconstruction on WIS 25 Across the Mississippi River

5. Report Date
June 2013

6. Performing Organization Code

7. Authors
Paul Littleton and Jagannath Mallela

8. Performing Organization Report No.

9. Performing Organization Name and Address
Applied Research Associates, Inc.
100 Trade Centre Drive, Suite 200
Champaign, IL 61820

10. Work Unit No. (TRAIS) C6B

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Office of Infrastructure
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

13. Type of Report and Period Covered
Final Report
September 2009 –September 2011

14. Sponsoring Agency Code

15. Supplementary Notes
Contracting Officers Technical Representatives: Byron Lord, Mary Huie

16. Abstract

As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Wisconsin Department of Transportation (WisDOT) was awarded a $1 million grant to demonstrate the use of proven, innovative technologies to deliver a $12.5 million project in less time than conventional construction.

This report discusses the use of multiple temporary bypass bridges to facilitate the reconstruction of a series of existing bridges. Through the use of bypass bridges to keep traffic flowing at minimal delay and at greater worker and public safety than traditional construction methods, this project surpassed the Highways for LIFE goals of fast, safe, and efficient reconstruction of structurally deficient bridges in an environmentally sensitive wetland. The bypasses enhanced the durability of the finished bridges by allowing for monolithic deck construction, which eliminated the longitudinal deck joint associated with traditional staged construction methods. This project also included innovations such as open pile bents, high performance concrete (HPC), precast bridge elements, and specially designed approach aprons, all of which added to the quality of the bridges.

The construction time was reduced by 45 percent compared to traditional staged construction. In addition, an estimated $3.6 million was saved in the total costs of construction, user delay, and safety costs, with the bulk of the savings attributed to minimizing delay costs. In other words, the innovations used in this project had a 29 percent cost benefit over traditional methods. While not meeting every HfL goal, the innovations demonstrated on the project are a step forward for WisDOT in terms of implementing future bridge projects where multiple temporary bypass bridges can by utilized to increase safety, increase quality, and save time and money.

17. Key Words
Temporary bypass bridge, HPC, open pile bent, precast bridge elements, approach apron

18. Distribution Statement
No restriction. This document is available to the public through the Highways for LIFE website:
http://www.fhwa.dot.gov/hfl/

Security Classif.(of this report)
Unclassified

19. Security Classif. (of this page)
Unclassified

20. No. of Pages
46

21. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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 yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2 (psi)	poundforce per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
		DENSITY		
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3

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	35.314	cubic feet	ft^3 m^3
	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	poundforce	lbf
kPA	kiloPascals	0.145	poundforce per square inch	lbf/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)

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

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 the Wisconsin Department of Transportation officials Paul Conlin P.E., Wendy Maves P.E., David Koepp P.E., and Chris Ouellette for their help in collecting contract documents and providing insight into the construction process.

CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND SYMBOLS

ADT	average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ADT	average daily traffic
dB(A)	A-weighted decibel
DOT	Department of Transportation
DNR	Department of Natural Resources
FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
HfL	Highways for LIFE
HMVMT	hundred million vehicle miles traveled
HPC	high performance concrete
Hz	hertz
IRI	International Roughness Index
MOT	maintenance of traffic
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
PCC	portland cement concrete
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SI	sound intensity
SRTT	standard reference test tire
WisDOT	Wisconsin Department of Transportation
WIS 25	Wisconsin Highway 25
VOC	vehicle operating cost

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration (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 an 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 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, then 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 on 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 miles in a rural area or less than 1.5 miles in an urban area (in both cases at a travel speed 20 percent less than the posted speed).
- **Quality**
    - Smoothness—International Roughness Index (IRI) measurement of less than 48 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 or more on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This report documents the Wisconsin Department of Transportation's (WisDOT) demonstration project encompassing the reconstruction of a series of four bridges on a vital two-lane highway across the Mississippi River linking Wisconsin to Minnesota. Presented herein are project details relevant to the HfL program, including the use of multiple temporary bypass bridges, open pile bents, precast bridge elements, high performance concrete (HPC), and special approach aprons to minimize traffic disruption while building high-quality bridges safely and efficiently. HfL performance metrics measurement, economic analysis, and lessons learned also are discussed.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The project was located on Wisconsin Highway 25 (WIS 25) between the village of Nelson, Wisconsin, and Wabasha, Minnesota. WIS 25 is the only connection across the Mississippi River between Wisconsin and Minnesota for more than 30 miles and is a vital link for commerce and emergency vehicles. This section of highway includes four bridges through the Nelson-Trevino Bottom State Natural Area that were in need of rehabilitation and one bridge over the Mississippi River which was in satisfactory condition and was not included in the project.

Of the four bridges that were reconstructed, only one bridge required widening to meet current standards. This bridge did not include any innovations but was added to the project contract to consolidate the amount of construction on this roadway as perceived by motorists. Traffic at this bridge was maintained during construction through the use of a single lane closure and temporary traffic lights.

The remaining three bridges are the primary focus of this report. During the reconstruction of these bridges, traffic was routed onto multiple temporary bypass bridges. The use of multiple bypass bridges was a first for WisDOT and is the featured innovation of this project for supporting safe and efficient work on three bridges simultaneously and improving quality by eliminating the longitudinal deck joint typical with conventional staged bridge construction. Other innovations demonstrated on this project include open bent piles, precast bridge elements, HPC, and special approach aprons.

HFL PERFORMANCE GOALS

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

- **Safety**
  - Work zone safety during construction—No crashes attributabe to construction activities occurred within the work, which meets the HfL goal of achieving a work zone crash rate equal to or less than the preconstruction rate. One incident unrelated to construction activities was noted.
  - Worker safety during construction—No workers were injured on the project, and the contractor achieved a score of 0.0 on the OSHA Form 300, meeting the HfL goal of less than 4.0.
  - Facility safety after construction—The finished project not only created a smoother bridges in most cases but wider bridge widths, additional off-road parking, and upgraded beam guards that meet the current highway standards. The net effect of these improvements is the improved safety performance of the facility after construction. The average post construction injury rate was only one sixth of the average preconstruction injury rate, and thus, exceeding the HfL goal of 20 percent reduction in injuries and fatalities.

- **Construction Congestion**
  - Faster construction—Because two of the bridges were several hundred feet long and in close proximity to each other, the maintenance of traffic (MOT) associated with traditional stage construction methods would have lasted two full construction seasons. The innovative use of multiple temporary bypass bridges to maintain two-way traffic allowed the contractor to schedule all major construction activities in only one season, effectively reducing the impact to the traveling public by 45 percent, narrowly missing the HfL goal of a 50 percent reduction in the time traffic is impacted compared to traditional construction methods.
  - Trip time— To assess the impact on motorists, travel time data were collected both before construction when the posted speed limit was 55 mi/hr and during construction when the posted speed limit was 45 mi/hr. The results document a 36 percent increase in travel time during peak construction activities. While not satisfying the HfL goal of no more than a 10 percent increase, two-way traffic was kept free flowing with no noticeable backups.
  - Queue length during construction—The project met the Hfl goal of less than a 0.5-mile queue length in a rural area, as there were no traffic backups at the three main bridges in which the temporary bypass bridges facilitated the free flow of traffic through the work zone. Only brief traffic queues of five or fewer vehicles were observed at the traffic signals for the bridge that was reconstructed with traditional staged construction.
- **Quality**
  - Smoothness —Smoothness across one of the main bridges was increased. IRI dropped on this bridge from a preconstruction value of 221 in/mi to a postconstruction 150 in/mi. The remaining bridges stayed relatively the same. 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 71 in/mi drop in IRI value on one of the bridges is a reflection of the high quality of construction.
  - Noise—Quality was measured in terms of sound intensity. The sound intensity data showed a moderate 1.1 dB(A) or greater reduction in noise from the two main bridges; however, the lowest measured value was 97.7 dB(A), which does not meet the HfL requirement of 96.0 dB(A) or less.

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 WisDOT's approach realized a cost savings of $3.6 million, or 29 percent of the total project, over conventional construction practices. A significant amount of the cost savings was from minimizing users delay cost though the use of multiple bypasses.

LESSONS LEARNED

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

- **Multiple Temporary Bypass Bridges**
    - Dialogue the WisDOT had with the US Fish and Wildlife Service, US Army Corps of Engineers, Wisconsin Department of Natural Resources (DNR), and the Wisconsin Transportation Builders early in the design process helped the project move smoothly.
    - The temporary bypasses created additional onsite storage space for equipment and material stockpiles. As a result, the staging area was less congested and safer for workers and equipment.
    - While not a major issue, settlement of the bypasses and temporary bridges was not estimated prior to construction. WisDOT learned that settlement, especially for construction on top of river sediment, should be included in the plans or estimated by the contractor and planned for accordingly.
- **Open Pile Bents**
    - Given the soft silty soils and relatively little rock, pile driving was straightforward. The contractor utilized a template to align the piles of each bent and, by doing so, accomplished two things: 1) saved time by positioning the template and not the individual piles and 2) insured the accuracy of the finished pile location to within 0.5 inch of the planned position (plans allowed for a 3-inch tolerance).
- **Precast Bridge Elements**
    - It is essential to have stringent quality control at the precast plant, by the manufacturer or the DOT or both, to guarantee the precast bridge elements are within tolerance before leaving the plant.
    - A large 110-ton crane was needed to lift the heavy precast elements into place; otherwise, a smaller crane would have been sufficient to carry out conventional cast-in-place bridge construction for this project.
    - A grout pump was indispensable in filling the pile pockets.
- **HPC**
    - HPC specifications were new to the supplier and required several durability tests on the new mix prior to use on the bridges. The lesson learned is that extra time and attention to details may be needed for suppliers to test and familiarize themselves with innovative materials such as HPC before the project begins.
    - Placing HPC during cool night conditions was necessary to control the mix temperature. Attempting only daylight pours during the hot summer months would have resulted in delays.

CONCLUSIONS

The innovations incorporated into this project were key to the success in reaching the HfL performance goals of increasing safety, reducing congestion, and increasing quality. The use of multiple temporary bypass bridges has increased the regional supply of bypass bridge materials for future projects. Moreover, the experience gained on this project will give WisDOT the background for planning future projects where these innovations could be useful.

PROJECT DETAILS

BACKGROUND

This project was located on WIS 25, between the village of Nelson in Buffalo County, Wisconsin, and the city of Wabasha in Wabasha County, Minnesota. WIS 25 is the only Mississippi River crossing between Wisconsin and Minnesota for more than 30 miles. The highway connects Wisconsin to Minnesota through the Nelson-Trevino Bottoms State Natural Area on a series of five bridges and a connecting causeway.

The Nelson-Trevino Bottoms State Natural Area is located below the confluence of the Chippewa and the Mississippi Rivers and, according to the Wisconsin Department of Natural Resources, features an extensive, undisturbed wilderness portion of the largest delta floodplain forest in the upper Midwest. The bottoms are a maze of forested floodplain and ever-changing oxbow meanders, marshes, sloughs and ephemeral ponds. The US Fish and Wildlife Service owns and regulates the approximately 3,740 acres that make up this natural area.

This project involved the rehabilitation of four of the five bridges on WIS 25 located in the natural area. The fifth bridge, the Nelson-Wabasha Interstate Bridge, did not require rehabilitation. This segment of roadway has one lane in each direction. Figure 1 shows the general location of the project and the location of the bridges.

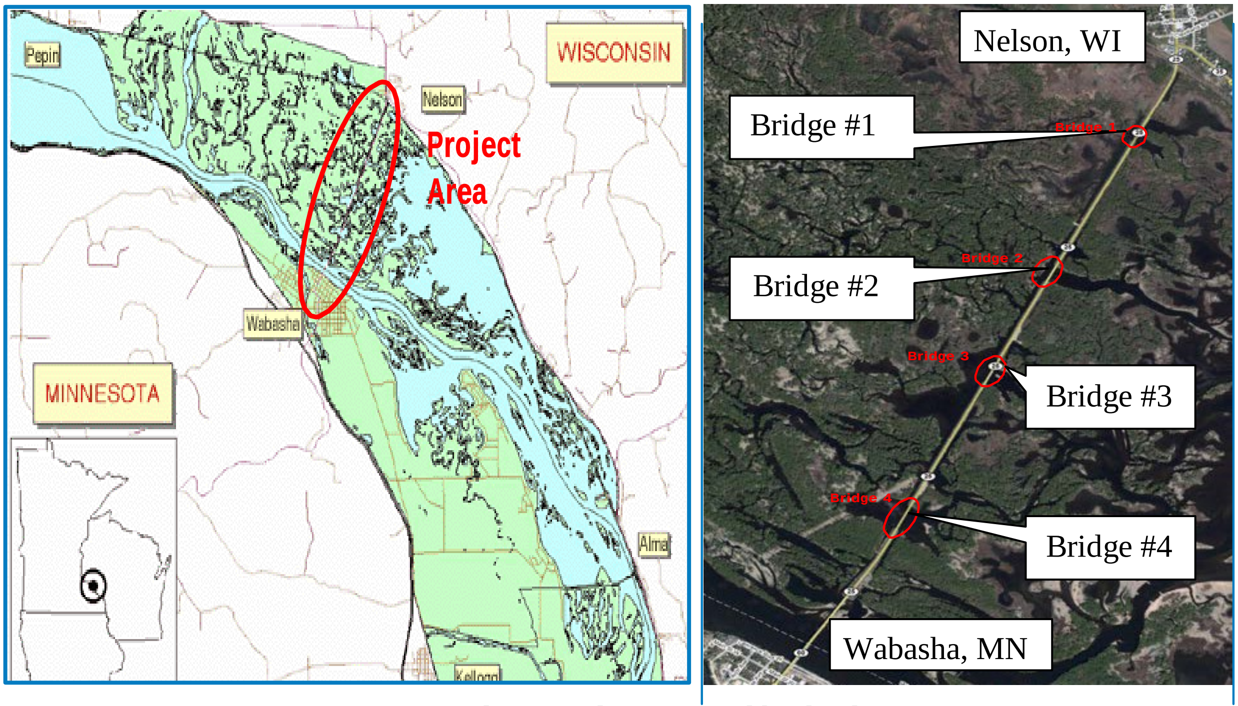


Figure 1. General project location and bridge locations.

Average daily traffic (ADT) between Nelson and Wabasha was 5,050 vehicles per day in 2009. Because of the rural locale of the bridges, implementing a detour route would result in nearly 70 extra miles roundtrip for motorists and would result in unacceptable delays for emergency response vehicles serving the river communities. Because of the need to maintain safety and the flow of commerce traffic and commuters on this vital interstate link, WisDOT considered several alternative contracting methods to minimize traffic inconvenience, including A+B bidding, the use of incentive/disincentive clauses, and building temporary bypass structures for traffic.

The DOT chose temporary bypass bridges through an evaluation of each of the methods based upon their overall effectiveness of meeting the project objectives of minimizing traffic inconveniences, minimizing environmental impacts, and ensuring high-quality bridges that will require minimal maintenance over their design life. Other innovations included in this project were:

- Open pile bents.
- Precast bridge elements.
- High performance concrete.
- Special approach aprons.

PROJECT DESCRIPTION

The first bridge (bridge #1) of this project is shown in Figure 2 and was an old 124-ft single span steel pony truss bridge. Rehabilitation replaced the existing superstructure with prestressed concrete girders and a new deck made of HPC. Because of the pony truss deign, the existing bridge did not lend itself to staged traffic control while being partially dismantled, so a temporary bypass bridge was necessary.

Figure 2. The pony truss bridge #1 prior to reconstruction.

Bridge #2 was a six-span, 408-ft steel girder bridge with transverse deck joints over each pier. This bridge was widened from 26.5 ft to the standard width (44 ft) by driving additional steel piles, filling the piles with reinforced concrete, extending the existing pier caps, placing additional steel girders, and extending the deck. The additional piers under construction can be seen in Figure 3. The drive lanes across the bridge remained largely unaffected by the new construction. The reconstruction was staged in two phases. During the first phase, one lane of traffic was maintained across the bridge for 2 months by utilizing temporary traffic signals. Then during the second phase, two-way traffic was established on the newly reconstructed portion of the bridge while the rest of the bridge was rebuilt. Since this bridge required only widening and the existing substructure was in good condition, traditional construction materials and techniques were sufficient.

Figure 3. Bridge #2 showing the piles added to support the deck widening.

Bridges #3 and #4 were each eight-span, 563-ft prestressed concrete girder bridges that were structurally deficient. Figure 4 shows the existing deteriorated deck conditions on bridge #3 and the weather deck of bridge #4. New steel piles were driven for the abutments and bents and, once in place, the piles were filled with reinforced concrete. Precast abutments and pier caps were then seated on the piles, followed by the placement of prestressed concrete girders and a deck made of HPC. Special approach aprons that located the expansion joint on the pavement side of the abutments and not between the deck and abutment were installed for these two bridges.

Figure 4. Existing bridge #3 (left) and existing bridge #4 (right).

The following sections discuss the key project innovations.

Multiple Bypass Bridges

Keeping WIS 25 open by routing traffic onto multiple temporary bypass bridges was an innovation for WisDOT. Although the use of temporary structures is not new, the amount of temporary structures being proposed for this particular project (66,000 square feet) provided the DOT an opportunity to push the envelope of typical construction practices in Wisconsin. Based on consultation with industry leaders, it was determined that this quantity of temporary bridges would stress the industry's local stockpile of temporary bridge material. The increased demand from this project has caused industry to increase supply, making bypass bridge materials readily available for future projects.

The temporary bypasses maintained the current two lanes of traffic around bridges #1, #3, and #4, allowing crews to rebuild the entire bridge decks monolithically, eliminating the longitudinal construction joint that otherwise would be present in traditional staged construction. Typically, during the second stage of construction on a bridge built one-half at a time, traffic using the half of the bridge built in the first stage causes vibrations along the reinforcing steel into the freshly placed concrete of the second stage. It is also more difficult to meet ride quality specifications across bridges built with staged construction due to the inherent problems associated with ensuring the formwork stays fixed to the first stage as the second stage deflects under traffic.

In addition to the increase in construction quality, WisDOT anticipated that by constructing temporary bridges capable of providing two-way traffic, user delay would be minimal. With conventional staged construction and use of traffic signals to control the traffic across the existing bridges during construction, the optimal cycle length was over 12 minutes. With the implementation of the temporary bridges, the traffic delay was predicted to be less than 1 minute. Actual travel time information (discussed later in this report) supports this hypothesis.

Another and very important advantage of utilizing bypasses was enhanced safety for workers and motorists. With the use of temporary bridges, workers were separated from traffic and were not exposed to worker/vehicle interaction. Moreover, by minimizing temporary traffic signals on this project, rear end collisions typically associated with such signals was eliminated.

An added benefit of using temporary bypasses was that it gave the contractor more general storage of their equipment. If the bridge had been constructed in two stages, there would have been a maximum of about 15 ft of pavement and gravel shoulder to position the cranes, equipment, etc at the end of the bridges.

The methods and means to construct temporary bypass bridges, while designed and constructed to standard requirements, were up to the contractor’s discretion. The local industry standard, and the type of construction chosen for this project, was to provide temporary wooden pile bents, either a wooden or precast pile cap, precast deck panels, and either beam guards or temporary railings to finish the bridge. Figure 5 shows the bypass being built at bridge #1, and Figure 6 shows the bypass at bridge #3 in use.

Figure 5. Aerial view of WIS 25 looking west toward Minnesota.

Figure 6. Temporary bypass bridge in use at bridge #3.

Open Pile Bents

The typical bridge construction technique used in Wisconsin utilizes pier type construction, meaning that the top of the piles are below grade and a footing is cast on top of the piles. A column or pier would then be used to support the beam seat. In an open pile bent bridge, the pilings are tied together above ground to form the beam seat. Figure 7 shows the two types of constructions.

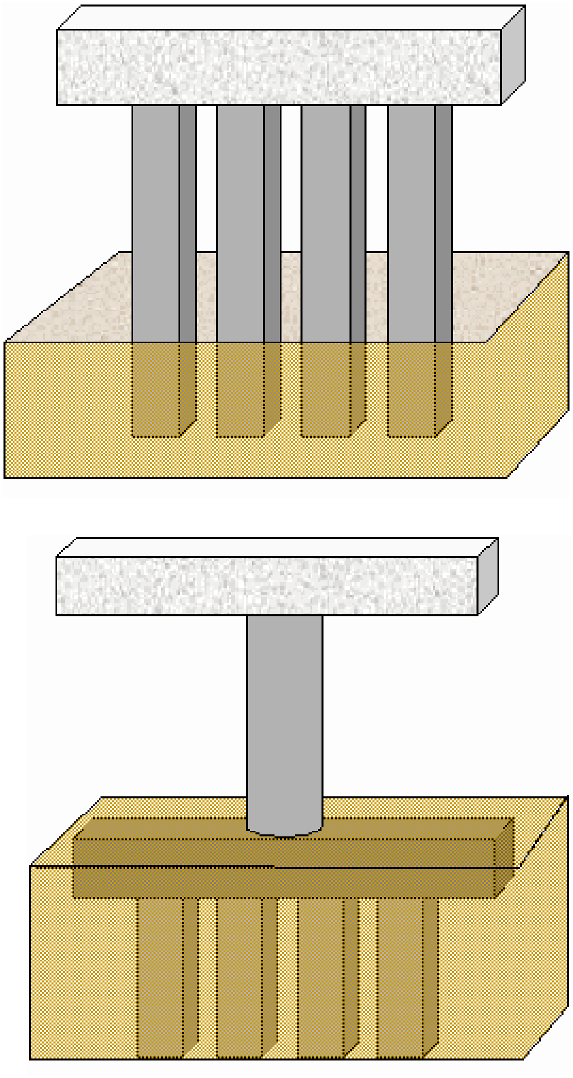


Figure 7. Comparison of an open pile bent (top) and pier (bottom) (source: WisDOT).

The open pile bent construction was well suited for shorter span lengths, resulting in smaller beam depth, which reduced the amount of grade change and associated earthwork needed for the new bridge and reduced the impact on adjacent wetlands. The use of open pile bents also helped to reduce the environmental impact on the causeway because the piles are exposed and serve as habitat for fish and other aquatic life. Figure 8 shows an open pile bent during construction, and Figure 9 shows the bents in service under the newly constructed bridge #3.

Figure 8. Open pile bent during construction at bridge #3 (source: WisDOT).

Figure 9. Finished open pile bents at bridge #3.

Precast Bridge Elements: Abutments and Pier Caps

The precast elements were cast in advance while other work was being done on the project, which helped to reduce the amount of time needed to construct the bridge. Abutments and pier caps came in two sections and were joined upon installation. They are held by two vertically positioned steel bars running through the joint and grouted into place. The contractor had no major issues placing the precast elements. Part of the success was from utilizing a template while driving the piles into proper position to receive the caps and abutment pieces (see Figure 10). Dimensional tolerances set forth in the contract's special provisions also helped to ensure proper assembly of the elements in the field. Figure 11 shows workers aligning half of the abutment over the piles during installation.

Figure 10. Template for driving the steel piles (source: WisDOT).

Figure 11. Precast abutment section being lowered into place (source: WisDOT).

After the abutments and pier caps were joined and grouted, a waterproof seal was applied. Figure 12 shows a close-up of the sealed connection at a pier cap.

Figure 12. Sealed joint between the two halves of a completed pier cap.

HPC

HPC was used in the superstructures of bridges #1, #3, and #4 to increase the longevity of the structure by reducing the amount of chloride solution permeability and increasing freeze-thaw resistance. In this way the new structures will be more durable than if made with standard portland cement concrete (PCC).

Special provisions for HPC in the contract documents tailored WisDOT's standard specifications in areas covering both material properties and construction. For example, tighter controls were set for the acceptable levels of chert in the mix, and maximum limits were set for the results of the finished concrete's wear and freeze-thaw soundness testing. The HPC and standard mix designs used in this project are presented in Table 1. The most significant difference between the two mix designs was that the HPC mix contained more water-reducing agent and more fly ash (resulting in a higher quantity of total cementitious material) than the standard PCC mix.

Table 1. HPC and standard PCC mix designs*.

Material	**HPC**	**Standard PCC**
Water	227 lb/cu.yd.	225 lb/cu.yd.
Type 1 Cement (ASTM C 150)	420 lb/cu.yd.	455 lb/cu.yd.
Class C Fly Ash (ASTM C 618)	180 lb/cu.yd.	115 lb/cu.yd.
Coarse Aggregate (1.5 to 0.375 in)	773 lb/cu.yd.	773 lb/cu.yd.
Coarse Aggregate (0.75 to 0.187 in)	1177 lb/cu.yd.	1177 lb/cu.yd.
Fine Aggregate	1167 lb/cu.yd.	1154 lb/cu.yd.
Water Reducer (KB 1000)	7.8 oz/100 lb	3.0 oz/100 lb
Air Entrainment Agent (Polychem AE)	6%	6%

*Data supplied by WisDOT.

Emphasis in the special provisions was placed on bridge deck construction with HPC, such as setting the maximum ambient air temperature to 80°F and reducing the acceptable evaporation rate on bridge decks from WisDOT's standard specified evaporation rate at or below 0.2 lb/sq.ft./hr to a rate at or below 0.15 lb/sq.ft./hr. As shown in Figure 13, deck pours often were scheduled at night to keep temperatures in check. The finished deck of bridge #3 is shown in Figure 14.

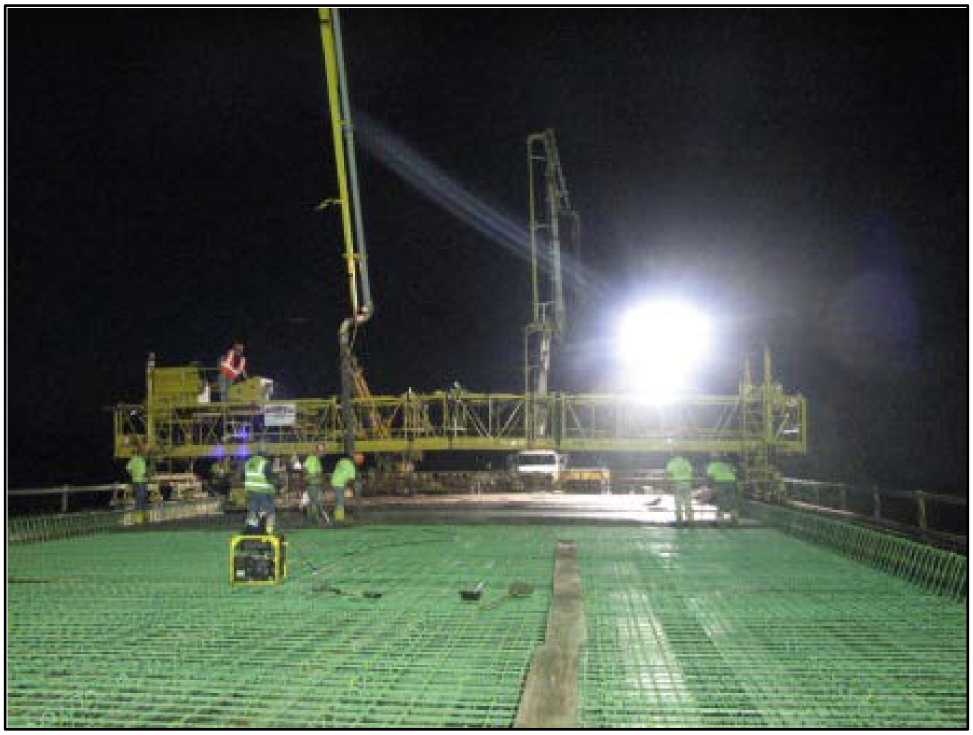


Figure 13. The deck pour at bridge #3.

Figure 14. Finished deck of bridge #3.

Special Approach Apron

Included in the bridge plans was a detail that relocated the conventional expansion joint location from the bridge deck to specially designed approach aprons. The innovative design feature is expected to extend the service life of the bridge by reducing the amount damage (and associated maintenance) caused by road salt solution that otherwise would leak onto the bridge elements below the deck if the expansion joints were located on the bridge deck. The durability of this design is enhanced further through the use of high-strength stainless steel reinforcing bars between the approach apron and the abutment. Figure 15 shows the cross section plan of the approach apron. Note the placement of stainless steel reinforcing bars joining the apron to the abutment and the expansion device at the opposite end of the apron.

Figure 15. Approach apron cross section.

In this innovative design, the apron has a rigid connection to the bridge deck. Expansion and contraction stress are relieved at a header located opposite the abutment. The footing and header structure was seated on undisturbed soil. The stainless steel reinforcing at the abutments is shown in Figure 16. Figure 17 shows the temporary form and standard epoxy-coated reinforcing steel for the footing and header.

Figure 16. Stainless steel reinforcing extending out of the abutment.

Figure 17. Formwork and reinforcing steel for the approach apron footing and header.

The finished approach slab shown in Figure 18 is similar in appearance to traditional construction except for the location of the expansion joint.

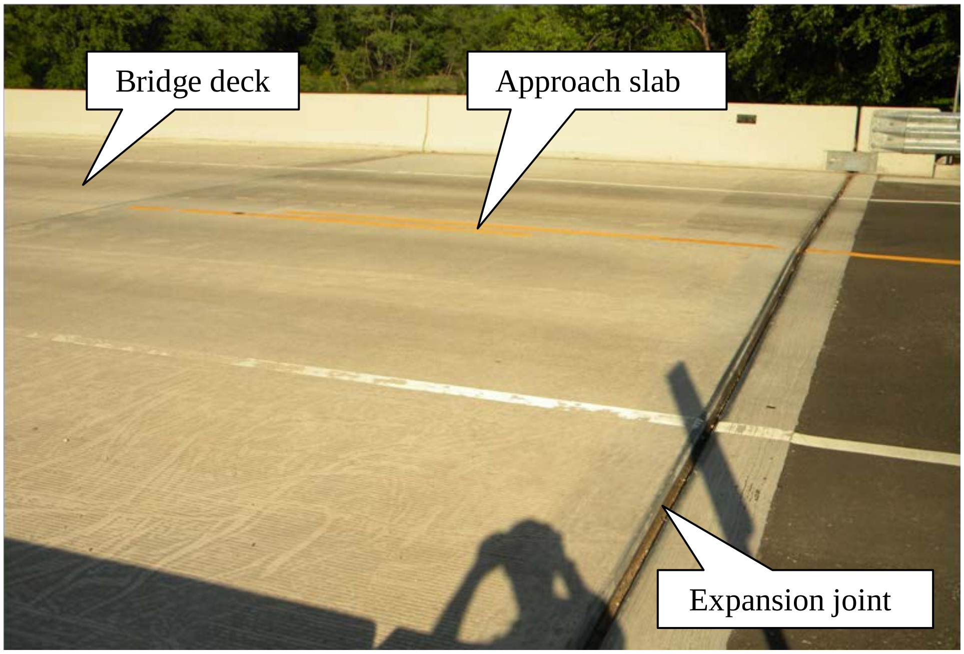


Figure 18. Completed approach slab.

DATA ACQUISITION AND ANALYSIS

Data on safety, traffic flow, quality, and user satisfaction before, during, and after construction were collected to determine if this project met the HfL performance goals. The primary objective of acquiring these types of data was to quantify project performance and provide an objective basis from which to determine the feasibility of the project innovations and to 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 WisDOT project met the HfL performance goals related to these areas.

SAFETY

Between 2000 and 2005 there were 19 documented crashes on this section of WIS 25. Wet or icy pavement conditions combined with motorists driving too fast for conditions contributed to nine of these accidents. Thirteen accidents involved injuries to 15 motorists. There were no fatalities or property damage (except for the vehicles involved) during this period. The average yearly crash rate was 77 per hundred million vehicle miles traveled (HMVMT), which is lower than the State average of 112 HMVMT. During this project one incident occurred within the work zone limits, but the incident was not related to construction activities or the presence of the work zone. By and large, the continuous flow of traffic through the work zone (traffic signals at bridge #2 notwithstanding) and separation of the workers from working around live traffic contributed to a successful safety record during construction. The contractor recorded no work-related injuries during construction, resulting in an OSHA Form 300 score of 0.0, which meets the HfL goal of 4.0 or less.

The safety performance of the facility after construction was evaluated using pre and post construction crash rates. Table 2 presents a detailed breakdown of post construction crash statistics. Table 3 presents the crash rates by severity type for both pre and post construction periods. As indicated in table 3, the total crashes increased marginally by 14.3 percent after construction, while the average post construction injury rate was only one-sixth of the average preconstruction injury rate. No fatal event was recorded before and after construction. Overall, the post construction safety performance of the project fully achieved the HfL goal of 20 percent reduction in injuries and fatalities.

Table 2. Postconstruction crash data

Period	Fatalities	Injuries	PDO	ADT
2010 (Nov - Dec)	0	0	0	5200
2011	0	0	4	
2012	0	1	2	
Total	0	1	6	

Table 3. Pre and post construction crash rates

	Preconstruction	Post construction	Difference
Days of Coverage	1825	791	
Average ADT	4883	5200	
Section Length	1.382	1.382	
Million Vehicle Miles Travelled	12.3	5.7	
Total Crashes	1.06	1.23	14.3%
Fatalities	0.00	0.00	-
Injuries	1.06	0.18	-500.0%
PDO	0.00	1.06	100.0%

CONSTRUCTION CONGESTION

WisDOT originally had intended to replace the three structures on WIS 25 in stages. The two longer structure replacements would have been done one-half at a time, with one bridge being built in 2009 and one being built in 2010. During construction, the maintenance of traffic would have been controlled by traffic signals at each end of the bridge. Because the cycle length necessary to clear the length of the bridge and clear the queued vehicles was unsatisfactory (5 to 10 minutes), the DOT considered alternatives to shorten the duration that highway users would be impacted. WisDOT explored limiting the construction window to one construction season; however, that required working on all of the structure replacements at the same time. This scenario required even longer cycle lengths since bridge #3 and bridge #4 were in close proximity and resulted in even longer user delay of 10 to 15 minutes.

WisDOT held a meeting onsite with industry representatives, environmental stakeholders, consultant designers, and in-house experts. One of the outcomes of the meeting was that the DOT would need an option to maintain two lanes of traffic through the use of temporary bridge.

By using the temporary structures, the construction time for the project was reduced and travel time through the work zone was kept to a minimum.

Travel Time

The most significant impact to travel time caused by the innovative use of multiple bypass bridges came from the period in the construction schedule when both bridge #3 and bridge #4 were under construction. Travel time data were collected before construction began and again while temporary bypasses were in use at bridges #3 and #4 to quantify the impact construction had on traffic. Unfortunately, travel times across the bypass at bridge #1 and through the signal lights at bridge #2 were not collected because these bridges were finished before the data were collected. However, a reasonable estimate of the additional travel time at bridge #1 can be inferred from the travel times on the other bridges, and the delay at bridge #2 can be estimated from the signal timing.

Data were collected utilizing the floating vehicle methodology in an effort to match the driving speeds of other vehicles along the 2.27-mile work zone in both directions from Nelson to the

State line. Data collection spanned 2 consecutive days during each visit—preconstruction and during construction. On these visits, data were collected on weekdays during daytime hours (7 am to 5:30 pm) when traffic demand was high and the work zone would have the greatest impact to traffic flow.

Overall, travel speeds in both directions averaged 50 mi/hr before construction and 38 mi/hr during construction. During construction, the posted speed was reduced from 55 mi/hr to 45 mi/hr. Prior to construction, the average travel time through the work zone was 164 seconds (0.0455 hours). The average travel time while the bypasses were active at bridges #3 and #4 was 213 seconds (0.0592 hours), or 49 seconds more than before construction. The average net delay under this circumstance was 0.0137 hours (0.0592 to 0.455 hours) per vehicle.

The short length of the bypass at bridge #1 would have had a minimal impact on travel times, whereas driving across the bypasses at the two larger bridges would have a greater impact on travel times. Therefore, a reasonable and conservative estimate of the delay while traveling across the relatively short temporary bypass for bridge #1 can be made assuming it would take the same amount of time to cross the bypasses at bridge #3 or #4. From the travel time data, the average additional time to cross either of the temporary bypasses at bridge #3 and #4 was 10 seconds per vehicle.

The construction schedule was such that the bypass at bridge #1 was in use for a short time, then traffic was switched onto all three bypasses and finally, toward the end of the project, only the bypasses at bridge #3 and #4 were in use. During part of the construction schedule when all three bypasses were in use simultaneously, the total estimated time to travel through the entire work zone under this condition would have been 213 seconds (from actual travel time data) plus the additional 10 seconds for bridge #1 for a total of 223 seconds (0.0619 hours), or 59 seconds more than before construction began.

The construction schedule was such that traffic was impacted by the temporary signals for two months in the fall of 2009 while crews worked on the first stage of bridge #2. Stage 2 accommodated two lanes of traffic. Therefore, no signal lights were needed after stage 1 was complete. During construction of bridge #2, WisDOT observed typical queue lengths of 5 vehicles or fewer while waiting on one signal cycle. Vehicles waiting on multiple cycles were not observed. Even though travel times were not documented while the signal lights were in use, a conservative estimate of the delay at this bridge can be made from the actual signal timing.

The Highway Capacity Manual (HCM) procedures for estimating delays due to traffic signal timings were analyzed.[1] Traffic signal timing creates three types of delays, which are combined to arrive at a total delay estimate:

- Uniform control delay assuming uniform arrivals.
- Incremental delay to account for the effect of random arrivals.
- Initial queue delay.

---

[1] *Highway Capacity Manual*. Transportation Research Board, Washington, DC. 2000.

The temporary signals at bridge #2 were in place in both directions of travel and functioning 24 hours a day. The signal timings used on the bridge are listed in Table 4:

Table 4. Signal timings at bridge #2.

Interval	Northbound	Southbound	Seconds	Percent of the cycle
1	G	R	32	28
2	Y	R	4	3
3	R	R	30	21
4	R	G	28	24
5	R	Y	4	3
6	R	R	30	21

For purposes of this analysis, initial queue delay was equal to zero. Uniform control delay is a function of the signal timing and volume-to-capacity ratio of the two approaches to the signal. The signal operated on a 134 second cycle, with green time of 32 seconds allocated in one direction and 28 seconds in the other. It was estimated that the peak-hour traffic volume in each direction of travel was approximately 225 vehicles per hour (based on an ADT of 5,050 vehicles per day, a design hourly volume of 7 percent, and a 60 percent assumed peak direction distribution split). Furthermore, it was estimated that the capacity of the traffic signal in the 28-second green time direction of travel was approximately 385 vehicles per hour (assuming a saturation flow rate of 1,600 vehicles per hour per lane). Consequently, the peak-hour volume-to-capacity ratio for the signal was estimated to be 0.58, and vehicles during the peak hour were estimated to experience an average of 45 seconds per vehicle. At very low volume times, this delay would drop to 39 seconds per vehicle. The contribution to control delay due to non-uniform arrivals and occasional oversaturation of the cycle was calculated to be very low as well.

During the peak period in the peak travel direction, an additional 6 seconds of delay was estimated to occur, which drops to less than 2 seconds during low volume periods. Consequently, the traffic signal created delays of 41 (39+2) to 51 (45+6) 51 seconds for an average of 46 seconds of delay per vehicle during the time that bridge #2 was under construction. Since bridge #2 was reconstructed separately from the others, the total estimated trip time would have been the actual preconstruction trip time of 164 seconds plus the 46 second delay, totaling 210 seconds or 0.0583 hours per vehicle. Table 5 summarizes the travel times. The cost associated with the additional times to traverse this section of highway is presented in the Economic Analysis section of this report.

During the peak construction period when all three bypasses were operational, the average difference in travel time was 0.0164 hours (0.0619 to 0.0455 hours) more than before construction. In other words, the period of peak construction increased travel time by 36 percent. The travel time increase exceeded the HfL goal of no more than 10 percent; however, the increase was due not only by the bypasses but also the 10 mi/hr lower posted speed limit. Traffic under this condition was kept free flowing, and WisDOT noticed no appreciable backups.

Table 5. Travel times.

Maintenance of traffic scenario	Time to travel through the work zone (hour/vehicle)
Before construction	0.0455
During construction with signals at bridge #2 only.	0.0583
During construction with the bypass at bridge #1 in use.	0.0483
During construction with the bypass at bridge #3 & #4 in use.	0.0592
During construction with the bypass at bridge #1, #3 & #4 in use.	0.0619

QUALITY

Pavement Test Site

Sound intensity and smoothness test data were collected from both northbound and southbound directions of WIS 25 before construction. Comparing these data to the test results after construction provides a measure of the quality of the finished bridges. The roadway improvements are covered under a separate contract and are not included in this analysis. Efforts focused on the two largest bridges (bridge #3 and #4) with monolithic decks plus bridge #2 with its jointed deck is included for comparison. Bridge #1 was excluded from this analysis since the shortness of its deck length would have limited the usefulness of the test data.

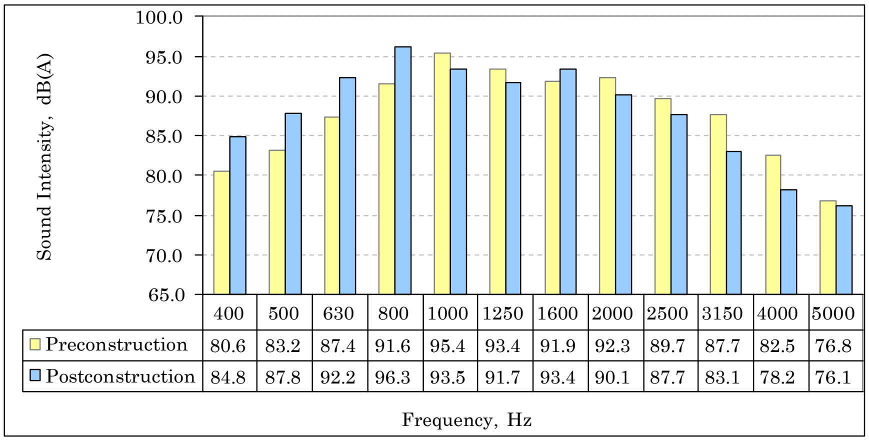
Sound Intensity Testing

Presently, WisDOT does not use the OBSI test method on any projects. However, this method was used to collect tire-pavement sound intensity (SI) measurements from the existing and newly constructed bridges for comparison.

SI measurements were made using the current accepted OBSI technique described in American Association of State Highway and Transportation Officials (AASHTO) TP 76-10, which includes dual vertical sound intensity probes and an ASTM recommended Standard Reference Test Tire (SRTT). SI data collection was done prior to construction and on the new bridge surfaces shortly after opening to traffic. The SI measurements were recorded and analyzed using an onboard computer and data collection system. A minimum of three runs were made in the right wheelpath of the project. The two microphone probes simultaneously captured noise data from the leading and trailing tire/pavement contact areas. Figure 19 shows the dual probe instrumentation and the tread pattern of the SRTT.

Figure 19. OBSI dual probe system and the SRTT.

The average of the front and rear OBSI values from both lane directions was computed for bridges #2, #3, and #4 to produce overall SI levels representing each bridge. Raw noise data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean SI levels were A-weighted to produce the SI frequency spectra in one-third octave bands, as shown in Figure 20 through Figure 22. The lower frequencies from bridges #3 and #4 show a decrease due in part to the longitudinal texture on the new bridge decks compared to the transverse texture on bridge #2.



	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
🟨 Preconstruction	80.6	83.2	87.4	91.6	95.4	93.4	91.9	92.3	89.7	87.7	82.5	76.8
🟦 Postconstruction	84.8	87.8	92.2	96.3	93.5	91.7	93.4	90.1	87.7	83.1	78.2	76.1

Figure 20. Mean A-weighted SI frequency spectra from bridge #2 before and after construction.

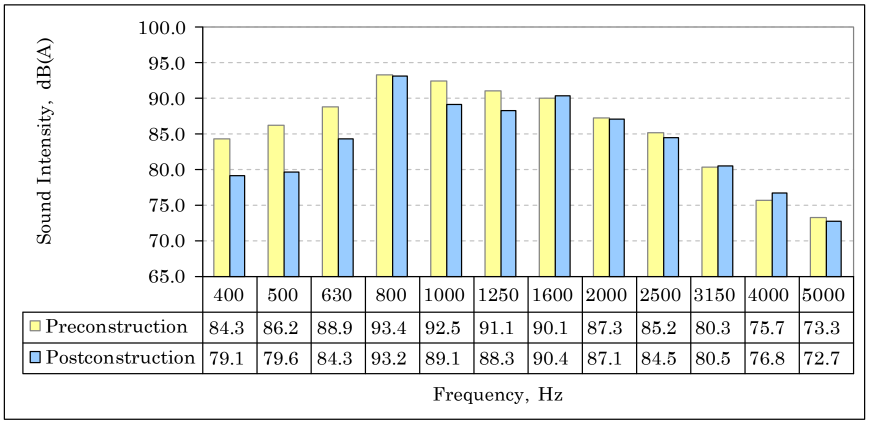


Figure 21. Mean A-weighted SI frequency spectra from bridge #3 before and after construction.

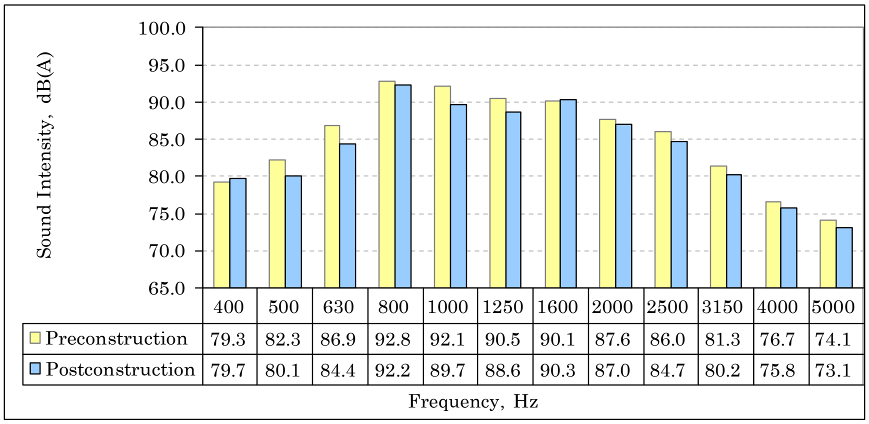


Figure 22. Mean A-weighted SI frequency spectra from bridge #4 before and after construction.

SI levels were calculated using logarithmic addition of the one-third octave band frequencies across the spectra. The SI levels are summarized in Table 6 for the bridge surfaces before construction. Even though bridge #2 was widened, the driving lanes remained essentially the same before and after construction, and the SI levels were expected to be similar. The SI level increased 0.5 dB(A). The completely reconstructed bridge decks of bridges #3 and #4 were 1.7 and 1.1 dB(A) quieter, respectively. While not meeting the HfL goal of 96.0 dB(A) or less, the noise coming from traffic on the two longest bridges has been reduced.

Table 6. Summary of the SI levels for the bridge surfaces before construction.

Bridge	**Preconstruction, SI (dB(A))**	**Postconstruction, SI (dB(A))**
Bridge # 2	101.1	101.6
Bridge # 3	99.5	97.8
Bridge # 4	98.8	97.7

Smoothness Measurement

Smoothness data collection was done in conjunction with the SI runs utilizing a high-speed inertial profiler integrated into the noise test vehicle. The profile data collected with this equipment provide IRI values, with lower values indicating a higher quality ride. Figure 23 is an image of the test vehicle showing the profiler positioned in-line with the right rear wheel. Figure 24 graphically presents the IRI values at 25-ft intervals for the existing bridge surfaces. For reference, the bridge locations are indicated by shaded areas. The mean IRI values computed for each bridge, excluding the roughness at the ends of the bridge, are summarized in Table 7.

As expected, bridge #2 remained more or less unchanged by construction, and the IRI value after construction was higher than for either bridge #3 or bridge #4. Bridge #3 showed the most improvement, with a reduction in IRI of 71.6 in/mi (or 32 percent), while bridge #4 showed a slight increase in IRI. Neither bridge #3 nor bridge #4 met the HfL goal of less than 48 in/mi after construction, which is more readily obtainable on long open stretches of highway.

Figure 23. High-speed inertial profiler mounted behind the test vehicle.

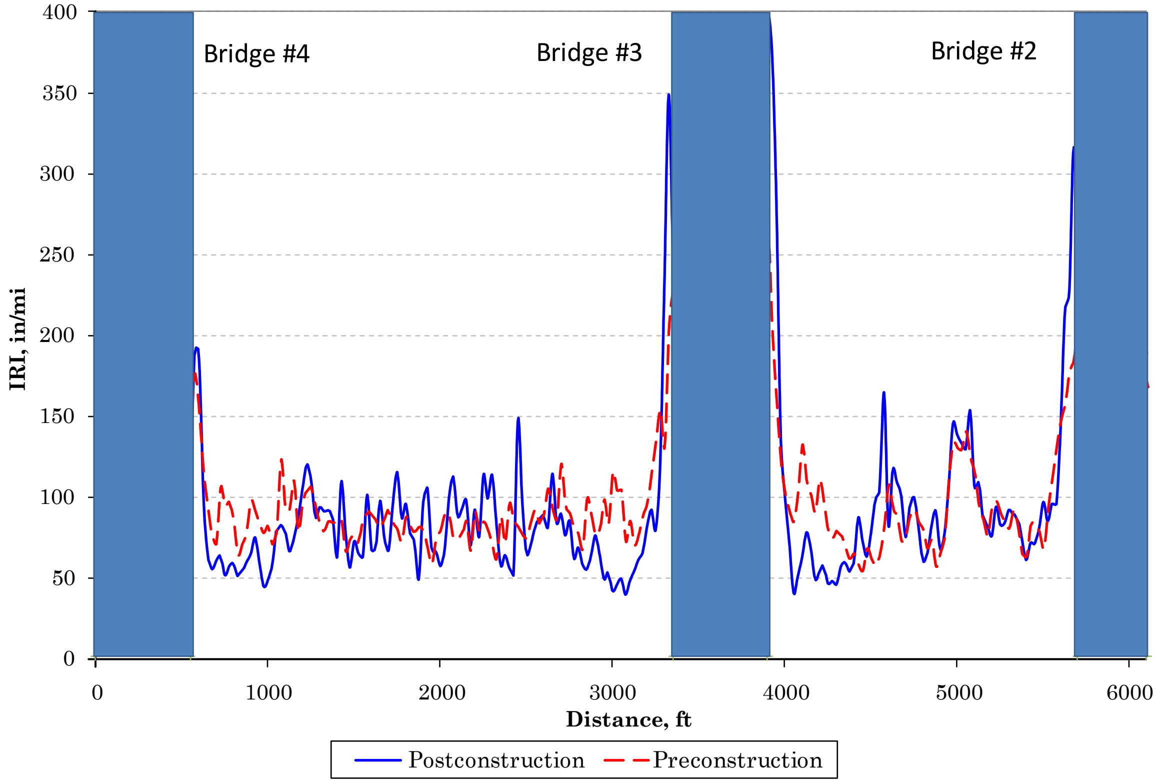


Figure 24. Mean IRI values computed at 25-ft intervals before construction.

Table 7. Pre- and post-reconstruction IRI values.

Bridge	Preconstruction, IRI (in/mi)	Postconstruction, IRI (in/mi)
Bridge #2	195	193
Bridge #3	221	150
Bridge #4	117	124

USER SATISFACTION

The HfL requirement for user satisfaction includes a performance goal of 4-plus on a Likert scale of 1–7 (in other words, 57 percent or more participants showing favorable response) for the following two questions:

- How satisfied is the user with the new facility compared with its previous condition?
- How satisfied is the user with the approach (multiple bypass bridges) used to construct the new facility in terms of minimizing disruption?

Instead of surveying users with the HfL questions, WisDOT invited 13 potential respondents from their weekly construction update address list to take an online survey asking the following questions on a 4 or 5 rating scale:

1. How would you rate the overall project?
2. During the construction project, how well were you kept up to date on the progress of the project?
3. During construction, how would you rate the demeanor of the construction crew present on the work site?
4. During construction, how was your commute through the construction zone inconvenienced?
5. Prior to construction of the new bridges on WIS 25 between Nelson, Wis. and Wabasha, Minn. how well did you feel you were kept informed of the project plans?

Of the 13 potential respondents, 6 participated in the survey. Overall, the response to the questions exceeded the HfL goal of 4 out of 7 (or the majority of the respondents) or more showing favorable response. Five of the six respondents gave an excellent rating to question #1, which closely addresses the HfL question of how satisfied the user is with the new facility. Five respondents also gave question #4 a favorable response. This question is similar to the HfL question gauging how satisfied the user is with the approach used to construct the new facility in terms of minimizing disruption. The complete results of the survey are contained in the appendix.

ECONOMIC ANALYSIS

A key aspect of HfL demonstration projects is quantifying, as much as possible, the value of the innovations deployed. This involves 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.

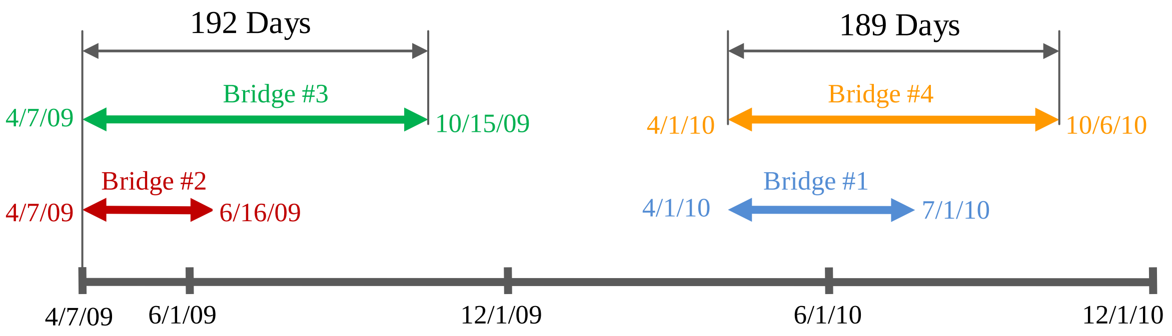
For this economic analysis, WisDOT supplied the cost figures for the as-built project. The assumptions for the baseline case were determined from discussions with WisDOT and national literature. Traditional methods would have involved the use of cast-in-place construction, conventional design details, and maintaining traffic through staged construction on bridges #3 and #4 over two construction seasons.

WisDOT determined early in the design process that a total route detour would be unacceptable from a safety standpoint, as emergency vehicles must use WIS 25 to maintain acceptable response times. The nearest river crossing would have made the round trip detour 70 miles. As a result, staged construction and the use of temporary traffic signals on bridges #3 and #4 would have been the traditional method to maintain traffic flow through the work zone. However, the short distance between these two bridges would not have afforded adequate length to store the queued vehicles waiting on the signal lights. Simultaneous construction under this condition would not have been possible, resulting in a much longer construction schedule, as the two longest bridges would have been replaced in separate construction seasons. In other words, the baseline construction scenario would have been to replace bridge #3 and widen bridge #2 in 2009 and then replace bridge #1 and bridge #4 in 2010. Bridge #1 was a steel pony truss structure that would have required the use of a bypass in either case. Moreover, since the substructure of bridge #2 was adequate and only widening was needed, staged construction would have been used on this bridge regardless of the work on the other bridges.

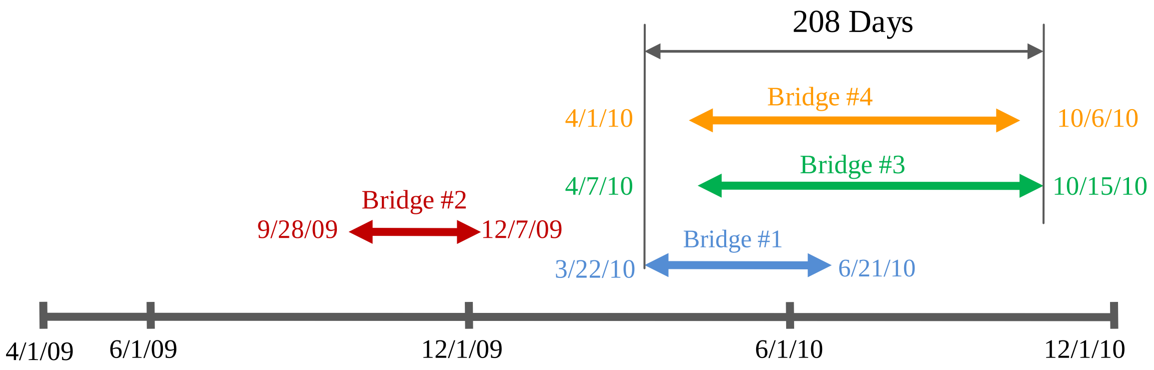
CONSTRUCTION TIME

Traditional construction methods would have lengthened the total construction schedule across two construction seasons to accommodate the reconstruction of bridges #3 and #4. Along with the use of the temporary bypass bridges, the use of precast elements helped reduce construction time by eliminating the amount of time needed to cure the concrete and allowed for overall quicker construction.

Traffic was impacted by work on the three bridges with bypasses for 208 days. The bypasses at bridges #3 and #4 were in effect for essentially the same time period—198 days. A reasonable estimate of the amount of time for the baseline case is the sum of the time required to construct bridge #3 (192 days) and bridge #4 (189 days), or a total of 381 days, during which time all the bridges could have been completed. Therefore, the time saved through the innovative use of multiple bypasses was 173 days (or 45 percent), which is close to the HfL goal of 50 percent reduction in the time traffic was impacted by construction compared to traditional construction methods. The timelines are illustrated in Figure 23.



Estimated timeline for traditional construction.



Actual construction timeline.

Figure 25. Traffic impact timeline.

CONSTRUCTION COSTS

Table 8 presents the 2009 construction costs of the baseline and the as-built alternatives. The as-built total cost was $112,376 more than the baseline case. The construction assumptions were provided by WisDOT. Bid costs from the awarded as-built contract served as the basis to estimate baseline costs such as:

- Cast-in-place concrete piers and abutments.
- Standard concrete bridge decks cast under phase construction.
- Standard epoxy coated steel and standard concrete in the approach aprons.
- Monthly rental of traffic signals for bridges #3 and #4.

Table 8. Capital cost calculation table.

Cost category	Baseline case	As-built case
Design and Engineering[1]	$ NA	$ NA
Bridge #1		
Bridge Construction	$ 608,824	$ 608,824
Temporary Bypass	$ 100,000	$ 100,000
Bridge #2		
Bridge Construction	$ 884,901	$ 884,901
Traffic Control (Traffic Signals Rental)	$ 13,644	$ 13,644
Bridge #3		
Approach Aprons[2]	$ 88,700	$ 48,000
Superstructure[2]	$ 1,544,331	$ 1,150,451
Abutments[3]	$ 154,342	$ 221,125
Piers[3]	$ 613,146	$ 784,470
Temporary Bypass	$ --	$ 300,000
Traffic Control (Traffic Signals Rental)	$ 47,754	$ --
Bridge #4		
Approach Aprons[2]	$ 88,700	$ 48,000
Superstructure[2]	$ 1,544,331	$ 1,150,451
Abutments[3]	$ 144,018	$ 210,131
Piers[3]	$ 577,746	$ 750,570
Temporary Bypass	$ --	$ 300,000
Traffic Control (Traffic Signals Rental)	$ 47,754	$ --
Pavement Improvements Between Bridges	$ 1,356,805	$ 1,356,805
Other Bridge Construction Items[4]	$ 4,571,597	$ 4,571,597
Total Cost	**$ 12,386,593**	**$ 12,498,969**

Notes:

[1] WisDOT had no accurate means of isolating the design and engineering costs between the baseline or as-built case.

[2] Forming in confined spaces during staged construction elevated the bid cost of concrete for the baseline case. The actual elevated cost was for bridge #2 and was applied to bridges #3 and #4.

[3] The cost of precast work along with the need for precision driven piles to insure proper alignment for the precast sections increased the cost of both the as-built abutments and piers over the baseline case.

[4] Other bridge construction items include bid items common to either the baseline or as-built case such as mobilization, surveying, excavation, removing the existing structures, girders (bridges #3 and #4), beam guards, riprap, seeding, and necessary hardware to complete the bridges.

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. VOC are assumed to be identical for the baseline and as-built case since the route length remained virtually the same through the work zone. The delay costs and safety-related costs are discussed in the following sections.

Delay Costs

The impact of traffic delay for the baseline case is based on using traditional staged construction methods with temporary traffic signals for bridges #3 and #4. The work zone traffic flow through the traffic signal at bridge #2 and the bypass at bridge #1 would have remained the same in both the baseline and as-built cases and therefore does not impact this analysis. The work zone speed limit was assumed to be the same in either case. The actual maximum delay caused when the bypasses at bridges #3 and #4 were in effect serves as a conservative comparison to the baseline scenario.

It was calculated that $3,612,245 was saved as a direct result of minimizing the construction schedule and installing temporary bypass bridges to keep two lanes of traffic moving through the work zone. The following provides a basis for this conclusion:

- WisDOT determined that the temporary signal cycle length necessary to clear the length of the bridge and clear the queued vehicles would have been 5 to 10 minutes. This would have caused an average 7.5-minute delay (0.125 hours per vehicle) in the traffic flow at either bridge #3 or bridge #4.
- Actual trip time data show the as-built delay was 0.0137 hours per vehicle when bypasses were in effect at both bridge #3 and bridge #4.
- The total duration of delay for the baseline scenario was estimated to have lasted 381 days, and the as-built delay duration lasted 208 days, as discussed previously.
- The 2009 ADT was 5,050 vehicles with 14 percent commercial vehicle traffic.
- Based on the Bureau of Labor Statistics[2] and the US Department of Transportation Guidelines,[3] the 2009 per hour passenger vehicle rate was $15.46 and the commercial vehicle rate was $19.14.

Using these assumptions and cost figures, the baseline delay cost for passenger vehicles is:

Delay = 5,050 (vehicles/day) * 0.86 (percent passenger vehicles)
* 0.125 (hours of delay/vehicle) * 381(days) * $15.46 (value per hour)
= $3,197,675

The baseline delay cost for commercial vehicles is:

Delay = 5,050 (vehicles/day) * 0.14 (percent commercial vehicles)
* 0.125 (hours of delay/vehicle) * 381(days) * $19.14 (value per hour)
= $644,461

The total baseline delay cost is:

Delay $_{\text{baseline}}$ = $3,197,675+ $644,461
= **$3,842,135**

---

[2] *May 2009Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates, Eau Claire, WI.* United States Department of Labor, Bureau of Labor Statistics.

[3] *Departmental Guidance for the Valuation of Travel Time in Economic Analysis*, US Department of Transportation, 1997. Rates are based on 1.6 person occupancy per passenger vehicles operating locally and single occupancy per truck operating locally.

The as-built delay cost for passenger vehicles is:

Delay = 5,050 (vehicles/day) * 0.86 (percent passenger vehicles)
* 0.0137 (hours of delay/vehicle) * 208 (days) * $15.46 (value per hour)
= $191,330

The as-built delay cost for commercial vehicles is:

Delay = 5,050 (vehicles/day) * 0.14 (percent passenger vehicles)
* 0.0137 (hours of delay/vehicle) * 208 (days) * $19.14 (value per hour)
= $38,561

The total as-built delay cost is:

$\text{Delay}_{\text{as-built}} = \$191{,}330 + \$38{,}561$
= **$229,891**

The delay cost deferential between the baseline and as-built case is:

$= \$3{,}842{,}135_{\text{baseline}} - \$229{,}891_{\text{as-built}}$
$\text{Delay}_{\text{Differential}}$ **= $3,612,244**

Safety Costs

As discussed earlier in this report, crashes on this section of highway over the past several years were below the State average. 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 2009 ADT for this section of highway was 5,050.
- WisDOT crash data for this section of highway shows 77 crashes per HMVMT (based on data from 2000 to 2005).
- The crash rate is further divided into crashes that result in property damage or personal injury:
  - According to WisDOT, 13 of the 19 crashes involved personal injury, for which the crash rate is:
    = 13/19 * 77 crashes / HMVMT
    = 52.7 crashes / HMVMT
  - The crash rate involving property damage is:
    = 77- 52.7 crashes / HMVMT
    = 24.3 crashes / HMVMT

Ullman et al.[4] 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 61 percent by night and 66 percent by day (an average of 63.5 percent) when a traffic lane was closed. Given this information, and considering the traffic volumes and hourly traffic variations on this highway and the expected construction schedules, Table 9 presents the number of vehicles that would have passed through the work zone for the as-built and baseline projects.

Table 9. Estimated total traffic for the intersection used to compute safety impacts for baseline and as-built scenarios.

	Baseline	**As-Built**
Two-way 2009 ADT, vehicles/day	5,050	5,050
Total number of construction days	365 (assumed)	198
Total traffic volume (millions) (Two-way ADT * construction days)	**1.84**	**1.00**

Table 9 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 (= 0.635, as discussed earlier). This is computed for the baseline case as follows:

- Estimated personal injury crashes due to the presence of a work zone:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (1.84) * 0.527 * (1.0 + 0.635) = 1.59 crashes

- Estimated property damage crashes due to presence of a work zone:

  = Total traffic volume (million vehicles) * crash rate (number/million vehicles) * risk escalation factor due to work zone
  = (1.84) * 0.243 * (1.0+0.635) = 0.73 crashes

---

[4] 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.

The elevated risk was monetized by assuming unit costs from Council et al.[5] for the various types of historical crashes. The following mean comprehensive 2009 cost per crash for an arterial highway with a posted traffic speed less than 45 mi/hr were used in the analysis:

- Personal injury and fatality crash—$90,189 (severity unknown, Level 5).
- Property damage crash—$8,853 (nature of crash unknown, Level 5).

Table 10 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 $149,863 as opposed to no costs for the as-built case. The $149,863 total is essentially the safety benefit of the as-built case.

Table 10. Comparison of safety costs—baseline versus as-built.

	Baseline	**As-built**
Personal injury and fatality crashes (= Crash cost ($/crash) * Number of crashes)	$143,400 (= $90,189*1.59)	$0 (No crashes)
Property damage crashes (= Crash cost ($/crash) * Number of crashes)	$6,463 (= $8,853*0.73)	$0 (No crashes)
Total	**$149,863**	**$0**

COST SUMMARY

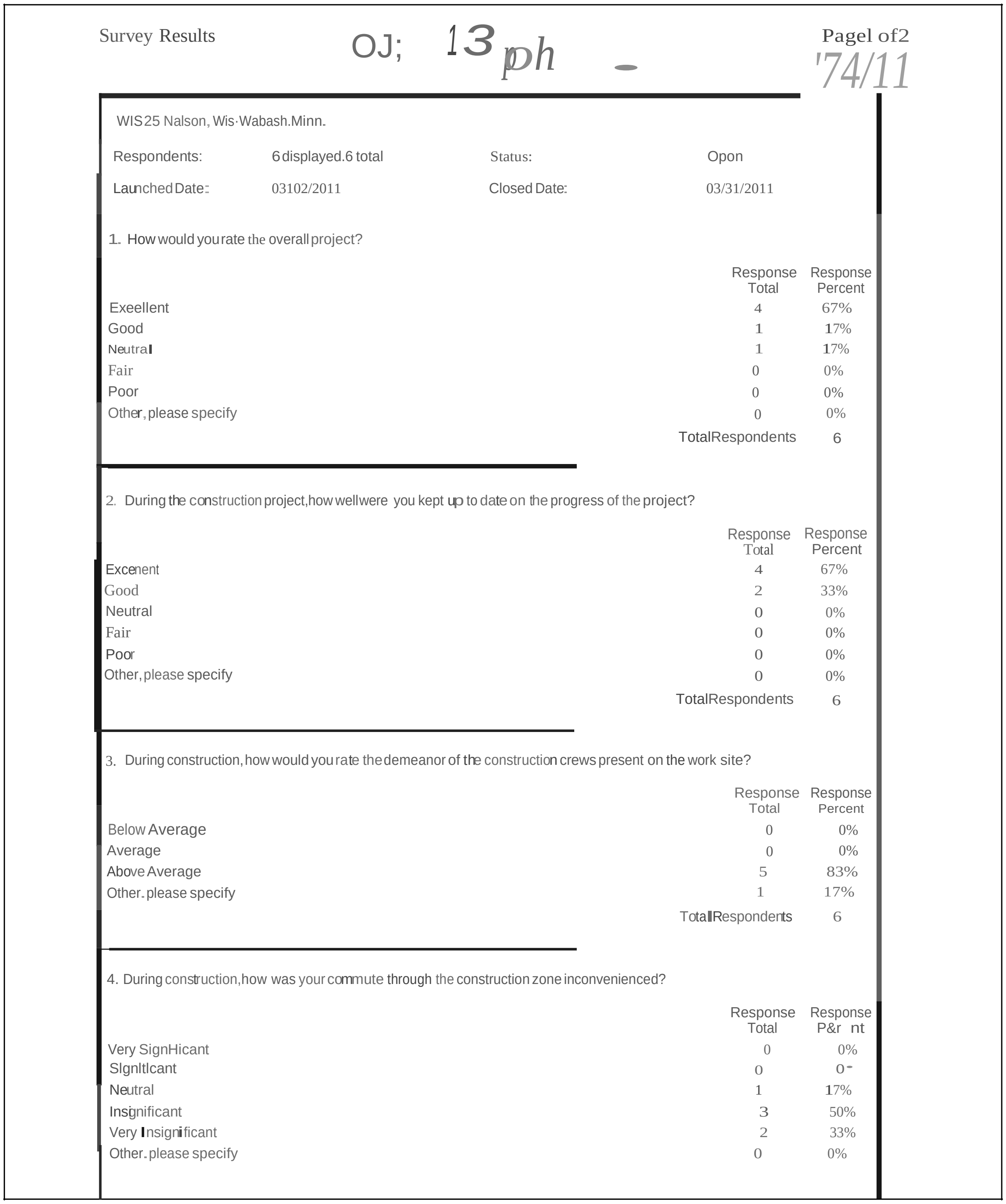
Delivering the project in less time than traditional methods cost users $112,376 in construction costs but saved users $3,612,244 in delay costs plus $149,863 in safety costs. Using the innovative HfL project delivery approach saved an estimated total of $3,649,731. In other words, the innovative approach to this $12.5 million project had a 29 percent cost benefit over traditional methods.

---

[5] 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.

APPENDIX

Results of the user satisfaction survey.



Survey Results OJ; 13 ph - Page 1 of 2 '74/11

WIS 25 Nalson, Wis·Wabash.Minn.

Respondents:	6 displayed.6 total	Status:	Open
Launched Date:	03102/2011	Closed Date:	03/31/2011

1. How would you rate the overall project?

	Response Total	Response Percent
Excellent	4	67%
Good	1	17%
Neutral	1	17%
Fair	0	0%
Poor	0	0%
Other, please specify	0	0%
Total Respondents		6

2. During the construction project, how well were you kept up to date on the progress of the project?

	Response Total	Response Percent
Excellent	4	67%
Good	2	33%
Neutral	0	0%
Fair	0	0%
Poor	0	0%
Other, please specify	0	0%
Total Respondents		6

3. During construction, how would you rate the demeanor of the construction crews present on the work site?

	Response Total	Response Percent
Below Average	0	0%
Average	0	0%
Above Average	5	83%
Other. please specify	1	17%
Total Respondents		6

4. During construction, how was your commute through the construction zone inconvenienced?

	Response Total	Response Percent
Very Significant	0	0%
Significant	0	0-
Neutral	1	17%
Insignificant	3	50%
Very Insignificant	2	33%
Other. please specify	0	0%

Results of the user satisfaction survey (continued).