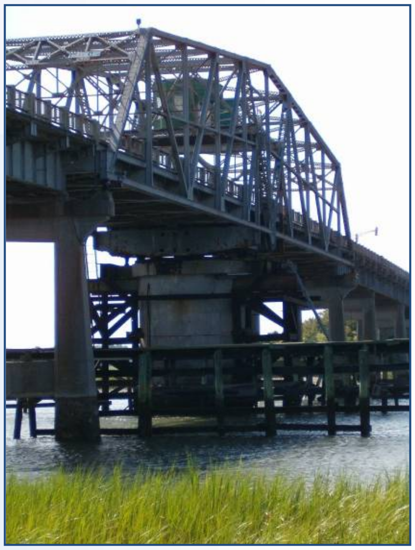
South Carolina Demonstration Project: Rapid Removal and Replacement of the SC 703 Ben Sawyer Bridge Over the Intracoastal Waterway in Charleston County

Final Report
September 2011

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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Rex D. Gilley, P.E., Jagannath Mallela, Jeff Mosher, P.E., Gerald L. Ullman, and Paul Littleton

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Applied Research Associates, Inc.
100 Trade Centre Drive, Suite 200
Champaign, IL 61820

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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 South Carolina Department of Transportation (SCDOT) was awarded a $1 million grant to demonstrate the use of proven, innovative technologies for accelerated bridge removal and replacement. This report documents accelerated bridge construction (ABC) techniques used to remove, widen, and replace the superstructure of the SC 703 bridge over the Intracoastal Waterway in less time than traditional construction methods.

This report contains a description of the existing bridge and the materials and techniques used during construction. Prefabricated modular superstructure segments, four per span, were used to simplify and expedite the construction. Under conventional construction, the impact of this project on the traveling public was estimated at 8 months, but with the use of accelerated construction techniques, the impact was reduced to 10 days.

Using ABC techniques added about $4.8 million to the initial construction cost of the project. However, a more comprehensive economic analysis including user cost savings shows that the project saved road users about $1.7 million (or 5 percent of the total project costs).

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accelerated bridge construction, design-build, economic analysis, Highways for LIFE, innovative construction

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
(none)	mil	25.4	micrometers	μm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square 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

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The project team would also like to acknowledge the support from Ryan Hamrick, Tyler VanderLinden, and Lyn Davis of PCL Constructors, Inc.; Tim Noles, John Low, Mike Sileno, and Andrew Barthle of Hardesty and Hanover, LLP; Greg Schuch of Florence and Hutcheson; and Kim Partenheimer, Fred Parkinson, Ray Moran, Graciela Patino, and Mike Elza of Parsons Brinkerhoff (PB Americas, Inc.).

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ABC	accelerated bridge construction
ADT	average daily traffic
ARAN	Automatic Road Analyzer
CE&I	construction and engineering inspection
dB(A)	A-weighted decibels
DB	design-build
DOT	department of transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
Hz	hertz
IRI	International Roughness Index
NCAT	National Center for Asphalt Technology
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
pdf	portable document format
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SI	sound intensity
SRTT	standard reference test tire
SCDOT	South Carolina Department of Transportation
TSP	technical special provision
vpd	vehicles per day
VOC	vehicle operating costs

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, 2009, and 2010. 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).
    - Sound—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 South Carolina Department of Transportation's (SCDOT) HfL demonstration project, which involved accelerated removal and replacement of a movable bridge over the Intracoastal Waterway. The report presents project details relevant to the HfL program, including accelerated bridge construction (ABC), 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 SCDOT HfL demonstration project used modular construction techniques and design-build (DB) contracting as key innovations in the ABC approach to replace the deteriorated superstructure of the Ben Sawyer Bridge.

The Ben Sawyer Bridge is a 247-foot (ft) long complex movable structure with a Pratt Thomas through truss swing span that provides motorist access over the 90-ft-wide Intracoastal Waterway between Mount Pleasant and Sullivan's Island, SC. A total of 452 ft of approach spans over environmentally sensitive marsh connect the swing span to the north and south abutments. Each approach span is comprised of six simply supported spans of concrete deck on built-up plate girders. The original structure was built in 1945 and was in need of repair . Because of the bridge's historical importance to the local community, it was critical that the appearance of the new superstructure closely resemble the existing truss and approach spans. Using the FHWA HfL grant, SCDOT decided to keep the existing substructure and alignment and replace all mechanical, electrical, and superstructure items during a minimal 10 day total bridge closure.

The modular construction techniques involved assembling the 1,200-kip swing span offsite on the Cooper River. Once completed, the swing span was loaded on barges and floated to the site. Capitalizing on the fluctuation in tide levels, crews raised the existing swing span off the pivot pier and lowered the new swing span into place.

The new approach spans were built next to the structure on temporary pipe-pile foundations and installed using a hydraulic sliding system. The new and existing approach spans were raised off their foundation and set on low-profile rollers, enabling the existing spans to be hydraulically jacked or slid from the existing alignment onto adjacent temporary foundations, while the new approach spans were slid into place from temporary foundations on the other side.

The decision to use DB was to allow for contractor/designer innovation and staging to accomplish the tight schedule under ABC. The chosen contractor (PCL Civil Constructors, Inc.) accelerated construction of the project from the initial estimate of 24 months to 18 months by performing a number of activities concurrently. All other bidding teams proposed completing the project in a 24-month period. PB Americas, Inc. managed the construction engineering and inspection (CE&I) and provided design review.

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—Modular construction beside the existing bridge or offsite plus total closure of the bridge during replacement of the superstructure eliminated the need for the public to travel through a potentially hazardous work zone. The work zone crash rate was 0, which meets the HfL goal of being equal to or less than the preconstruction rate at the project location.
  - 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.
  - Facility safety after construction—The finished project provides 14-ft lane widths to safely accommodate both motorists and bicyclists and a 5.5-ft sidewalk for pedestrians—a marked improvement over the narrow 10-ft travel lanes and 2.5-ft sidewalk of the old structure. While these safety improvements are promising, the net effect they will have on the HfL goal of 20 percent reduction in fatalities and injuries in 3-year crash rates compared to preconstruction rates has yet to be determined.

- **Construction Congestion**
  - Faster construction— As a result of ABC, traffic impact was limited to 10 days instead of the 8 months needed for traditional construction methods. This was a 96 percent reduction in the time traffic was impacted. The reduced traffic impact far exceeds the HfL goal of 50 percent reduction in the time traffic was impacted compared to traditional construction methods.
  - Trip time—Traffic flow across the bridge and essentially through the work zone was either not impacted by construction activities or, for a short time, completely detoured. The trip time was evaluated by comparing the total trip time accumulated under the actual detour and the 8-month detour required by traditional construction. The as-built approach had less than a 1percent accumulated increase in trip time compared to the duration of traditional construction, far less than the HfL goal of no more than a 10 percent increase in trip time compared to the average preconstruction conditions.
  - Queue length during construction—Most of the construction was done off the bridge or during brief periods at night when traffic was light. Some deliveries were made during the day. On those occasions, queues were not more than 0.25 mi long, meeting the HFL goal of maintaining a moving queue length of less than 0.5 mi in a rural area near the posted speed.

- **Quality**
  - Smoothness and sound—The IRI value for the approach spans dropped from 133.7 in/mi before construction to 76.8 in/mi after construction, and the swing span dropped from 183.3 to 75.9 in/mi. While not meeting the HfL goal of 48 in/mi, it was an average 51 percent increase in smoothness over the existing structure. Sound quality was also improved by the new construction. The sound intensity (SI) value for the approach spans dropped from 102.0 to 101.3 dB(A), and the swing span dropped from 104.0 to 100.4 dB(A). Even though the SI results failed to meet the HfL goal of

less than 96.0 dB(A), the results were a noticeable reduction. It is difficult to achieve a smooth, quiet ride on a bridge because of the joints, but the ride quality has improved.

  - User satisfaction—A user satisfaction survey was not conducted for this project.

ECONOMIC ANALYSIS

Using innovative techniques such as modular construction and a hydraulic sliding system to remove and replace the bridge substantially reduced the duration of traffic detours. Even though traditional construction costs may have been lower, an economic analysis of the user costs associated with SCDOT's innovative approach offset the increased cost of construction over traditional methods by $1 million or 3 percent of the delivered project cost.

LESSONS LEARNED

- **Definition of Fully Operational**

  When the critical milestone was set for the total closure, a detailed definition of Fully Operational should have been defined in the contract so that both the Owner and Contractor could jointly determine if the swing span is ready to be opened to traffic. This should include but not limited to; all system checks needed, all operation mode checks, all necessary alignment measurements, etc. With the incentives/disincentives attached to this critical milestone, time is essential for staff on both sides.

- **Fabrication Inspection**

  For SCDOT, the off-site inspection was a challenge and the state’s CE&I consultant was used. The inspection necessary for fabrication should be included in future contracts along with required notification from the contractor to allow for travel. As part of this, the definition of fabrication should be included to include inspection requirements for forging, casting, and final machining.

- **Preclosure Checklist**

  On this project the determination of whether or not the contractor was ready to begin the closure was a challenge for SCDOT. A contract deliverable should be included in future contracts requiring the contractor to submit for approval a pre-closure checklist. The contractor should provide the owner with a list of items to be complete prior to start of the total closure. This will aid both the contractor and owner is setting the start of this critical milestone.

CONCLUSIONS

SCDOT's innovative approach was successful in delivering a quality product quickly, safely, and with less interruption to the public compared to traditional methods. The use of modular construction and a hydraulic sliding system to set portions of the bridge in position allowed SCDOT to minimize the duration of traffic detours, saving both time and money.

PROJECT DETAILS

BACKGROUND

The existing Ben Sawyer Bridge was opened in 1945 and is eligible for inclusion on the National Register of Historic Places. South Carolina Route 703 is the only direct access to Sullivan's Island from Mount Pleasant (figure 1), and residents consider this bridge part of their culture and history.

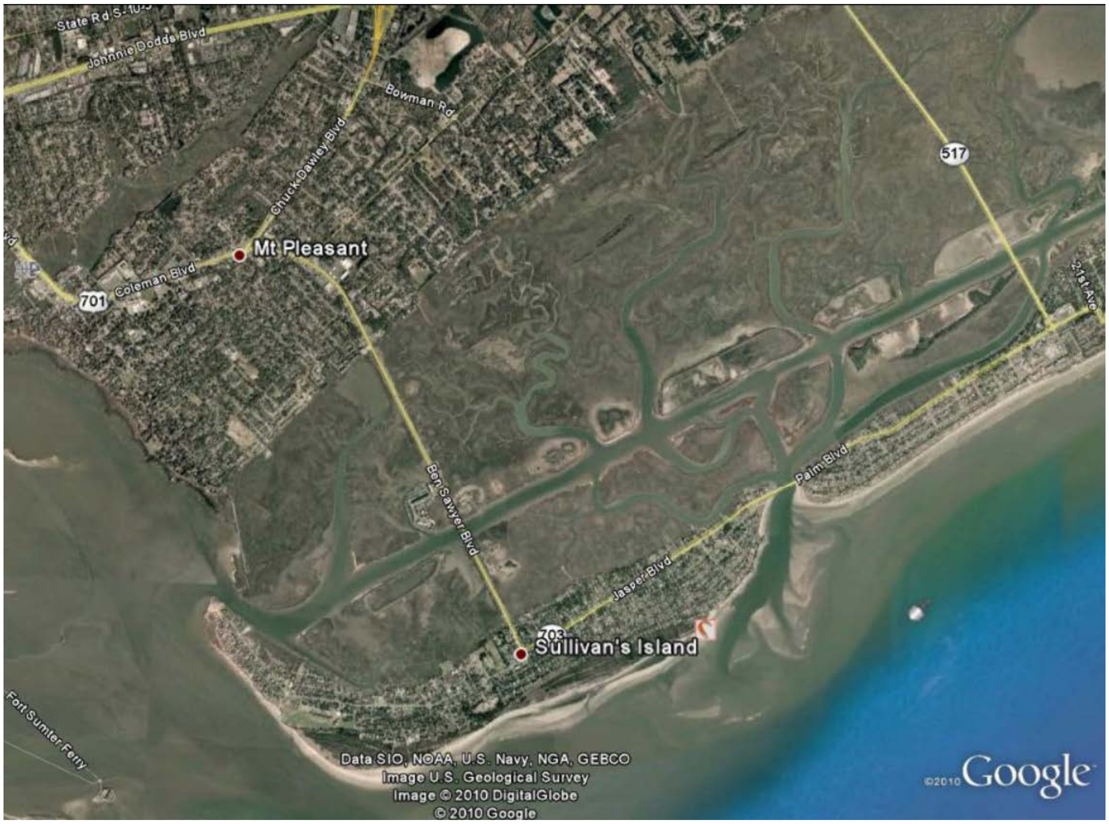


Figure 1. Location map for SC 703 over the Intracoastal Waterway (Source: Google Maps).

In 1998, SCDOT proposed replacing the aging swing-span bridge with a high-level, fixed-span bridge. The local community was adamant about preserving the appearance and characteristics of the existing structure. The project was delayed in fiscal year 2000 because of an inability to reach an appropriate compromise. In 2005, the project was revived when SCDOT introduced a proposal to rehabilitate as much of the existing structure as possible. Components that were not considered feasible or economical for rehabilitation would be replaced with new components similar in appearance.

A public information meeting was held in September 2005 to present the project to the community. Several kiosks were set up before the meeting to distribute the project newsletter and provide information on the new proposal. The information meeting was followed by a public hearing in June 2007. At the meetings, renderings and computer animations of the proposed structure were displayed and discussed. The community was notified of the meetings through signs, postcards, newspaper articles, and legal advertisements. Additional meetings were held with municipalities during this time to update them on the status of the project. They were also notified of the information meetings and hearings via phone followed by individual letters. Since 2005, the project has enjoyed considerable support from the community and its leaders.

As part of this process, in 2005 SCDOT's engineering consultant performed a detailed inspection of the bridge and developed a report that studied various options for improving this vital transportation link. The options investigated in the PB Americas, Inc. *Ben Sawyer Inspection Report, September 2005* are as follows:

- **Option 1a—**Rehabilitate the approach and swing spans to restore the load-carrying capacity to at least the American Association of State Highway and Transportation Officials (AASHTO) HS-20 highway load rating standard.
- **Option 1b—**Rehabilitate the approach and swing spans to restore the load-carrying capacity to at least the AASHTO HS-20 standard and increase the sidewalk on one side to at least 6 ft wide.
- **Option 2—**Rehabilitate the approach spans and increase sidewalk width on one side to 6 ft. Replace the entire truss with a new truss with at least a 6-ft sidewalk.
- **Option 3—**Replace the truss and approach spans with new spans that accommodate at least a 6-ft sidewalk. Reuse the existing substructure.

These options were developed with the following criteria in mind:

- The bridge could not be replaced with a high-level crossing.
- Any repair or rehabilitation must replicate the look of the existing structure.
- An increase in sidewalk width, if possible, was desirable.
- Any work should be staged so that traffic closures are minimized.

SCDOT's *Environmental Assessment for the Ben Sawyer Bridge Project, September 2006* further describes the alternatives by providing estimated traffic interruption or bridge downtime, lifespan, and cost.

Table 1 summarizes this information. Environmental concerns and public opposition eliminated the option of building a new bridge next to the existing bridge. SCDOT's traditional construction method of replacing the entire superstructure, as stated in its HfL grant application, would have been to replace the bridge on the existing alignment, necessitating a complete closure of the bridge for at least 8 months.

Table 1. Summary of alternatives.

Option	Description	Cost Estimate[2]	Bridge Downtime	Lifespan	
				Approach Spans	Swing Span
		(Millions)	(Weeks)	(Years)	(Years)
1a	Rehabilitate approach structures and movable span. Ultimate section matches existing. Reuse existing substructures.	$15.8 to $17.0	8–10 weeks of night single-lane closures plus a 3-day total shutdown[1]	50	15–20
1b	Rehabilitate approach structures and movable span. Add at least a 6-ft pedestrian trail to one side of both existing structures. Reuse existing substructures.	$16.7 to $18.1	8–10 weeks of night single-lane closures plus a 3-day total shutdown[1]	50	15–20
2	Rehabilitate approach structures and add at least a 6-ft pedestrian trail to existing structure. Replace movable span with float-in superstructure that includes a pedestrian walkway. Reuse existing substructures.	$17.4 to $18.9	8–10 weeks of night single-lane closures plus a 1-week total shutdown[1]	50	75
3	Replace approach superstructure with new slide-in superstructure with at least a 6-ft pedestrian walkway. Replace movable span with float-in superstructure that includes a pedestrian walkway. Reuse existing substructures.	$21.1 to $22.9	1-week total shutdown	75	75

[1] Assumes work on both approaches occurs simultaneously.

[2] Cost estimates are in 2005 dollars and do not consider escalation.

Option 3 was the recommended option and the one used to complete this project. The reasons for this recommendation are as follows:

- Creates the shortest amount of inconvenience to the traveling public
- Creates the least risk of cost or schedule growth
- Provides the longest life and does not require a second rehabilitation in 20 years
- Accommodates improved pedestrian and bike access while maintaining the look of the existing structure
- Has the lowest future maintenance costs because the fewest existing components are used
- Accommodates the reuse of existing substructures and keeps the bridge on the same alignment to minimize or eliminate right-of-way issues

Primary Construction and Design Constraints

Bridge Width

The existing Ben Sawyer bridge deck was 26 ft wide curb to curb, providing one travel lane in each direction. A 2.5-ft raised sidewalk was provided on each side. Because SC 703 had heavy bike and pedestrian traffic, the requirement to widen the travel lanes to 14-ft shared-use lanes was written into the contract. The width for the existing sidewalks was combined on the west side of the bridge, making one sidewalk 5.5 ft wide. Figure 2 illustrates the new lane widths and sidewalk.

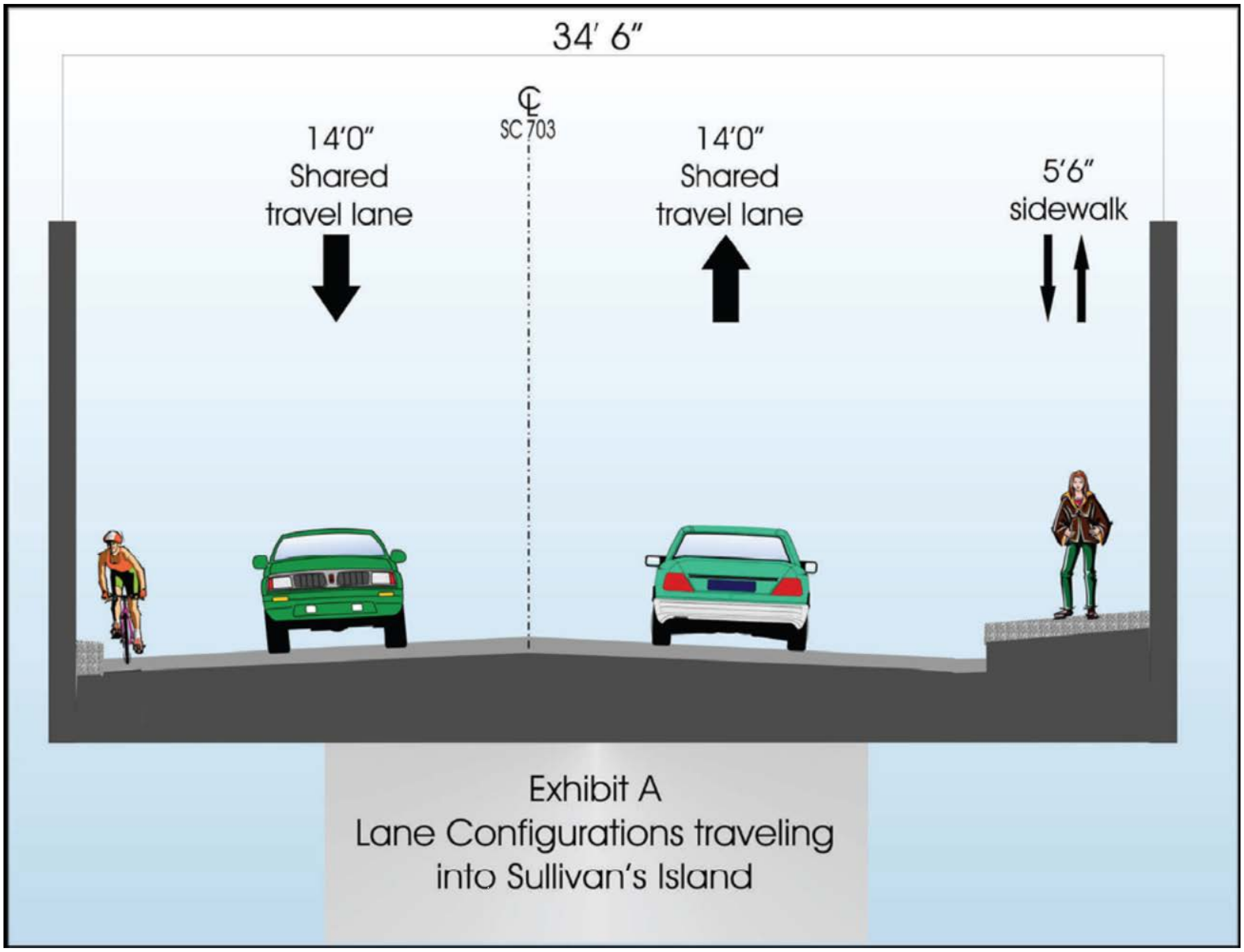


Figure 2. Typical planned cross section.

Weight

The existing foundation was reused to support the new superstructure, which restricted the total weight of the new construction. The total weight of the new construction exceeded the existing weight by more than 110 percent, so a seismic and foundation analysis of the entire structure was conducted. The entire structure performed adequately with the exception of the abutments. Two additional piles were driven at each abutment to help distribute the additional load.

Closure

SCDOT originally made a commitment to local authorities that the bridge would be removed from service for only 7 days or 168 hours. During construction, a large hole was discovered in the top of the pivot pier before the closure. The hole was caused by the 1989 hurricane Hugo when the bridge was knocked off the center bearing. Repairing the hole was critical to the integrity of the pivot pier. An additional 66 hours was added to the closure milestone due to the unforeseen repair needed for the pivot pier. During the closure, Charleston, SC, set the record for the most snow received in a single event in recorded history. With the unexpected weather conditions, the contractor finished the closure in 234 hours or about 10 days.

Aesthetics

Local authorities wanted the new superstructure to closely resemble aesthetically the existing truss and approach spans. The bridge is eligible for the National Register of Historic Places because the structure is uncommon and is an intact example of a mid-20th century center-pivot swing-span bridge. SCDOT even went to the extent of requiring the use of rivet head bolts on the new swing span, as shown in figure 3, to mimic the riveted construction style of the 1940s.

Figure 3. Closeup of the rivet head bolts.

PROJECT DESCRIPTION

Contracting Process

The contract was procured using DB methods and included special language to ensure the best value for the project. The request for proposal required that each contractor submit a technical proposal as well as a cost proposal. Each technical proposal was scored, and then each cost proposal was divided by its respective technical score to determine the adjusted low cost for contract award.

The allowed duration of the bridge closure was 168 hours with stipulations on when that 168-hour window could occur. Incentive pay of $2,500 per hour was given for each hour the closure was shortened. A disincentive of $2,500 per hour was specified for any hours over the 168-hour limit, with no cap on that portion.

Site Conditions

The area immediately surrounding the project was environmentally sensitive tidal wetlands. The approaches on either side of the swing span were comprised of two sets of three spans 70 ft, 86 ft, and 70 ft long and made of built-up steel plate girders. The single swing span consisted of a steel through truss 247 ft long. New machinery and electrical components were designed, manufactured, and installed. The swing span is operated using two independent drive systems, adding redundancy.

The minimum clearance on the Intracoastal Waterway was 65 ft. Having a high-profile fixed bridge was ruled out because (a) the bridge could be rehabilitated, (b) the bridge spans sensitive wetlands, and (c) local opinion was very strong on maintaining an on-alignment solution that aesthetically resembled the existing bridge. Building a temporary structure was not feasible because of potential environmental impacts, Intracoastal Waterway requirements, and practicality. The prefabricated method using sequenced construction techniques and a slide-in approach was the result of allowing the contractor/designer the flexibility to incorporate innovation under the DB approach.

Substructure Condition

The existing substructure, shown in figure 4, was cast-in-place concrete piers supported by creosote-treated timber piles. An inspection of the foundation determined that the existing substructure was in fair condition and could be reused with only minor crack and spall repair. The contract allowed for 10 cubic ft of spall repair and 600 linear ft of crack repair, and these quantities were not exceeded.

Figure 4. Approach span existing piers.

Temporary trestles were installed on each side of the approaches with a temporary foundation installed on the west side of the structure. The new approach superstructure was constructed on the temporary foundation. Figure 5 shows the plan view and elevation for the temporary trestles next to the existing approaches. Figure 6 shows a typical section view through an approach span and trestle.

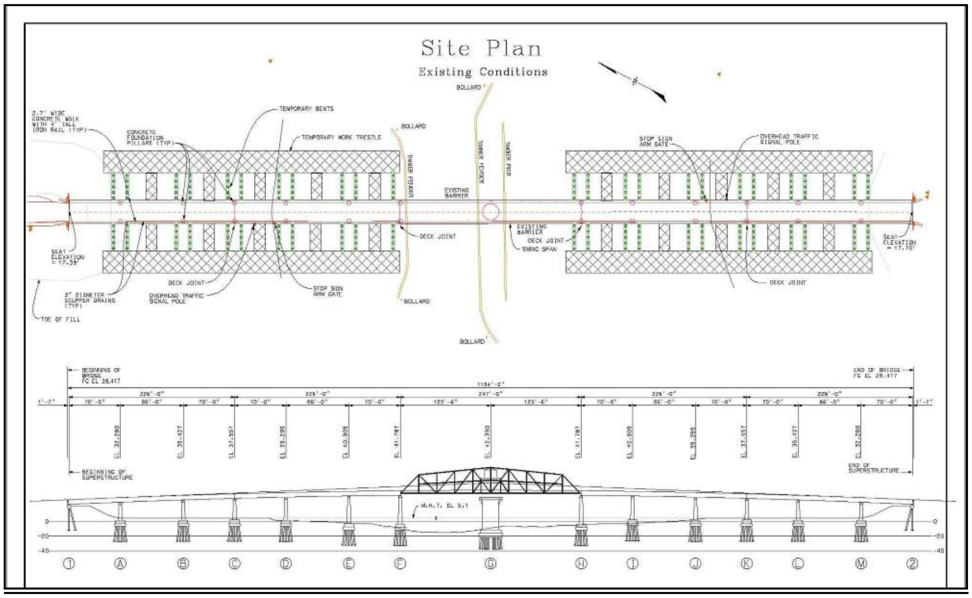


Figure 5. Bridge plan and elevation.

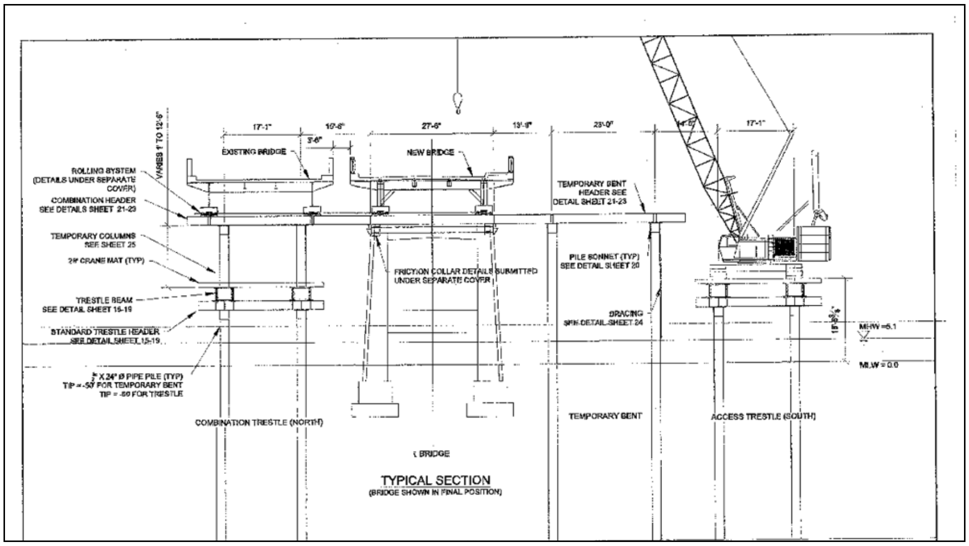


Figure 6. Typical section through an approach span and trestle.

Approach Construction

The new approaches were identical on each side of the swing. The main support for the approach spans were two built-up plate steel girders connected with typical wide flange steel members. On the outside of the girders, the deck was supported by built-up cantilevered beams. The deck consisted of stay-in-place forms, two mats of steel reinforcing, and lightweight concrete. The lightweight concrete was used to keep the bridge weight within the load limit of the existing foundation. An end view of a new approach span (painted white) is shown in figure 7.

Figure 7. New approach span before sliding into place.

During the bridge closure, the approach structures were raised onto low-profile rollers and hydraulically pulled to the east with individual pumps and jacks at each bent. Operators used air horns and radios to keep in contact with each other, and each operator moved the bridge a predetermined distance each time. PCL was very cautious not the pull the new approach spans past the final bearing locations because the jacks would have to be relocated to pull back in the opposite direction, resulting in the loss of valuable time within the closure milestone.

Swing Span Construction

The profile of the new swing span closely resembled the existing swing span. A new bridgetender's house, figure 8, was centered in the truss over the swing span, matching the original. The bridge deck was constructed with an exodermic deck to reduce weight and add rigidity. The majority of the machinery was centered on the center pivot shown in figure 9 (undergoing repairs). Figure 10 shows the limited machinery, common at each end of the swing span so when the bridge is in the closed position it will perform in a supported manner.

Figure 8. New bridgetender's house.

Figure 9. Pivot pier repairs during bridge closure.

Figure 10. New swing span machinery.

The swing span superstructure, machinery, and controls were assembled offsite at a local decommissioned U.S. Navy base. Once completed, the swing span was placed on a set of tandem barges and shipped to the site in transport position, with the swing span secured close to the deck of the barge to lower the center of gravity and make the system more stable for transportation. Figure 11 shows the new swing span being shipped to the site.

Figure 11. New swing span being transported to the bridge site.

Once onsite, the new swing span was raised closer to the bridge elevation, set on temporary supports, and prepared for placement on the repaired pivot pier. Timing the tides was critical for removing and setting the swing spans. The tide change at the site is about 6 ft between high and low tide, with two high tides a day. The free ends of the barges were placed under the existing swing span, and when the tide came in the existing swing span was raised off its bearing and removed. Figure 12 shows the existing and new swing spans on the barges.

Figure 12. Existing and new swing spans shown side by side on supporting barges.

The center pier was prepared for the new swing span and the new swing span was set on the foundation during the outgoing tide. The center bearing was then grouted and bolted into final location. Figure 13 shows an aerial view of the swing span placement operation and the new bridge approaches. The completed bridge is shown in figure 14.

Figure 13. Existing and new bridge elements before bridge closure.

Figure 14. Completed bridge replacement.

DATA ACQUISITION AND ANALYSIS

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

- Achieve a safer work environment for the traveling public and workers.
- Reduce construction time and minimize traffic interruptions.
- Deliver a higher quality project than attainable under traditional construction methods.

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

SAFETY

A permanent work zone, which would have posed a hazard to the public and workers, was not needed on this project because of offsite construction of the bridge and approach sections away from live traffic crossing the bridge. Records of worker safety were not available for comparison to the HfL safety goals.

CONSTRUCTION CONGESTION

Introduction

The project to rehabilitate the Ben Sawyer Bridge, which carries SC 703 over the Intracoastal Waterway between Mount Pleasant and Sullivan’s Island, was an ABC design-build project that required full closure of the bridge for a period of time during the project. SC 703 is a two-lane highway that typically carries about 14,100 vehicles per day (vpd) with about 5 percent trucks. It is the primary route on and off Sullivan’s Island for many residents, although a parallel facility is located about 3 miles to the northeast (SC 517, Palms Boulevard). During most of the project, the bridge was allowed to remain open to travel in both directions. Other than occasional slowdowns because of construction vehicles entering and exiting the work area, travel impacts to the local community appeared to be minimal. Consequently, the primary impacts to travelers and the local community appeared to occur only during the days when the bridge was closed and traffic diverted to the parallel route (SC 517).

To assess the impacts of the total bridge closure, researchers conducted a series of travel time runs to determine the additional travel time required to traverse the detour route (compared to the normal travel route along SC 703) and the total hours of vehicle delay per day that resulted from that detour. Travel time studies were conducted before the bridge closure on October 23–24, 2009. The bridge was closed the week of February 7, 2010. Researchers returned to the site and collected travel times on February 9–11, 2010.

Data Collection

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 detour route. Data were collected only during daytime hours, since traffic demands would be lower at night and any effects of the total roadway closure would be smaller. Specifically, data were collected in both studies from 7 to 9 a.m., 11:30 a.m. to 1:30 p.m., and 3 to 6 p.m.

Figure 15 illustrates the study region and identifies key nodes used in the travel time data collection process. Table 2 identifies the travel distance between nodes and the typical average speed on each segment during the October 2009 data collection. The analysis was based on the desire to compare travel times between the interchange of I-526 and Long Point Road to the north (node 1) and the intersection of Ben Sawyer Boulevard and Jasper Boulevard on Sullivan's Island (node 4). The normal route for that segment would simply be SC 703 to I-526. For the detour route, travelers at the Ben Sawyer Boulevard–Jasper Boulevard intersection would need to travel northeast to the Jasper Boulevard–Isle of Palms Connector intersection, northwest along the Isle of Palms Connector (also known as SC 517) to the intersection with U.S. 17/701, and then left to reach the interchange with I-526. The detour adds 4.1 mi to the trip.

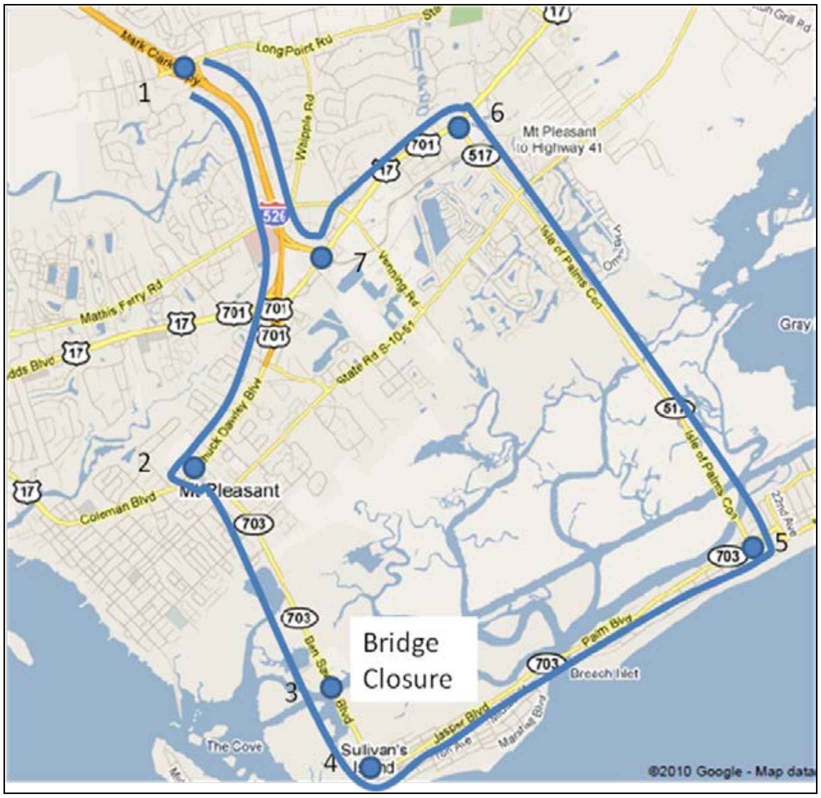


Figure 15. Ben Sawyer Bridge closure analysis region. (Source: Google Maps)

Table 2. Summary of distances and speeds on route segments in the analysis region.

Node	Location	Distance (mi)	Average Speed (mi/hr)
Normal Travel Route			
1	SB I-526 at Long Point Road		
2	U.S. 17 and SC 703	3.4	41
3	Midspan Ben Sawyer Bridge	2.0	29
4	Ben Sawyer and Jasper Boulevards (SC 703)	0.7	35
	TOTAL	6.1	36
Detour Route			
1	SB I-526 at Long Point Road		
7	U.S. 701/17 and I-526	1.7	50
6	SC 517 and U.S. 701/17	1.4	23
5	Palm Boulevard/SC 703 and SC 517	3.8	41
4	Ben Sawyer and Jasper Boulevards (SC 703)	3.3	35
	TOTAL	**10.2**	**36**

Seven travel time runs were made over each segment each day in each direction. Analysis of the October 2009 data found no significant travel time peaks during the day, so the data from the 2 days were averaged together. A similar result was obtained during the travel time data collection effort in February 2010, and those travel times were also averaged by segment. A comparison of the southbound segment travel times between the two data collection periods is in table 3.

Table 3. Southbound travel time comparisons.

Node	Location	Oct. 2009	Feb. 2010	Difference (minutes)
1	SB I-526 at Long Point Road			
2	U.S. 17 and SC 703	5.3	---	---
3	Midspan Ben Sawyer Bridge	4.6	---	---
4	Ben Sawyer and Jasper Boulevards (SC 703)	1.2	---	---
	TOTAL	**11.1**	---	---
1	SB I-526 at Long Point Road			
7	U.S. 701/17 and I-526	2.1	2.3	0.2
6	SC 517 and U.S. 701/17	3.7	4.0	0.3
5	Palm Boulevard/SC 703 and SC 517	5.5	5.6	0.1
4	Ben Sawyer and Jasper Boulevards (SC 703)	5.7	5.7	0.0
	TOTAL	**17.0**	**17.6**	**0.6**

Northbound segment travel times are provided in table 4. Overall, the effect of diverted traffic southbound appeared to be negligible. The lower part of table 3 shows that the segment travel times on the detour route were only slightly higher (0.3 minutes or less) in February 2010 than in

October 2009. The overall detour route duration in February 2010 was only 0.6 minutes longer than in October 2009, an increase of only 3.5 percent. In contrast, it appears that the additional traffic on the detour route did increase travel times somewhat in February 2010 compared to October 2009. Route segment travel times increased by 0.4 to 1.4 minutes, and the total route travel time in February 2010 was 3.2 minutes longer than in October 2009, a 20 percent increase. Most of the increase occurred on the U.S. 17/701 segment and the segment that includes the entrance onto I-526.

Table 4. Northbound travel time comparisons.

Node	Location	Oct. 2009	Feb. 2010	Difference (minutes)
4	Ben Sawyer and Jasper Boulevards (SC 703)			
3	Midspan Ben Sawyer Bridge	2.6	---	---
2	U.S. 17 and SC 703	3.5	---	---
1	SB I-526 at Long Point Road Exit	4.9	---	---
	TOTAL	**11.3**	---	---
4	Ben Sawyer and Jasper Boulevards (SC 703)			
5	Palm Boulevard/SC 703 and SC 517	5.3	5.7	0.4
6	SC 517 and U.S.701/17	5.6	6.1	0.5
7	U.S. 701/17 and I-526	3.0	4.4	1.4
1	SB I-526 at Long Point Road Exit	1.8	2.7	0.9
	TOTAL	**15.7**	**18.9**	**3.2**

Table 5 presents a comparison of automatic traffic recorder count data from February 2010 on SC 703 and SC 517, as well as historical count data for those locations. It appears that up to 84 percent of the traffic normally using SC 703 used the detour via SC 517 to get on and off the island. Overall, the combined counts of the two stations were essentially identical to their historical averages, indicating that the temporary bridge closure did not affect the number of trips made between the island and mainland.

Table 5. Daily traffic volumes on SC 703 and SC 517.

Route	Feb. 2010	Historical	Difference	Percent Difference
Northbound:				
SC 703	864	5,430	-4,566	-84
SC 517	10,341	5,966	+4,466	+75
TOTAL	11,296	11,396	-100	-1
Southbound:				
SC 703	862	5,433	-4571	-84
SC 517	10,516	6,004	+4512	+75
TOTAL	11,378	11,437	-60	-1

Delay Analysis Results

Traffic forced to divert from SC 703 experienced longer travel times and travel distances via the detour route. The additional travel distance is estimated as the amount of diverting traffic (4,566 vpd northbound and 4,571 vpd southbound) times the additional travel distance via the detour (4.1 mi). Each day of the full bridge closure resulted in the following:

(4,566+4,571) * 4.1 = 37,462 additional vehicle-miles traveled per day

The detour route resulted in 6.5 minutes of additional travel time southbound and 7.6 minutes of increased travel time northbound per trip. Using the same diverted traffic numbers, this equates to the following:

(4,566 * 7.6/60) + (4,571 * 6.5/60) = 1,074 vehicle-hours of delay per day

Vehicles normally using U.S. 17/701 and those normally using I-526 northbound also experienced minor (less than 2 minutes) travel time increases as a result of SC 703 diverting traffic. Traffic counts on those segments were not available for use in the analysis. If one assumes that one-half of the traffic normally using SC 517 also uses the section between SC 517 and I-526, this slight travel time increase on those segments translates to the following:

((5,966vpd/2) * (2.3/60)) + ((6,004vpd/2) * (0.5/60)) = 139 vehicle-hours of delay per day

The combined delay was 1,213 vehicle-hours of delay per day (1,074 + 139) caused by the bridge closure. In total, the amount of delay over the 10 days the detour was active was 12,130 vehicle-hours (1,213 vehicle-hours of delay per day * 10 days).

Evaluating trip time before and during construction of the project is not directly comparable because the work zone across the bridge was either not impacted or the bridge was closed. A more suitable method is to consider the total accumulated trip time incurred during the actual detour duration under ABC compared to the traditional alternative of an 8-month closure. An 8-month detour would have accumulated 7,103,328 vehicle-hours of delay (1,213 vehicle-hours of delay per day over the period), so the innovative approach resulted in less than 1 percent increase in total accumulated trip time. Therefore, the travel time increase and resulting delays generated were minimal, far below the HfL goal of less than 10 percent increase in trip time considering traditional construction methods.

QUALITY

Pavement Test Site

Sound intensity and smoothness test data were collected before and after construction from the swing span and approach spans. Comparing these results provides a measure of quality of the finished project. Data were collected by personnel from the National Center for Asphalt Technology (NCAT) in Auburn, AL.

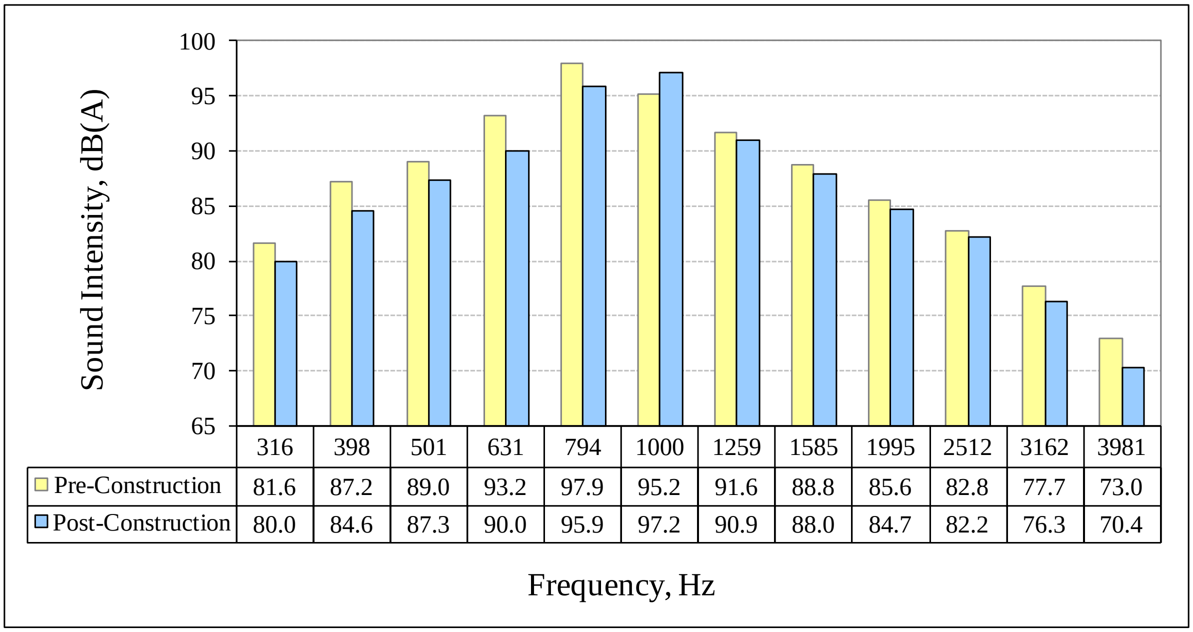
Sound Intensity Testing

SCDOT does not use the OBSI test method on any projects. Nevertheless, this method was used to record SI measurements from where the tire meets the bridge surface. The SI measurements were made using the currently accepted OBSI technique, AASHTO TP 76-10, which includes dual vertical sound intensity probes and an ASTM-recommended standard reference test tire (SRTT). Multiple measurements were made at 45 mi/h in the right wheelpath. The SI probes simultaneously captured data from the leading and trailing tire-bridge surface contact areas. Figure 16 shows the dual probe instrumentation and the tread pattern of the SRTT.

Figure 16. OBSI dual probe system and the SRTT. (Source: NCAT)

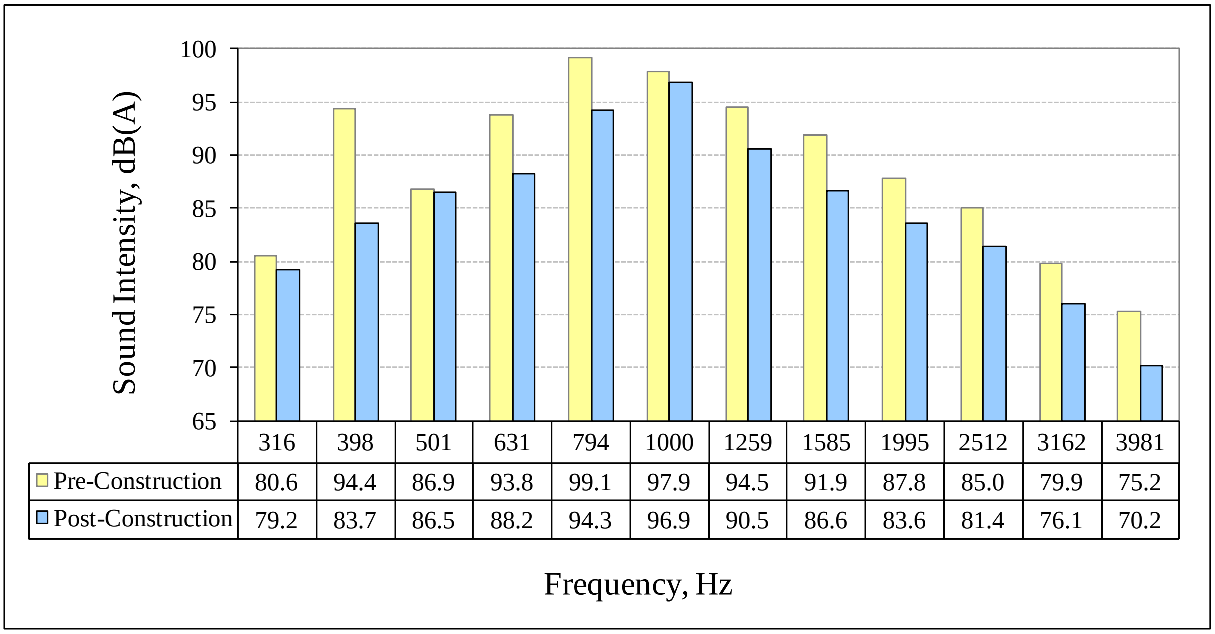
The average of the front and rear SI values was computed for the bridge and approach spans to produce SI values representing each segment. Raw data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean SI levels are A-weighted to produce the sound intensity frequency spectra in one-third octave bands, as shown in figures 17 and 18 for the existing approach spans and swing span, respectively.

Generally, the SI spectra show the expected results of the new construction, in which the value for nearly all frequencies was reduced. The spike in the existing bridge deck at 398 hertz (Hz) was likely the result of the tire interacting with the exposed steel reinforcement. The new diamond-ground concrete bridge surface shows no such spike.



	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
🟨 Pre-Construction	81.6	87.2	89.0	93.2	97.9	95.2	91.6	88.8	85.6	82.8	77.7	73.0
🟦 Post-Construction	80.0	84.6	87.3	90.0	95.9	97.2	90.9	88.0	84.7	82.2	76.3	70.4

Figure 17. SI frequency spectra for the approach spans before and after construction.



	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
🟨 Pre-Construction	80.6	94.4	86.9	93.8	99.1	97.9	94.5	91.9	87.8	85.0	79.9	75.2
🟦 Post-Construction	79.2	83.7	86.5	88.2	94.3	96.9	90.5	86.6	83.6	81.4	76.1	70.2

Figure 18. SI frequency spectra of the swing span before and after construction.

Global SI levels were calculated using logarithmic addition of the one-third octave band frequencies across the spectra. The value of the approach spans dropped from 102.0 to 101.3 dB(A), and the swing span dropped from 104.0 to 100.4 dB(A). While not meeting the HfL goal of 96.0 dB(A), the new swing span was 3.6 dB(A) quieter than the old bridge and the approach spans were slightly quieter. The global SI levels are summarized in table 6.

Table 6. Summary of the global SI levels before and after construction.

Section	Preconstruction SI (dB(A))	Postconstruction SI (dB(A))
Approach Spans	102.0	101.3
Swing Span	104.0	100.4

Smoothness Measurement

Smoothness testing was done in conjunction with the SI testing using NCAT's Automatic Road Analyzer (ARAN) van, shown in figure 19. This equipment collects data from both wheelpaths via high-speed inertial profilers, the results of which are reported as IRI values. Figure 20 graphically presents the mean IRI values at 25-ft intervals for the existing bridge and approach span surfaces. For reference, the bridge location is shaded in the figure. The preconstruction data show a large peak value near the center of the bridge and several other peaks throughout the approach spans, while the new construction has eliminated all but the spikes at the joints between the swing span and the approach spans.

Figure 19. Auburn University ARAN van. (Source: NCAT)

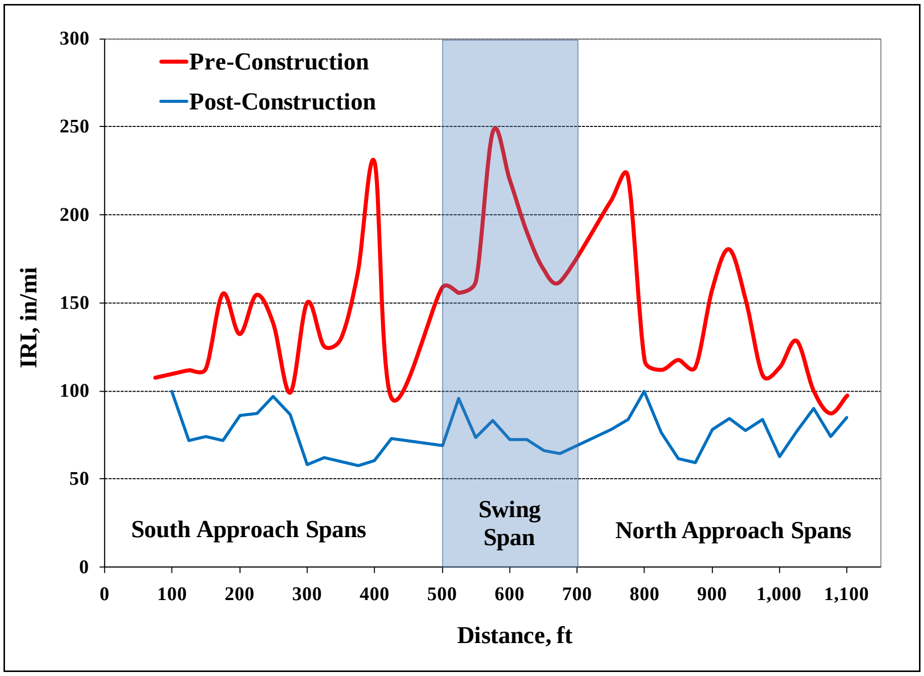


Figure 20. Mean IRI values for the bridge and approach spans before and after construction.

The average IRI value for the approach spans dropped from 133.7 to 76.8 in/mi and the swing span dropped from 183.3 to 75.9 in/mi. This represents an average 51 percent reduction in IRI and reflects the increase in both ride and construction quality. The IRI values are summarized in table 7.

The HfL goals for SI of 96.0 dB(A) and IRI of 48 in/mi, which reasonably can be met on long, open stretches of pavement, were not met on this project. It is extremely difficult to achieve these mean ride and sound measurements on a bridge because of the influence of the bumps at each joint in the structure on the mean. Nonetheless, the new construction is a noticeable improvement over the existing conditions.

Table 7. IRI values before and after construction.

Bridge or Pavement Section	Preconstruction IRI (in/mi)	Postconstruction IRI (in/mi)
Approach Spans	133.7	76.8
Swing Span	183.3	75.9

USER SATISFACTION

SCDOT succeeded in addressing the public's concerns about preserving the unique appearance of the bridge while at the same time delivering a safer bridge with minimum disruption to traffic. A user survey was not conducted to measure the degree of satisfaction after the bridge was complete.

TECHNOLOGY TRANSFER

To promote the innovations of prefabricated bridge elements, maintenance-of-traffic schemes, and accelerated construction, SCDOT and FHWA sponsored a 1-day workshop. The workshop, held April 28, 2010, in Sullivan's Island, SC, consisted of presentations by State staff, construction contractors, and FHWA consultants. A site visit was conducted near the end of the day. Individuals from State highway agencies, FHWA, the construction industry, and local agencies attended the workshop. Appendix A contains the workshop agenda and list of presenters. Showcase presentations can be viewed at www.pdshowcase.org/home/showcase/23.

Figure 21. Discussion of the project.

Figure 22. Boat ride to see the bridge site.

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 the baseline case and is an important component of the economic analysis.

The baseline case is based on SCDOT's traditional construction method to completely replace the entire superstructure during an 8-month total closure of the bridge. Under this approach, the anticipated lifespan of the baseline bridge would be the same as the as-built bridge. This assumes that the previously presented options to simply rehabilitate the existing bridge under partial lane closures would not have been pursued. Otherwise, the resulting lifespans between the baseline and as-built cases would have been dissimilar, as noted in table 1, and not easily comparable.

CONSTRUCTION TIME

Not only was the overall construction duration trimmed from 24 to 18 months by employing ABC techniques, but the user impact was drastically reduced from an estimated 8 months (244 days) to 10 days. The time saved for vehicles that used the detour was 234 days (244 - 10 days).

DETOUR

As noted earlier, the designated detour added about 4.1 mi to the trip length to reach Sullivan's Island, and the resulting delay was estimated at 1,213 vehicle-hours of delay per each day of the bridge closure.

CONSTRUCTION COSTS

Table 8 presents the baseline and as-built construction costs taken from the actual contract bid. It was assumed that the choice of DB or traditional contracting would not influence the construction costs and that the most compelling factor was the difference between modular and build-in-place construction techniques. Other assumptions were made in selecting significant cost factors, as noted in table 8. Therefore, the information presented is a subjective analysis of the likely cost differential rather than a rigorous computation of a cost differential. Nevertheless, the resulting cost comparison shows the as-built case is $4,800,000 more than the baseline case ($31,474,000 - $26,674,000).

Table 8. Capital cost calculation table.

Cost Category	Baseline Case	As-Built Case
Design and Submittals	$ 3,650,000	$ 3,650,000
Bonds and Insurance	$ 500,000	$ 500,000
Swing Span and Approach Spans		
Swing Span Removal and Fabrication	$ 3,250,000	$ 3,250,000
Swing Span Placement[1]	$ 750,000	$ 750,000
Approach Spans Removal and Fabrication[2]	$ 10,200,000	$ 10,200,000
Substructure Repairs	$ 55,000	$ 55,000
Temporary Trestle and Bents	$ --	$ 4,800,000
Machinery Components	$ 2,750,000	$ 2,750,000
Electrical Components	$ 2,850,000	$ 2,850,000
Bridgetender's House	$ 500,000	$ 500,000
Fender System Replacement	$ 600,000	$ 600,000
Mobilization[2]	$ 1,569,000	$ 1,569,000
Total Cost	**$ 26,674,000**	**$ 31,474,000**

Notes:

[1] Swing span replacement would likely be the same off site construction for either case given the intra-coastal constraints by the Coast Guard.

[2] A reliable cost for hydraulic jacking was not available, so the cost is included in both the baseline and as-built cases.

[3] Mobilization is assumed to be the same.

USER COSTS

Generally, three categories of user costs are used in an economic/life-cycle cost analysis: vehicle operating costs (VOC), delay costs, and crash- and safety-related costs. Because the bridge would have been closed to traffic in either case, the possible safety hazard to the traveling public from a work zone was eliminated, so safety-related costs were not evaluated. However, VOC and delay costs were compared and are discussed in the following subsections.

VOC

The savings in VOC from using ABC is essentially the difference between the mileage-related VOC applied to the 244 days of detour time for the baseline case and the 10 days for the as-built case. Assuming average unit costs of $0.24 per mile for passenger vehicles and $0.65 per mile for commercial vehicles for the variable operating costs[1] (including costs for fuel, maintenance and repair, tires, and depreciation) based on highway travel and given the traffic study revealed actual traffic volumes for the bridge were 4,566 northbound and 4,571 southbound, or 9,137 total average daily traffic (ADT) with 5 percent commercial vehicles, the following VOC is computed:

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[1] Barnes and Langworthy (2003), *The Per-Mile Costs of Operating Automobiles and Trucks*, Report No. MN/RC 2003-19, Submitted to Minnesota Department of Transportation. Adjusted for fuel price increase and inflation in 2009.

Baseline Case

$\text{VOC}_{\text{passenger}}$ = 9,137 (ADT) * 0.95 (percent passenger vehicles) * 4.1 (mi) * $0.24 (per mi) * 244 (days)
= $2,084,069

$\text{VOC}_{\text{commercial}}$ = 9,137 (ADT) * 0.05 (percent commercial vehicles) * 4.1 (mi) * $0.65 (per mi) * 244 (days)
= $297,071

The total baseline VOC is as follows:
$\text{VOC}_{\text{baseline}}$ = $2,084,069+ $297,071
= **$2,381,141**

As-Built Case

$\text{VOC}_{\text{passenger}}$ = 9,137 (ADT) * 0.95 (percent passenger vehicles) * 4.1 (mi) * $0.24 (per mi) * 10 (days)
= $85,413

$\text{VOC}_{\text{commercial}}$ = 9,137 (ADT) * 0.05 (percent commercial vehicles) * 4.1 (mi) * $0.65 (per mi) * 10 (days)
= $12,175

The total as-built VOC is as follows:
$\text{VOC}_{\text{as-built}}$ = $85,413 + $12,175
= **$97,588**

The total saving in VOC because of the detour differential between the baseline and as-built scenarios is as follows:
$\text{VOC}_{\text{Differential}}$ = $2,381,141$_{\text{baseline}}$ – $97,588$_{\text{As-built}}$
= **$2,283,553**

Delay Costs

It was calculated that $4,256,212 was saved by reducing the duration of the bridge closure. The following provides a basis for this conclusion:

- The savings in delay cost can be determined by applying an hourly value to the time road users were delayed by the detour.
- As discussed earlier, the time spent traversing the detour route was 1,213 vehicle-hours per day.
- Based on the Bureau of Labor Statistics[2] and the U.S. Department of Transportation Guidelines,[3] the per-hour passenger vehicle rate was $14.86 and the commercial vehicle rate was $17.24.

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[2] *May 2009 Metropolitan and Nonmetropolitan Area Occupational Employment and Wage Estimates, Charleston, SC.* U.S. Department of Labor, Bureau of Labor Statistics.

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

Using these assumptions and cost figures the saving in delay cost is as follows:

Baseline Case

$\text{Delay}_{\text{passenger}}$ = 1,213 (vehicle-hours/day) * 0.95 (percent passenger vehicles)
* $14.86 (per hour) * 244 (days)
= $4,178,237

$\text{Delay}_{\text{commercial}}$ = 1,213 (vehicle-hours/day) * 0.05 (percent commercial vehicles)
* $17.24 (per hour) * 244 (days)
= $255,128

The total baseline delay cost is as follows:
$\text{Delay}_{\text{baseline}}$ = $4,178,237 + $255,128
= $4,433,365

As-Built Case

$\text{Delay}_{\text{passenger}}$ = 1,213 (vehicle-hours/day) * 0.95 (percent passenger vehicles)
* $14.86 (per hour) * 10 (days)
= $171,239

$\text{Delay}_{\text{commercial}}$ = 1,213 (vehicle-hours/day) * 0.05 (percent commercial vehicles)
* $17.24 (per hour) * 10 (days)
= $10,456

The total as-built delay cost is as follows:
$\text{Delay}_{\text{as-built}}$ = $171,239 + $10,456
= **$181,695**

The total saving in delay costs because of the detour differential between the baseline and as-built scenarios is as follows:
$\text{Delay}_{\text{Differential}}$ = $4,433,365 $_{\text{Baseline}}$ – $181,695 $_{\text{As-built}}$
= **$4,251,669**

COST SUMMARY

From a construction cost standpoint, traditional construction methods would have cost SCDOT about $4,800,000 less than accelerated construction. On the other hand, ABC techniques shortened the time vehicles would have been detoured and as a result saved an estimated $6,535,222 in combined VOC and delay costs ($2,283,553 + $4,251,669). The net savings on this project totaled $1,735,222 ($6,535,222 – $4,800,000). The HfL project delivery approach, therefore, realized an overall cost savings exceeding the incremental increase in construction largely because of the time saved by using modular construction.

APPENDIX A: WORKSHOP AGENDA

April 28, 2010

Highways for LIFE: SC Route 703 Accelerated Bridge Construction

AGENDA

Wednesday, April 28, 2010

Meeting Moderator: Frank Chapman, Facilitator – RDA Resources

8:30am - 9:00am	**Registration and Sign In**
9:00am – 9:10am	**Welcome and Introductions** Robert Clark, District Engineering Administrator - SCDOT
9:10am – 9:30am	**Highways for LIFE Overview** Video Presentation Robert Lee, Division Administrator – FHWA - SC Division
9:30am – 9:50am	**Why Accelerated Bridge Construction, Why Now & How?** Claude Napier, Senior Structural Engineer – FHWA Resource Center
9:50am – 10:05am	**Traditional vs. Accelerated Bridge Construction** Tony Fallaw, Program Manager – SCDOT
10:05am – 10:20am	**Break**
10:20am – 11:00am	**SCDOT Project Overview** Leland Colvin, Assistant Construction Engineer – SCDOT Kim Partenheimer, Project Manager – PB Americas, Inc.
11:00am – 11:45am	**Contractor Perspective** Ryan Hamrick, Project Manager – PCL Civil Constructors, Inc.
11:45am - 12:45pm	**Lunch *(provided)***
12:45pm – 3:45pm	**Boat Tour to Ben Sawyer Bridge**

Transportation will be provided to and from the Patriot's Point boat launch. Upon completion of the boat tour, our showcase will be over. You are welcome to drive your personal vehicle to the boat launch site but there may be a nominal parking fee.

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