Maryland Demonstration Project: Baltimore-Washington Parkway/West Nursery Road Bridge Superstructure Replacement Using SPMTs

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. "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.

NOTICE

QUALITY ASSURANCE STATEMENT

<table>
<tr><td>1. Report</td><td>2. Government Accession No</td><td colspan="2">3. Recipient's Catalog No</td></tr>
<tr><td colspan="2">3. Title and Subtitle:
Maryland Demonstration Project: Baltimore-Washington Parkway/West Nursery Road Bridge Superstructure Replacement Using SPMTs</td><td colspan="2">5. Report Date
June 2013
6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Authors
Amar Bhajandas, P.E., and Jagannath Mallela</td><td colspan="2">8. Performing Organization Report</td></tr>
<tr><td colspan="2">9. Performing Organization Name and Address
Applied Research Associates, Inc.
100 Trade Centre Drive, Suite 200
Champaign, IL 61820</td><td colspan="2">10. Work Unit (TRAIS) C6B

11. Contract or Grant</td></tr>
<tr><td colspan="2">12. Sponsoring Agency Name and Address
Office of Infrastructure
Federal Highway Administration
1200 New Jersey Avenue, SE
Washington, DC 20590</td><td colspan="2">12. Type of Report and Period Covered

Final Report
March 2013
14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
Contracting Officers Technical Representatives: Byron Lord, Mary Huie</td></tr>
<tr><td colspan="4">16. Abstract
As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Maryland State Highway Administration was awarded a $600,000 grant to demonstrate the use of proven, innovative technologies for accelerated bridge superstructure removal and replacement. This report documents accelerated bridge construction techniques using self-propelled modular transporters (SPMTs) to remove and replace the superstructures of two West Nursery Road bridges over northbound and southbound Baltimore-Washington Parkway (MD 295) over two consecutive weekends. This report includes construction details of the bridge superstructures built in the median of MD 295, just north of the existing bridges, on temporary support structures.

Using conventional construction methods, the impact of this project on the traveling public was estimated at 7 months, during which four lanes of West Nursery Road traffic would have been reduced to two lanes, one in each direction. However, using SPMTs reduced the impact to 2 weekend nights for MD 295 northbound and southbound traffic and 2 weekends, from midnight on Friday to 8 a.m. on Sunday, for West Nursery Road users.

The traditional approach would have included a temporary bridge to carry West Nursery Road traffic during construction. It would have also required reconfiguring ramps, acquiring right-of-way, and constructing temporary approach roadways to the temporary bridge. The estimated cost of the temporary bridge was about the same as the $865,700 cost for SPMT deployment, but the SPMT option reduced user costs by $324,000, about 7 percent of the project construction cost.

Because of the success of this project, the Maryland State Highway Administration will consider SPMT use on future projects, where it is feasible and appropriate for conditions.</td></tr>
<tr><td colspan="2">17. Key Words
Highways for LIFE, accelerated bridge construction, self-propelled modular transporter, SPMT, innovative construction, economic analysis, prefabricated bridge elements and systems, full lane closure</td><td colspan="2">18. Distribution Statement
No restriction. This document is available to the public through www.fhwa.dot.gov/hfl.</td></tr>
<tr><td>Security Classif.(of this report)
Unclassified</td><td>19. Security Classif. (of this page)
Unclassified</td><td>20. of Pages
75</td><td>21. Price</td></tr>
</table>

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)

CONTENTS

FIGURES

TABLES

ABBREVIATIONS AND SYMBOLS

ABC	accelerated bridge construction
ADT	average daily traffic
BWI	Baltimore-Washington International Airport
FHWA	Federal Highway Administration
HfL	Highways for LIFE
LCAP	Lane Closure Analysis Program
LOPB	loss of public benefit
MDSHA	Maryland State Highway Administration
OSHA	Occupational Safety and Health Administration
QC/QA	quality control/quality assurance
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SPMT	self-propelled modular transporter

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 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 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 has issued open solicitations for HfL project applications since fiscal year 2006. 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 State 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) in a rural area or less than 1.5 mi in an urban area (in both cases at a travel speed 20 percent less than the posted speed).

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

- Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels, using the onboard sound intensity 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 accelerated bridge construction (ABC) techniques used to remove and replace the superstructures of two West Nursery Road bridges over northbound and southbound Baltimore-Washington Parkway (MD 295) over two consecutive weekends. The report presents project details relevant to the HfL program, including innovative construction highlights, rapid superstructure removal and replacement using self-propelled modular transporters (SPMT), HfL performance metrics measurement, and economic analysis. Technology transfer activities that took place during the project and lessons learned are also discussed.

This report includes construction details of the bridge superstructures built in the median of MD 295, just north of the existing bridges, on temporary abutments. It also discusses the use of SPMTs to remove each old superstructure and to replace it with a new one. Under conventional construction methods, the impact of this project on the traveling public was estimated at 7 months, but with the use of accelerated construction techniques, the impact was reduced to two weekend nights for MD 295 northbound and southbound traffic and two weekends for West Nursery Road users.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

West Nursery Road in Linthicum, MD, carries two bridges over Baltimore-Washington Parkway (MD 295), which has average daily traffic (ADT) estimated at 108,000. West Nursery Road, with ADT of 22,000, serves as an important access point for local businesses and residents in the area, commonly known as the BWI Hotel District. The project involved the removal and replacement of the superstructures of the bridges, which were built in 1949. Each replaced superstructure was a single span, about 70 feet (ft) long and 53 ft wide.

Bridge No. 02014 over northbound MD 295 was structurally deficient, with patching over 13 percent of the concrete deck and areas of steel beams experiencing section loss, especially at the joints. In addition, the substructure had numerous spalls and cracks. On a scale of 0 to 100, the sufficiency rating for the bridge was 61.9.

Bridge No. 02217 over southbound MD 295 was also structurally deficient, with patching over more than 25 percent of the concrete deck and section loss, spalls, and cracks similar to Bridge No. 02014. Its sufficiency rating was 60.2.

The Maryland State Highway Administration (MDSHA) addressed the deficiencies quickly and rehabilitated the two bridges using SPMTs. This innovative technique, used for the first time to remove and replace superstructures in the Mid-Atlantic region, was determined to be safer, significantly faster, and less obtrusive to the traveling public than traditional construction methods.

Highlights of the project and MDSHA's strategies for successful completion include the following:

- Offsite construction of replacement superstructures for both bridges, including girders, deck, and parapets, took place in a staging area in the grass median of MD 295 just north of the bridges, with minimal impact on the traveling public. Each single-span replacement superstructure was 70 ft long and 59 ft wide—6 ft wider than the replaced superstructure.
- Each new superstructure weighed about 500 tons.
- Once the replacement superstructures were completed, SPMTs were used to remove the old superstructures and haul them to a previously erected temporary bent in the median area, where they were demolished away from traffic.
- Bearing pedestals for two girders for each structure were installed between the removal of the existing superstructure and placement of the new superstructure, which could not be done in advance.
- Each direction of MD 295 was closed for less than 8 hours on a Friday night during the old superstructure removal and transportation offsite.
- SPMTs were used to transport the new superstructures and place them over new bearings. Each direction of MD 295 was closed for less than 8 hours on a Saturday night for transportation and placement of the new superstructures on their bearings.

- West Nursery Road was closed for 34 hours from Friday night to 8 a.m. on Sunday to accommodate removal and replacement of each superstructure.
- Substructure rehabilitation and backwall work was performed in a manner that allowed four lanes of traffic on both bridges during peak travel times.
- MDSHA used the lane rental concept to motivate the contractor to perform the superstructure move in the provided timeframe efficiently and safely.

The innovations employed on the project represented many firsts for MDSHA, including the removal and replacement of two superstructures using SPMTs. Each operation took 34 hours or less and has significantly raised customers' expectations for the delivery of future MDSHA highway projects.

DATA COLLECTION

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

No worker injuries or motorist incidents were reported during construction, which means MDSHA exceeded the HfL requirements for worker and motorist safety. Segments of MD 295 that included the West Nursery Road bridges and parts of pavements on either side of the structures were selected to determine the operational safety of the structures before construction. The 3-year crash histories revealed numerous crashes, but none that could be attributed directly to the structure that was replaced. No motorist incidents have been reported since the construction of the new bridge structure.

Before SPMT use was considered for this project, an analysis of eight alternatives pointed to total superstructure replacement matching the existing bridge geometry. MDSHA explored multiphased construction of the bridges and a single-phase construction using a two-lane temporary bridge to channel West Nursery Road traffic and determined the latter was more practical for the conditions. This alternative also involved right-of-way acquisition, construction of a temporary roadway, reconfiguration of ramps, and a construction duration estimated at 12 months. This alternative would have reduced lane capacity by 50 percent for about 7 months, requiring lane merging and shifting. Such disturbance to the traffic flow substantially increases the potential for crashes.

This section of West Nursery Road serves as a business and hotel corridor. Besides other local impacts, construction work at the bridges would impact about 5,000 employees at Northrop Grumman, around-the-clock operations at a mail facility, and visitors to about 20 area hotels and a movie theater complex that attracts about 6,000 people on an average weekend. During the planning and construction of the West Nursery Road bridges, MDSHA implemented an aggressive, comprehensive communication effort with the communities and businesses in the affected zones. Through fliers, newsletters, e-mails, and MDSHA's Web site, the public was kept aware of key project schedules. MDSHA officials met with the local business associations, Baltimore-Washington International Airport representatives, and individual businesses most affected by the project. On the Web site, a project summary page that included a webcam at the site offered live updates of progress being made. The agency also prepared detour cards for visitors to area hotels, restaurants, and theaters.

There were no complaints from local businesses or residents during the West Nursery Road closure periods. A postconstruction survey indicated that the businesses, commuters, and residents were very satisfied with the minimal impact of construction on travel delay. As a result, MDSHA exceeded the HfL customer satisfaction expectation.

ECONOMIC ANALYSIS

The benefits and costs of this innovative project approach were compared with those of a project using a traditional approach. MDSHA supplied most of the cost figures for the as-built project, and the cost assumptions for the traditional approach were determined from discussions with MDSHA, FHWA DelMar Division staff, and national literature.

The economic analysis revealed that MDSHA's approach realized a cost savings of at least $324,000, or 7 percent, over conventional construction practices. The cost savings were primarily due to reduced delay costs.

LESSONS LEARNED

Through this project, MDSHA gained valuable insights on the innovative processes deployed, both those that were successful and those that need improvement in future project delivery:

- The closure periods for MD 295 and West Nursery Road were adequate.
- The lane rental concept used on this project was effective.
- Traffic analysis and predictions were confirmed by actual observations.
- The owner, designer, contractor, and heavy lift subcontractor worked together as a team.
- The new bridge was erected quickly, and traffic disruption was minimized.
- The prime contractor is very dependent on the heavy lift subcontractor for the schedule. On projects with penalty delays, the contractor is exposed to greater risk over which it has little control. The subcontractor may or may not participate in the risk taking.
- It is important for the project team to fully understand the capabilities of SPMT equipment and develop a detailed plan for the move with specific hold points that are approved by the owner, design team, and prime contractor.
- Jacking the existing structure off the bearing seats before SPMT deployment worked well.
- It is important to ensure that there is full bearing in bearing areas because even weld splatter can affect full contact.
- The SPMT equipment is sophisticated. As with cranes, proper deployment depends on the skill set of the operator.
- It is important to be thoroughly familiar with the staging area and thoroughly aware of all the grade changes and obstructions along each path of SPMT travel.
- Consider the deck and SPMT as separate elements and not as one connected element. Give thought to how the two elements will be connected to ensure stability. Have a

detailed plan of strapping and rigging, if permitted, and ensure that loading implications are appropriately considered.

- Provide adequate time for strapping the superstructure to the SPMT because it can be time-consuming.
- Explore alternative methods of demolition, including demolition in place with appropriate shielding. Tying the existing superstructure to the SPMT on this project took a significant amount of time.
- Although the contractor properly addressed the quality control and quality assurance (QC/QA) issues of the temporary support structures in the median using an outside source, the owner should specifically address QC/QA of temporary support structures on future contracts.
- Give detailed thought to the curing of a deck that is above ground level, including how to keep it wet.
- Have concrete test equipment at the worksite and a certified technician acceptable to the owner available to monitor testing.

PUBLIC INVOLVEMENT

MDSHA's comprehensive public outreach efforts were very effective, with no complaints received on delays caused by the move. The approach to educate—and not just inform—is likely a model that can be used at other locations when innovative technology is deployed. MDSHA's consideration of both local residents and visitors to the area was particularly effective.

In addition to the benefits noted, the offsite construction enhanced motorist and worker safety and minimized traffic disruptions and related congestion.

CONCLUSIONS

From the standpoint of construction speed, motorist and user safety, cost, and quality, this project was a success and embodied the ideals of the HfL program. MDSHA learned that careful planning, coupled with aggressive public outreach and the use of ABC technologies, can result in projects that serve as watershed events in the way they are delivered to the public. A postconstruction stakeholder survey clearly indicated that local businesses, commuters, and residents did not experience major delays as a result of the bridge work and were satisfied with the project.

Because of the success of this project, MDSHA plans to consider SPMT technology in the future. The SPMT option will be considered where an ample staging area is available and site conditions make SPMT deployment feasible.

PROJECT DETAILS

BACKGROUND

West Nursery Road in Linthicum, MD, is an important access point for local businesses and residents. The road carries two bridges over MD 295 and has an ADT of 22,000 vehicles. Bridge No. 02014 crosses over northbound MD 295, while Bridge No. 02217 crosses over southbound MD 295. A length of at-grade roadway built on fill is located between the two bridges. The two bridges were built in 1949.

Before they were replaced, each superstructure was a single span about 70 ft long and 53 ft wide. The clear roadway width was 44 ft with a 4-ft sidewalk on each side. The exterior girders on both bridges were made of built-up steel sections that also served as barriers on the bridges. Single-strand metal rail and chain link fences were mounted on these through girders.

Both bridges exhibited significantly deteriorated elements that required repair or replacement.

Figure 1 shows the project location in relation to the Baltimore-Washington metropolitan area. Figure 2 shows the site's proximity to I-195 and I-695. Figure 3 is an aerial view of the site, with the bridge staging area identified. Figures 2 and 3 were part of MDSHA's public outreach documents.

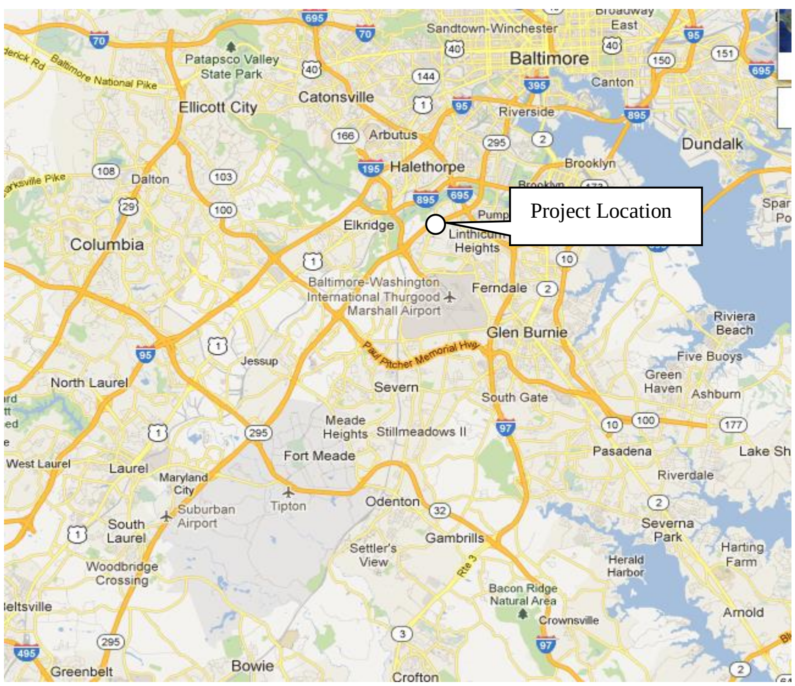


Figure 1. Project location in the Baltimore-Washington area.

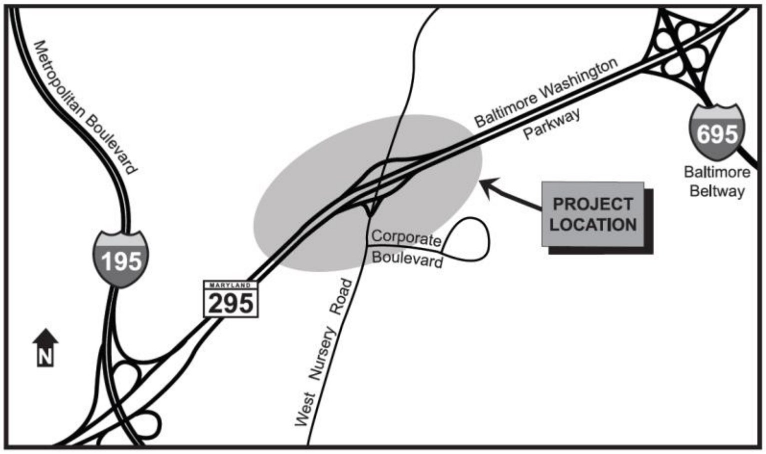


Figure 2. Project location in relation to I-195 and I-695.

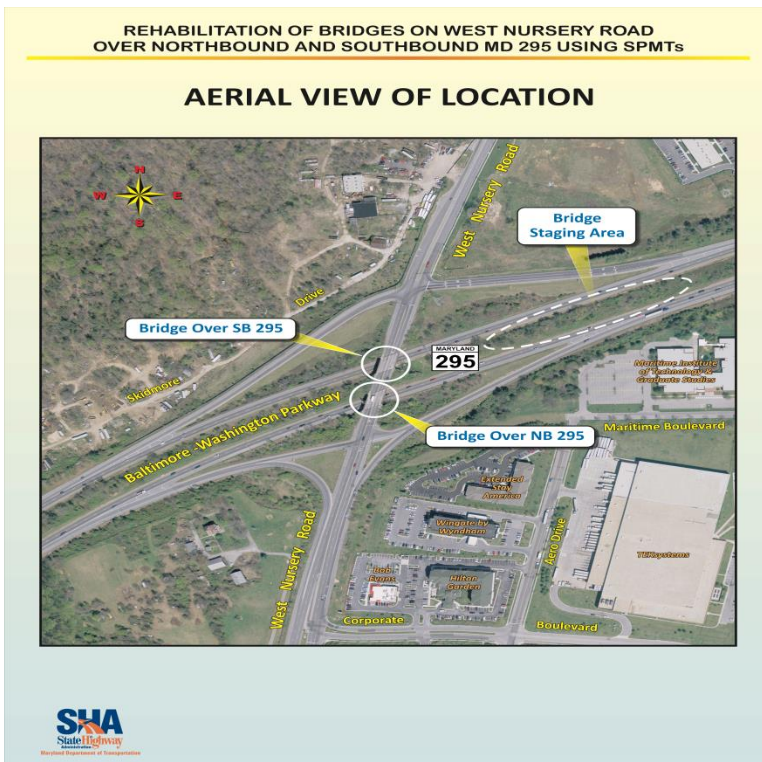


Figure 3. Aerial view of bridges and staging area.

Both bridges are simply supported, are on a 52-degree skew, and are supported on reinforced concrete abutments. Figures 4 and 5 show the bridge elevation from MD 295, and figures 6 through 8 show typical conditions of the superstructures before replacement.

Figure 4. Elevation of Bridge No. 02014 (northbound).

Figure 5. Elevation of Bridge No. 02217 (southbound).

Figure 6. Extensive patches in bridge deck.

Figure 7. Sidewalk and deck deterioration.

Figure 8. Cracking on underside of bridge.

MDSHA considered eight alternatives to address deteriorating conditions. The alternatives considered a variety of options, including just deck replacement or total structure replacement, same width or increased width, and single-stage construction or two-stage construction. The State's decision was based on numerous factors, and the analysis pointed to the alternative of total superstructure replacement matching existing bridge geometry using a temporary bridge for maintaining two lanes of traffic in one phase of construction. The decision matrix is in Appendix A. Figure 9 illustrates each replacement structure's typical section of an 11-ft travel lane, 11.5-ft passing lane, and 5-ft shoulder in each direction with an out-to-out deck width of 59 ft using this alternative. Figure 10 shows the engineering drawing comparing the new section to the section replaced, which was 53 ft out to out.

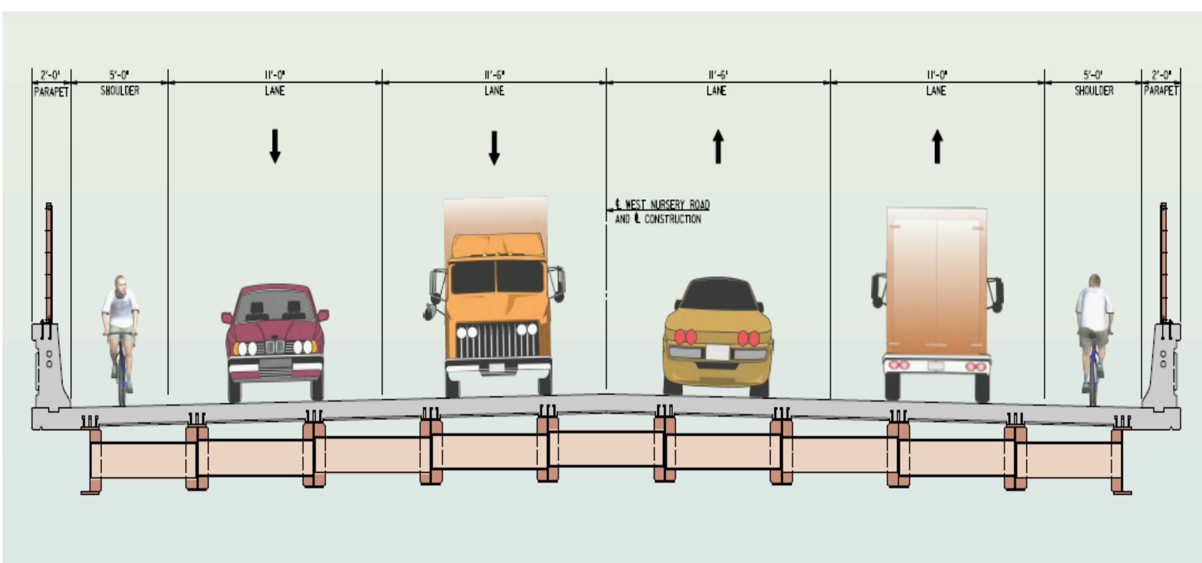


Figure 9. Typical section of replacement superstructure.

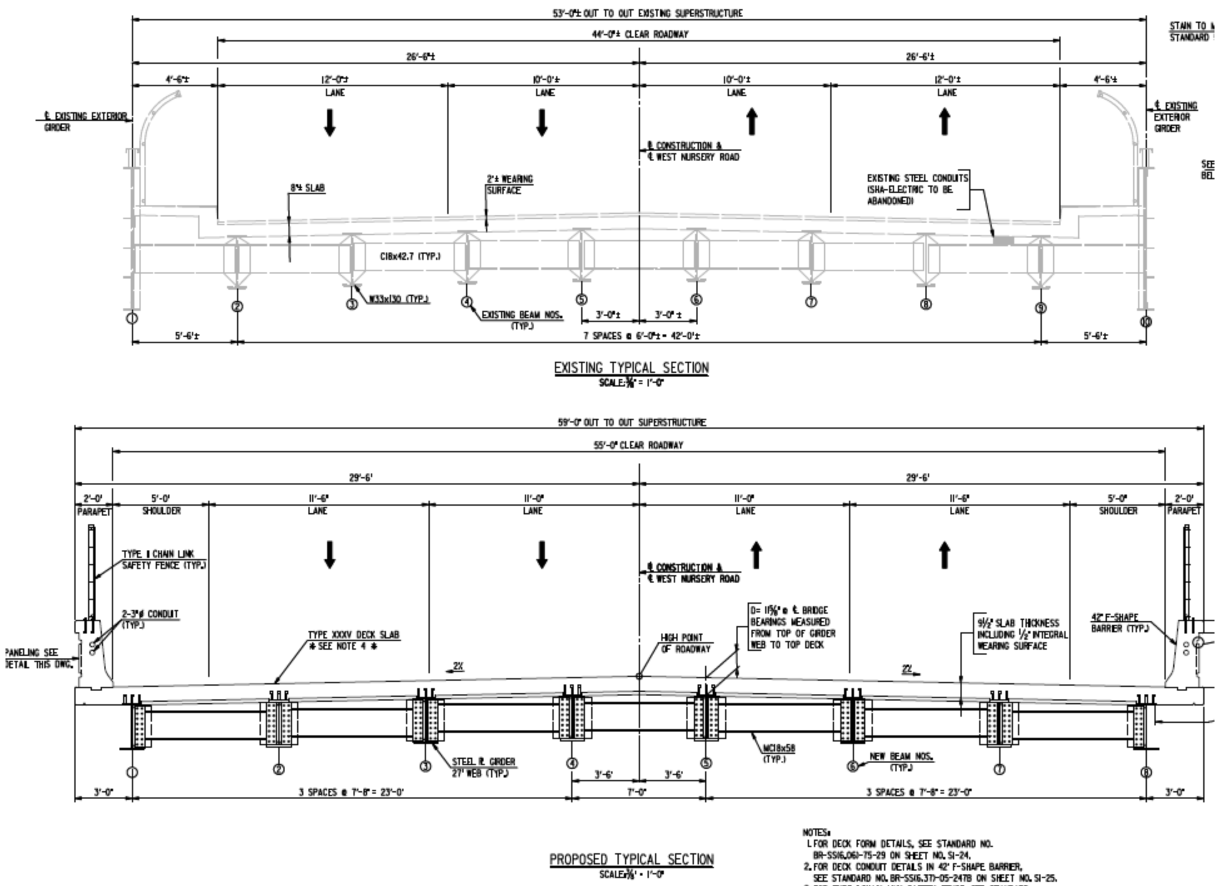


Figure 10. Typical sections, existing and proposed.

This alternative included the following challenges:

- Acquisition of right-of-way for the temporary bridge.
- Construction of a temporary road to the temporary bridge.
- Reconfiguration of ramps.
- Reduction in lane capacity of West Nursery Road by 50 percent (from four lanes to two, one in each direction) on the temporary bridge for 7 months.

In summer 2010, MDSHA examined the possibility of using an SPMT, since it would eliminate the need for a temporary bridge and the attendant challenges listed above. It also would accomplish the following:

- Reduce onsite construction time.
- Reduce disruption to traffic.
- Improve construction-related safety.
- Improve quality because of construction in a controlled environment in the staging area with no construction time restrictions.
- Reduce user costs.

These advantages had to be balanced against the high mobilization costs for the SPMT and the need for subcontractors that specialize in heavy lifting. It was estimated that the additional costs of SPMT deployment (e.g., mobilization, grading of the median, rebuilding of shoulders, and construction of temporary towers to support superstructures) would be about the same as the cost of a temporary bridge and its substructures, which was about $800,000.

The following served as excellent reference sources:

- Utah Department of Transportation (UDOT) *SPMT Process Manual and Design Guide*
- FHWA *Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges*, June 2007
- Fred Doehring, UDOT deputy structures engineer and deputy preconstruction engineer

Preliminary analysis indicated that there was sufficient land area near both bridges on MD 295 where new the superstructures could be built and the old ones demolished. The ground surface offered by MD 295 was relatively flat, making SPMT deployment feasible. The ground also provided sufficient bearing capacity with minor strengthening of the limited shoulder area. Furthermore, there were no challenging utility issues to contend with because the bridges did not carry any utilities.

MDSHA applied for HfL funding for deployment of the innovative technology for the first time in the State. The State proposed building replacement superstructures for both bridges in the grass median of MD 295, immediately next to the existing bridges. Once complete, SPMTs would be used to remove the existing superstructures, which would be brought to previously erected falsework in the median area, where they could be demolished away from traffic. While the existing bridges were being transported offsite, the pedestals for two lines of girders, the bearing areas of which were inaccessible because of the proximity of the existing girders at these locations, would be constructed to accept the new superstructures. Next, the prefabricated superstructures would be transported and set in place using SPMTs. The plan was to complete removal and replacement of each superstructure over a weekend, with impacts on MD 295 traffic limited to Friday and Saturday nights. Substructure rehabilitation work would be conducted while superstructures were being fabricated in the median with minimal impacts to traffic.

On August 17, 2011, FHWA announced an HfL discretionary grant of $600,000 for the project.

Project Engineering

The project engineering team successfully used a variety of software tools to model site conditions. The team was able to increase underclearance by 3 or 4 inches (in), where needed, to increase clearance to 16 ft by using thick webs (7/8 in), shallow plate girders (27 in deep), and thick flange plates. The sharp skew angle controlled the design, and the move itself impacted only the reinforcement in the deck and parapets.

The following are highlights of the design challenges and the remedies and actions taken (in parentheses):

- Special design and analysis considered stress reversal because of differing support locations. The SPMT support was at 16 percent of the span, about 11 ft along skew from the end, or about 8 ft perpendicular to the abutment. (Additional reinforcing steel was used in the deck and parapets, girders were designed for negative bending, and diaphragms, connections, and stiffeners were designed for multiple loading conditions.)
- Accommodation for stresses in deck and parapets was needed because of potential twisting of the deck caused by severe skew during the move and transfer on supports. (Additional reinforcing steel was placed in the decks and parapets.)
- Dynamic effects of the move on the deck and girders were considered. (Fifteen percent was added to dead load, as recommended by the references listed in the previous section.)
- Anticipated deflection during the move was considered. (Camber rebound of girders was calculated.)

The design team tried to respace girders to the extent possible so that the bearing areas could be prepared before the move, but bearing areas for two central girders were inaccessible. The bearing pedestals for these girders were built after the existing central girders were removed and before the new structures were placed. The project team used high early strength, rapid-setting polymer concrete with a 2-hour strength requirement of 4,000 pounds per square inch (psi).

Since there was a short time period between the removal and replacement of the superstructures, the project team prepared the existing substructure units to the fullest extent possible in advance of the move:

- Removing sidewalks and fascia girders before the move to allow modification of pilasters and end posts at each corner to accommodate the move and the wider superstructure (see figures 11 through 14)
- Holding anchor bolts for the steel bearing assembly in place against the underside of the bridge during the move, then lowering and grouting in abutments before restoring traffic (see Figure 15)
- Providing 4-in-diameter oversized holes for the anchor bolts for the steel bearings, in the abutments for grout placement and construction tolerances

Figure 11. Old structure, showing sidewalks and severe skew.

Figure 12. Corner condition modification to accommodate replacement superstructure.

Figure 13. Modification of pilasters and end posts in process.

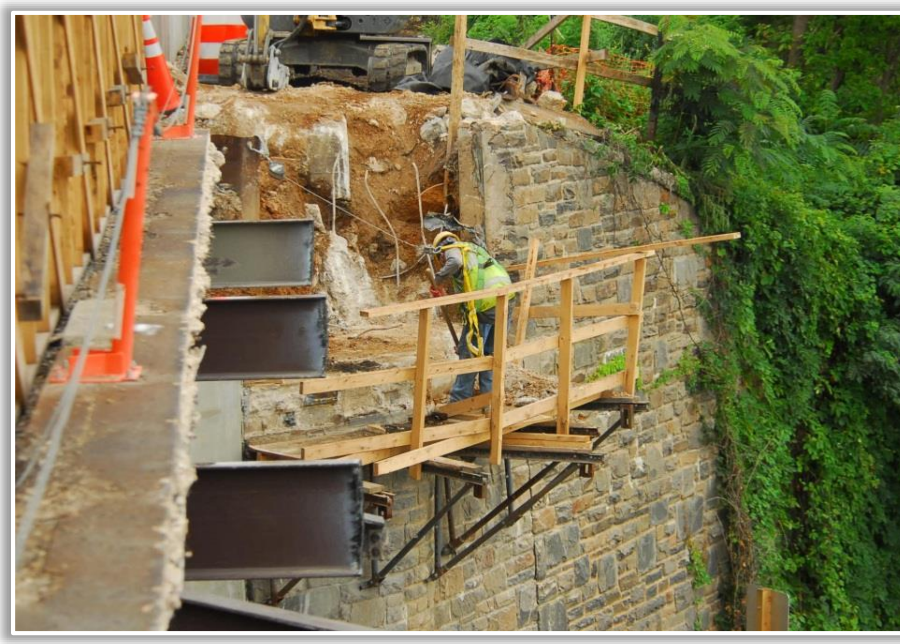


Figure 14. View of bearing area preparation to accommodate wider structure.


Figure 15. View of anchor bolts.

SPMT Deployment

The SPMT is a platform vehicle that can move loads such as bridge systems weighing several thousand tons with precision within a fraction of an inch. The loads are supported by numerous pairs of independently steered wheels, each with its own hydraulic jack. Loaded SPMTs typically travel at 4 miles per hour (mi/h) or less, and on this project the SPMT moved at about 0.5 mi/h. Figures 16 through 18 show SPMT deployment.

Typically, the SPMT is computer-controlled. The person operating the computer manipulates the steering, lifting, driving, and braking. The SPMT can pivot 360 degrees, and the computer self levels units while driving. The unit used on this project had a 16- to 20-inch vertical stroke available for operational purposes and lifting items in place.

Figure 16. SPMT with multiple wheels supporting structure.

Figure 17. SPMT supporting old superstructure.

Figure 18. SPMT supporting completed superstructure for bridge over MD 295 northbound.

MDSHA coordinated with prequalified heavy lifters throughout the design phase and included special provisions on SPMT deployment in the contract proposal. Appendix B shows the special provisions, “Transporting Existing Bridge Superstructures and New Superstructures Using SPMT.” The provisions include requirements on design of the movement system, lifting system, and submittals. Each axle line was required to have a capacity of 25 tons for a maximum load of 16 tons. Tolerances after setting were 0.5 in in the longitudinal and transverse direction and 0.125 in in the vertical direction. The successful contractor for the project selected the SPMT subcontractor from one of the three that had been prequalified.

The contractor provided details of the actual move, engineering of the temporary steel support substructures for the bridge assemblies, and calculations for SPMT trailer stability. The contractor also provided contingency plans, maximum wind speed during move, bridge monitoring system details, safety plans, and hazardous materials plans. MDSHA’s consultant on the project designed the superstructure in its final location and considered stress reversal and dynamic effects during lifting and moving.

MDSHA’s public outreach plan included basic information on its Web site on the SPMT to explain the innovative approach to bridge construction to the public. Figure 19 shows a sample of the information provided, and Appendix C includes additional factsheets.

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

May - November 2012

SPMTs - Making the Move

How self-propelled modular transporters (SPMTs) will remove the existing West Nursery Road bridges

Step 1	SPMTs are assembled in the construction staging area (MD 295 median). Two lines of 18 axles each are linked together and controlled by a single remote control power pack unit. Lattice/ jacks are placed atop the SPMT assembly.
Step 2	The SPMT assembly is guided down MD 295 and positioned under the first West Nursery Road bridge to be removed.
Step 3	The SPMT assembly is raised to meet the existing bridge. The bridge is secured to the SPMT assembly.
Step 4	The final bridge retaining bolts are removed. (Most of the bridge removal preparation has been accomplished prior to placement of the SPMTs.)
Step 5	The old bridge is lifted from its anchor points, driven to the median staging area and placed on temporary supports for demolition.

See reverse for installation steps

Figure 19. Sample factsheet from MDSHA Web site.

Project Construction

For this project, the MDSHA Web site updated visitors on progress during construction, using photographs and brief descriptions on the highlighted activities. Figures 20 through 35 and the accompanying quoted text show the information presented to the public on this project. Information in italics provides additional technical content.

Figure 20. Median with temporary steel supports.

"June/July—The new bridge superstructures will be constructed in the MD 295 median on top of these temporary supports. Once completed, the new bridges will be carried into place by SPMTs." *The contractor built three support bents—two for the two new superstructures and one for supporting the existing superstructure. This meant that the first existing superstructure removed had to be demolished in the period between the weekend removal and replacement activities to make room for the second existing superstructure.*

Figure 21. Progress on fabrication of new superstructures.

"Mid-July—The new bridge superstructures are quickly taking shape in the MD 295 median." *The contractor used a third-party source for QC/QA of the temporary substructures.*

Figure 22. Superstructure in median before placement of deck concrete.

"Mid-July—Metal deck pans have been installed on the beams of the new superstructures. In early August, the new concrete bridge decks will be formed on top of the deck pans." *Work in the median allowed the contractor to perform these activities independent of onsite construction, away from traffic and with minimal time or shift constraints. It also enabled a compressed schedule with work being performed at the project site and staging area simultaneously.*

Figure 23. Existing superstructure with sidewalk, fence, and fascia beam.

"July 17—This fascia beam just behind the fence is one of four exterior beams to be removed from the existing bridges. Over the next several days workers will take out the concrete walkway and fence in preparation for the beam removal." *The sidewalks on the existing bridge and the fascia girders needed to be removed before the move to allow modification of pilasters and end posts at each corner to accommodate the move.*

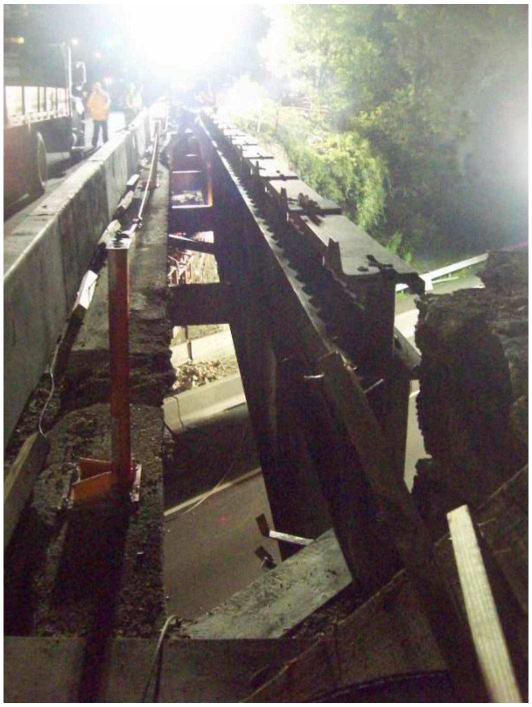


Figure 24. Fascia beam ready for removal.

"July 29—The fascia beam is nearly ready for removal. (Note safety barrier in place.)"

Figure 25. Removal of fascia beam.

"July 30—The first of four fascia beams is removed during the overnight hours of July 29-30. Removing the beams now will reduce bridge weight and facilitate removal of the existing bridge superstructures. The remaining beams will be removed during overnight hours to minimize traffic impacts."

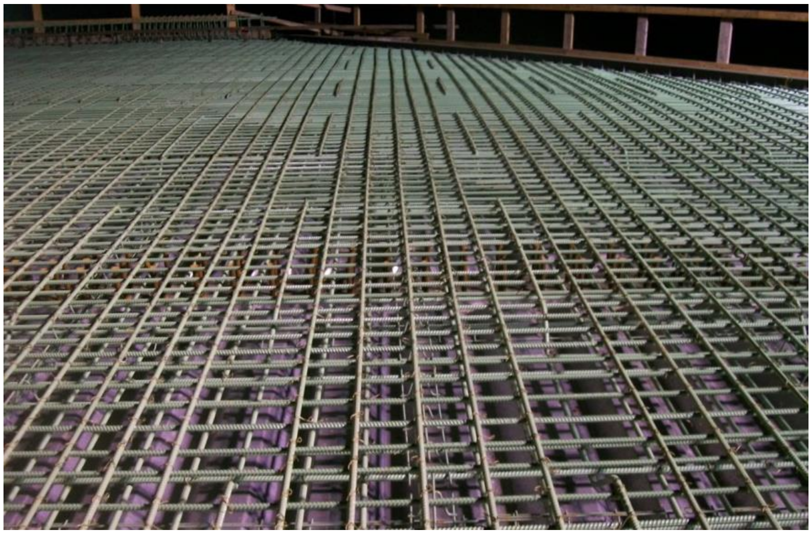


Figure 26. Deck reinforcement.

"August 10—Work continues on the new bridges in the MD 295 median. These reinforcing steel bars (rebar) are tied together across the entire bridge structure. Concrete will be placed in this area via a special pump." *Additional reinforcing steel was placed in the deck to account for stress reversal because of differing support locations during the move. The SPMT support locations were about 11 ft along the skew from each end (16 percent of span length).*

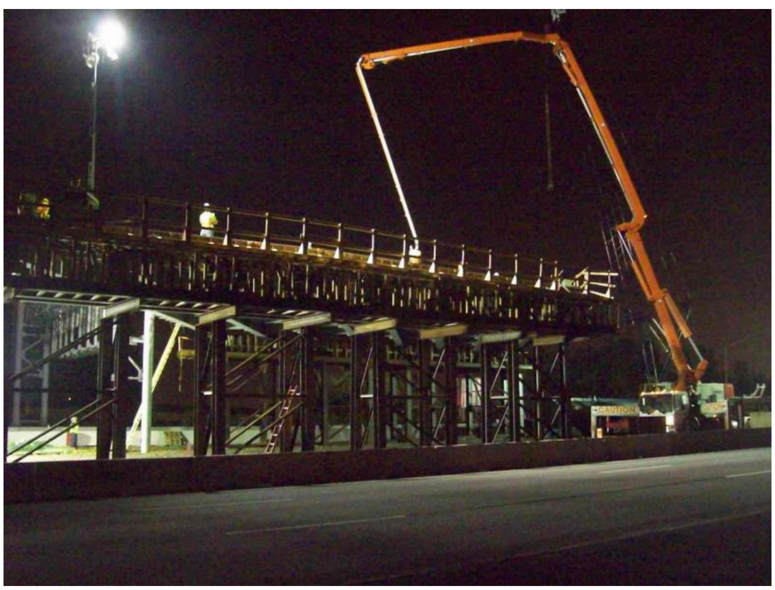


Figure 27. Deck concrete pumping equipment.

"August 10—A pumping truck is poised for the first bridge deck concrete placement. Shortly after 2 a.m. the concrete began flowing. Concrete trucks then arrived every 15 minutes to continuously supply the pumper, and the operation continued into the daylight hours." *Unlike deck concrete placed at grade in conventional construction, the elevated superstructure required pumped concrete.*

Figure 28. Deck concrete placement.

"August 10—A worker guides the concrete pump tube around the new bridge deck area. Working throughout the night and early morning, crews placed and finished about 150 cubic yards of concrete. This process will be repeated within a few weeks for the second bridge." *The compressive strength of the concrete was tested at a laboratory about 5 mi from the jobsite.*

Figure 29. Existing superstructure with fascia beams removed.

"August 16—All four fascia beams were removed from the existing bridges by early August. This was necessary to reduce weight and facilitate removal of the existing structures in October. Crews also gained improved access to repair the existing walls."

Figure 30. Reinforcement and formwork for parapet construction.

"September 4—Wood forms are being constructed for one of the concrete parapets (side walls). On the second bridge (background) you can see where one of the parapets has already been poured and the forms removed." *Additional reinforcing steel was placed in the parapets to account for stress reversal because of differing support locations during the move and lifting. Because the deck was elevated, water had to be pumped and the wet concrete had to be properly covered to ensure adequate curing.*

Figure 31. One of two ends of the temporary structure to support removed superstructure.

"October 12—This is one of the two temporary supports that will support the old bridges for demolition in the MD 295 median. SPMTs will remove the old bridges, carry them along MD 295 to the median staging area, and lower them onto these supports. Crews will then demolish the old bridges and recycle much of the concrete and steel."

Figure 32. Completed new superstructure in median.

"October 12—The new bridges are almost ready to be moved into place. The steel beams have been painted and the concrete decks have been grooved to improve traction and drainage. SPMTs will lift the bridges from the temporary support structures and move them down MD 295 into place."

Figure 33. New superstructure being maneuvered into place on abutment.

"November 3—The new bridge over northbound MD 295 moves slowly into place between the West Nursery Road abutments as workers monitor alignment and clearance. Within 4 hours the new bridge was moved from the staging area down MD 295 and secured into place. Traffic was restored on all roads by early morning."

On Friday, November 2, 2012, West Nursery Road was closed to traffic at 10 p.m. MD 295 northbound was closed on Saturday at 12 a.m. and traffic was detoured to the exit and on ramps. The SPMT removed the old superstructure over the northbound lanes and placed it on the temporary supports in the median of MD 295 for future dismantling and demolition. The entire *operation took less than 6 hours, and MD 295 was reopened to traffic on Saturday at 6 a.m. During the day on Saturday, bearing seats for two central girders that were inaccessible before the move were cast between superstructure removal and replacement using a 100 percent reactive rapid-setting, solvent-free methyl methacrylate polymer concrete system with a 2-hour strength of 4,000 psi and a 1-hour maximum curing time. (West Nursery Road remained closed throughout the day). At about 12 a.m. on Sunday, November 4, MD 295 was closed and traffic detoured on the ramps again. The new replacement superstructure weighing about 500 tons was transported by SPMT and installed in less than 6 hours, and MD 295 northbound was opened to traffic. All four lanes of West Nursery Road (with steel plates placed over the backwall trench) were opened to traffic by 8 a.m. Sunday, within 34 hours after closure.*

Figure 34. New superstructure in place on abutment.

"November 4—The first new bridge is in place and open to traffic over northbound MD 295." *It is important to fully understand the capabilities of SPMT equipment and develop a very detailed plan for the move with specific hold points that are approved by the owner, design team, and prime contractor. It is also important to be thoroughly familiar with the staging area and be thoroughly aware of all the grade changes and obstructions along each path of SPMT travel.*

Figure 35. Old superstructure on MD 295 southbound being moved into place in the median.

"November 10—The old West Nursery Road Bridge over southbound MD 295 is carried by SPMTs to the median staging area for demolition." *Removal and replacement of the superstructure was completed within the allowed closure period on both weekends.*

Traffic Management

The West Nursery Road/MD 295 interchange is a diamond interchange, with West Nursery Road passing over MD 295 on two bridge structures. MD 295 is classified as an urban freeway with ADT of 108, 000 vehicles with about 5 percent trucks. The two lanes of traffic in each direction through the project area were expanded to three lanes in each direction before construction as part of an earlier highway improvement project. West Nursery Road is an arterial roadway maintained by Anne Arundel County that carries about 22,000 ADT and has two signals at the interchange.

A maintenance of traffic analysis during construction showed the following:

- Construction using an SPMT would likely result in shorter construction duration, less disruption to traffic flow, and lower user costs than the conventional alternative.
- MDSHA uses a State-specific Lane Closure Analysis Program (LCAP) to estimate the impacts of lane closures and determine the best closure schedules. Using a work zone capacity of 1,760 vehicles per hour per lane and "acceptable" thresholds of freeway queuing of less than 1 mi (or up to 1.5 mi for peak periods not to exceed 2 hours), it was determined that reducing MD 295 from three lanes to two to perform abutment work both along the outside and inside shoulder would be acceptable.
- The analysis allotted 6 hours for removing old structures and 8 hours for installing replacement structures. During these periods, traffic on MD 295 would exit the mainline at the West Nursery Road ramp, travel straight through the existing traffic signal on West Nursery Road, and rejoin MD 295 via the entrance ramp from West Nursery Road(Figure 36 shows this detour). The traffic on West Nursery Road was detoured (Figure 37).

Figure 36. MD 295 traffic movement during closure.

Figure 37. West Nursery Road traffic detour during closure.

- Hourly traffic volumes on MD 295 indicated that midweek bridge removal and replacement would not meet the acceptable thresholds. However, weekend closures using a lane capacity of 1,170 vehicles per hour per lane (three lanes to one) starting Friday night would be acceptable. By 7 a.m. Saturday, queues approaching the lane drop would exceed 1 mi and would continue to worsen. By 9 a.m. Sunday a similar traffic impact would be encountered.
- No congestion was anticipated on West Nursery Road until Monday morning.

Road Rental

To complete the removal and replacement of the bridge superstructures as quickly as possible and to minimize the amount of time MD 295 and West Nursery Road were closed and detours were in place, MDSHA included a special provision on road rental in the contract (see Appendix D). The road rental would apply during designated periods as follows:

- MD 295 northbound—Midnight Friday to 6 a.m. Saturday for superstructure removal and restart at midnight Saturday to 8 a.m. Sunday for superstructure installation
- MD 295 southbound—11 p.m. Friday to 6 a.m. Saturday for superstructure removal and restart at 11 p.m. Friday to 8 a.m. Sunday for superstructure installation
- West Nursery Road—10 p.m. Friday to 8 a.m. Sunday for superstructure removal and installation for each bridge

Table 1 shows the hourly rental rates, which were based on road user costs.

Table 1. Hourly rental rates.

Roadway	**Rental Rate (per hour, all lanes)**
MD 295 southbound	$ 175
MD 295 northbound	$ 125
West Nursery Road (both directions)	$1,500

Total road rental charges of $106,550 were calculated for the designated period based on the road rental rate. Table 2 shows the calculations.

Table 2. Total road rental for designated period.

Roadway	**Allowed Closure (hour)**	**Road Rental Rate ($/hour)**	**Total Rental Cost**
MD 295 southbound	16	$ 175	$ 2,800
MD 295 northbound	14	$ 125	$ 17,500
West Nursery Road (both directions)	68	$1,500	$102,000
		Total	$106,550

No direct payment would be made to the contractor for the road rental lump sum. The contractor would receive an incentive payment equal to the lump sum road rental amount minus the amount of the road rental assessments.

Table 3 shows the road rental rate outside the designated period, based on Maryland SHA standard established rates, in the form of disincentive.

Table 3. Road rental rates (assessed deductions) outside the designated period.

Roadway	Elapsed Time (minutes)	Deduction
MD 295	1–10	$2,000
MD 295	>10	$1,000 per minute (in addition to the original 10-minute deduction)
West Nursery Road	1–10	$300
West Nursery Road	>10	$150 per minute (in addition to the original 10-minute deduction)

The contract specified that roadway rental times and assessed deductions would be evaluated independently for each weekend (i.e., rental times from each weekend would not be added together for determining assessed deductions).

The actual experience of queuing during removal and replacement of the northbound superstructure during designated periods was less than the State's thresholds and quite similar to projections. Furthermore, queuing was less during the southbound superstructure removal and replacement. Even in this instance, the queues were less than the State's thresholds and similar to projections.

Public Information and Outreach

A public information and outreach plan is a key component of traffic management. Key goals of the plan include making stakeholders aware of the project, alerting them about potential impacts, modifying travel to reduce traffic congestion during project construction, and promoting project support.

MDSHA personnel took the approach to "inform regionally and educate locally." Planning began more than a year before the start of construction. Outreach personnel established a contact list and continuously updated it, and they held numerous face-to-face meetings with emergency organizations, businesses, hotels, and restaurants in the area.

This section of West Nursery Road serves as a business and hotel corridor. Besides other local impacts, construction work at the bridges would impact about 5,000 employees at Northrop Grumman, around-the-clock operations at a mail facility, and visitors to about 20 area hotels and a movie theater complex that attracts about 6,000 people on an average weekend. During the planning and construction of the West Nursery Road bridges, MDSHA implemented an aggressive, comprehensive communication effort with the businesses in the affected zones. Through fliers, newsletters, e-mails, and MDSHA's Web site, the public was kept aware of key project schedules. MDSHA officials met with local business associations, Baltimore-Washington International Airport representatives, and individual businesses most affected by the project. A Web site project summary page that included a webcam at the site offered live updates of progress being made. The agency also prepared detour cards for visitors to area hotels, restaurants, and theaters (see appendix C).

There were no complaints from local businesses or residents during the roadway closure periods. MDSHA's approach to consider not only local residents but also the many visitors to the area in its outreach was particularly effective.

DATA ACQUISITION AND ANALYSIS

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

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

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

SAFETY

The use of SPMTs for this project provided several safety benefits. The SPMT technology enabled the superstructures to be fabricated in the median staging area, away from traffic and behind barriers. This improved the safety of the workers in the work zone as well as motorists, who were not exposed to typical work zone hazards. Also, work could be performed during the day without interruptions throughout the construction process.

The HfL performance goals for safety include worker and motorist safety goals during construction. During the construction of the West Nursery Road project, no worker injuries were reported , which means MDSHA exceeded the HfL goal for worker safety (incident rate of less than 4.0 based on the rate reported on OSHA Form 300).

A 2.38-mi segment of MD 295 between I-195 and I-695 was selected for the operational safety reporting before construction. This roadway segment included the West Nursery Road bridges and part of the pavement on either side of the structure. MDSHA's 3-year crash history (2008–2010) for the project area was as follows:

- This roadway segment experienced 153 reported crashes, 41 percent of which were rear-end collisions, the most common type in the project area. There was a heavier concentration of crashes near the I-195 and I-695 interchanges.
- There were 67 personal injury crashes on this roadway segment.
- There was one fatal crash (alcohol-related) near the I-695 overpass.
- The crash rate on this roadway segment—66.0 crashes per 100 million vehicle miles—was higher than the statewide average of 47.6 crashes per 100 million vehicle miles.
- Twenty-six percent of crashes (less than the statewide average) occurred at night, suggesting that the lighting and delineation on this section of the highway is sufficient.

The history at the two signalized intersections on West Nursery Road during the same 3-year period was as follows:

- There were 12 reported crashes, eight of which occurred at the intersection with the northbound ramps and four at the intersection with the southbound ramps.
- Six of the crashes involved left-turning vehicles. Drivers were unable to make left turns when West Nursery Road was closed and the detour was implemented.
- One crash occurred at night.

Crash data at the interchange ramps for a 3-year period (2006–2008) showed four crashes, three of which occurred during wet conditions.

No crashes were reported during construction of this project, meeting the HfL goal.

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

Construction Congestion

The HfL performance goal on construction congestion is a 50 percent reduction in the time highway users are impacted, compared to traditional construction.

If a traditional approach had been used to remove and replace the bridge incrementally while maintaining traffic on a temporary bridge, MDSHA estimates that it would have taken 12 months to complete the project and that construction-related user impacts would have been felt for more than 7 months. The four lanes of traffic on the existing bridges on West Nursery Road would have been reduced to two lanes (one lane in each direction) that would have been maintained on the temporary bridge for 7 months. A road user cost analysis using MDSHA's loss of public benefit (LOPB) methodology estimated user costs for the conventional option at $300,000 and impact on users for 7 months.

In contrast, under the SPMT option, the construction duration for the project was about 7 months, and removal and replacement of each structure impacted users of West Nursery Road for only 2 weekends (less than 36 hours each weekend). Therefore, construction impact on West Nursery Road users in terms of mobility was reduced from 7 months to less than 3 days. Users of MD 295 northbound were affected with only a diversion of traffic from the mainline to the ramps for only 2 nights, as were users of MD southbound, for a total of 4 weekend nights.

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

Quality

This project involved bridge superstructure replacement that matched the existing roadway grades. The only roadway work was to tie the new construction to the existing approach roadways. Therefore, only minimal roadway work was planned. Also, each structure was only about 70 ft long. Because of the very limited length of improvement, it was decided not to make any smoothness assessments. The new riding surfaces of the bridge decks, however, are a great improvement over the deficient, patched surfaces of the original bridges.

SPMT use also enabled high-quality superstructure construction under controlled conditions in the median without the construction time restrictions of performing conventional onsite bridge construction, such as erecting beams and stay-in place forms, installing shear studs, tying deck reinforcement, placing and curing deck concrete, and removing temporary formwork.

Advanced materials were not used on this project. The advancement on this project was the delivery of the material in an efficient manner without disrupting the traveling public.

USER SATISFACTION

During the planning and construction of the West Nursery Road project, MDSHA implemented an aggressive, comprehensive communication effort with residents and businesses in the affected zones to keep them informed of all activities. Before the project was advertised, public meetings were held and a project brochure was distributed in the communities. MDSHA officials met with local business associations, Baltimore-Washington International Airport representatives, and individual businesses most affected by the project. The goal was to educate the community on the need for the project, its timeline and innovative aspects, and how the innovation would compress the construction time and minimize impacts.

MDSHA's Web page for this project was continuously updated. The information provided included the following:

- Project schedule, including special traffic messages
- Project documents, including news releases, factsheets, traffic impacts, and information on detours and typical bridge sections
- Project contacts
- Maps
- Media information showing project progress with photographs
- Opportunity for Web site visitors to provide feedback
- Answers to frequently asked questions

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

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

No complaints were received from businesses or residents during the weekend bridge structure moves.

MDSHA conducted a postconstruction stakeholder survey of businesses, commuters, and residences. A total of 16 responses were received out of a target population of 60, a response rate of 27 percent. The population consisted of the primary business outreach contact list for hotels, restaurants, and other employers along West Nursery Road and east of MD 295 in what is commonly known as the BWI Hotel District. Survey methods included e-mailing the survey as a fill-in form followed by e-mailing a link to the survey on the Survey Monkey® online tool. E-mailing the document directly generated 13 responses and Survey Monkey generated three.

The survey and comments provided by the respondents is in Appendix E.

Highlights of the survey responses are as follows:

- None of the 16 respondents reported experiencing a major delay of more than 30 minutes in their commute as a result of bridge work. Eleven respondents (69 percent) experienced no delay at all.
- Twelve respondents (75 percent) reported no impact or minor business impact.
- Fourteen respondents (88 percent) affirmed that MDSHA's communication on closures and detours was "very effective."
- Fourteen respondents (88 percent) affirmed awareness of the deployment of innovative technology on this project.

TECHNOLOGY TRANSFER

By executing a precise, well-coordinated plan, MDSHA successfully removed and replaced the West Nursery Road bridges over MD 295 during two consecutive weekends in November 2012. MDSHA proved that ABC is a cost-effective solution, even for structures with challenging geometric constraints like a sharp skew.

To accelerate adoption of this proven innovation nationwide and particularly in the Mid-Atlantic region, representatives of MDSHA and FHWA's Delmar Division and HfL team developed and implemented a technology transfer plan that included a 4-hour Web conference on the afternoon of January 10, 2013. A total of 89 individuals participated, including representatives from other State highway agencies, FHWA, other government agencies, consulting firms, and academia. The participant list and Webinar agenda are in Appendix F.

The Webinar included presentations on the project design, construction, SPMT, removal and replacement of the bridges, and public information and outreach efforts. Presenters included representatives of MDSHA, FHWA, the design consultant, and the contractor. Participants were offered the opportunity to submit questions to the presenters.

FHWA's Maryland Division area engineer served as the moderator, and FHWA's bridge and tunnel construction engineer served as the facilitator. They ensured that the Webinar proceeded smoothly and that participants' questions were answered.

The project manager presented an overview of the project, including the alternatives considered, the feasibility analysis for the use of SPMTs, and a comparison of costs between the SPMT alternative and the conventional alternative.

The consultant made a presentation on the SPMT, including its description, advantages, and disadvantages, and pointed to the reference sources available for any agency considering deploying this innovative tool on projects. He discussed the feasibility analysis performed on the use of the SPMT, design impacts, and special provisions on the technology included in the contract proposal.

The consultant also made a presentation on project engineering, including how the project team addressed design challenges of differing support locations during SPMT deployment, the impact of severe skew during the move and transfer to temporary supports, the dynamic effects of the move, and the accommodation of bearing replacement during the brief closure periods of superstructure removal and replacement. He also discussed how the underclearance was increased to MDSHA's minimum goal of 16 ft.

A senior traffic engineer with the consultant presented the traffic management plan for the project. It included closure periods and detours during superstructure removal and replacement for each bridge. He also discussed the road rental concept and the incentives and disincentives to complete the removal and replacement of structures during the designated closure periods. He concluded that, overall, the maintenance of traffic during project construction went well.

MDSHA District Community Liaison Robert Rager detailed the administration's public outreach efforts. Eighty-eight percent of respondents to a user satisfaction survey indicated that MDSHA communicated road closure and detour information "very effectively."

Project team members outlined the lessons learned on the project. The participants submitted numerous questions on the challenges during construction, which the team ably answered. MDSHA's assistant district engineer for construction for District 5 presented lessons learned from a construction perspective and presented changes that should be considered in future contracts of this type.

The Webinar was a tremendous success. Participants from States, academia, and the consultant community learned about the ABC and SPMT concepts and their practical implementation on a successful project.

ECONOMIC ANALYSIS

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

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

CONSTRUCTION TIME

MDSHA believes that, through the use of innovative construction technologies such as SPMTs and ABC, it was able to dramatically reduce the impact of this project’s construction on roadway users. For the as-built case, although the substructure and superstructure took 4 or 5 months to complete, the impact on users was minimal until the West Nursery Road bridges were ready to be removed and replaced.

If a traditional approach had been used to remove and replace the bridge incrementally while maintaining traffic on a temporary bridge, MDSHA estimates that it would have taken 12 months to complete the project and that construction-related user impacts would have been felt for more than 7 months. In contrast, under the SPMT option, the construction duration for the project was 7 months and removal and replacement of each structure impacted users of West Nursery Road for only 2 weekends. Users of MD 295 northbound were affected with only a diversion of traffic from the mainline to the ramps for 2 nights, as were users of MD 295 southbound.

The following detours were in effect during the superstructure removal and replacement:

- MD 295 northbound—Midnight Friday to 6 a.m. Saturday for superstructure removal and restart at midnight Saturday to 8 a.m. Sunday for superstructure installation
- MD 295 southbound—11 p.m. Friday to 6 a.m. Saturday for superstructure removal and restart at 11 p.m. Friday to 8 a.m. Sunday for superstructure installation
- West Nursery Road—10 p.m. Friday to 8 a.m. Sunday for superstructure removal and installation for each bridge

CONSTRUCTION COSTS

Table 4 presents construction costs related to the SPMT, including grading of the median area, construction of temporary towers to support the removed structure, and two replacement superstructures. Amounts shown are actual bid prices.

Table 4. Costs attributed to SPMT deployment.

Item	Cost
Transporting superstructures	$450,000
Grading median	$5,700
Rebuilding shoulders	$120,000
Constructing temporary towers	$290,000
Total	$865,700

MDSHA estimated that the additional costs related to a temporary structure to manage West Nursery Road traffic for the conventional option was about $800,000. Also, this alternative required reconfiguring ramps, acquiring right-of-way, and constructing temporary approach roadways to the temporary bridge. A detailed analysis of the additional costs was not done because the agency had decided on the SPMT option based on the costs of the temporary bridge alone. The project manager estimated the additional costs at $100,000 to $200,000, indicating that the construction cost of SPMT deployment was about the same as the temporary bridge option.

USER COSTS

User costs are defined as added vehicle operating costs and delay costs to highway users due to construction activity. These costs are incurred because of extra travel distance using detours and when motorists are delayed by congestion in the work zone. The project team used MDSHA's LOPB methodology to calculate user costs. The calculations showed the following:

- User cost per night detouring MD 295 traffic using West Nursery Road Ramps = $7,000.
- User cost for detouring West Nursery Road traffic due to closure during each weekend = $34,000.
- User cost for each day of channeling traffic on to temporary bridge = $2,000.

Using these figures, user costs for the SPMT option were calculated as follows:

2 (superstructures) x 2 (nights) x $7,000 + 2 (weekends) x $34,000 = $96,000

In comparison, user costs for the conventional option of using a temporary bridge for 7 months were calculated as follows:

7 (months) x 30 (days per month) x $2,000 = $420,000

Therefore, ABC techniques saved $324,000 in user costs.

COST SUMMARY

Traditional construction methods would have cost MDSHA about the same as accelerated construction using the SPMT. Traditional methods, however, would have generated $324,000 more in user costs. With the low bid on the project of $4,641,533.35, the savings in user costs were about 7 percent.

APPENDIX A: DECISION ANALYSIS MATRIX

The Maryland State Highway Administration considered eight alternatives for the project. The table below shows objectives and the variety of factors that went into the decision-making.

OBJECTIVES / ALTERNATIVES		ALTERNATIVE NO. 1 DECK REPLACEMENT MATCHING EXISTING BRIDGE GEOMETRY		
DESCRIPTION		MD STANDARD 8 1/2" DECK USING NORMAL-WEIGHT CONCRETE, REPLACE FASCIA GIRDERS, PARAPETS AND PILASTERS.		
PROPOSED TRAFFIC CONTROL		2 PHASE CONSTRUCTION - MAINTAIN 2 OF THE 4 LANES DURING CONSRUCTION ON EXISTING BRIDGE		
NOTES		FUTURE WEARING SURFACE AND STAY-IN-PLACE FORMS UTILIZED		
MUSTS		**COMMENTS**	**GO / NO**	
CARRY HS 25 LIVE LOAD		HS-25 POSSIBLE	GO	
PROVIDE / MATCH EXISTING HORIZONTAL AND VERTICAL CLEARANCES BOTH ABOVE AND BENEATH STRUCTURE		EXISTING VERTICAL AND HORIZONTAL CLEARANCES WILL REMAIN THE SAME	GO	
USE CRASH TESTED BARRIER ON BRIDGE AND APPROACH ROADWAYS		YES	GO	
WANTS	**WEIGHT**	**COMMENTS**	**SCORE**	**WEIGHTED SCORE**
LONGEST SERVICE LIFE W/O MAJOR REHABILITATION	10	25 YEARS ESTIMATED SERVICE LIFE	5	50
IMPROVE CONDITION & SERVICE LIFE OF THE SUPERSTRUCTURE UNITS.	9	NEW DECK	7	63
IMPROVE CONDITION & SERVICE LIFE OF THE SUBSTRUCTURE UNITS.	9	NEW PILASTERS	5	45
CONSTRUCTION COST	8	$1.5 M	9	72
LEAST IMPACT ON TRAFFIC DURING CONSTRUCTION (months traffic impacted)	8	2 LANES OF 2-WAY TRAFFIC POSSIBLE (12 months)	7	56
CONSTRUCTION DURATION	8	12 MONTHS	9	72
EASE OF CONSTRUCTION	8	CONVENTIONAL STAGED DECK REPLACEMENT	10	80
MEETS MINIMUM VERTICAL UNDER CLEARANCE REQUIREMENT	7	CONFINED TO PRESENT CLEARANCE OF 16'-0"	0	0
ABILITY TO ACCOMMODATE FUTURE WIDENING	6	EXISTING ABUTMENTS CAN ACCOMMODATE WIDENING	5	30
DESIGN COSTS	3	--	10	30
NEED FOR PROPERTY / ROW ACQUISITION	4	NONE REQUIRED	10	40
IMPACTS TO ENVIRONMENTAL FEATURES	4	CLEANING AND PAINTING EXISTING GIRDERS	6	24
UTILITY RELOCATIONS	2	NO OBVIOUS RELOCATIONS IDENTIFIED	10	20
DESIGN DURATION	2	--	10	20
AESTHETIC OPPORTUNITIES	2	PARAPETS & FASCIA GIRDERS	5	10
PERMITS REQUIRED	2	--	10	20
			TOTAL	**632**
RISK / ADVERSE CONSEQUENCES				
POTENTIAL IMPACT TO TRAFFIC / MOTORISTS		MODERATE - LANE REDUCTION DURING STAGED CONSTRUCTION WILL REDUCE CAPACITY BY 50 % FOR THE DURATION OF CONSTRUCTION.		
STRUCTURE IMPACTS		REHABILITATION OF EXISTING STRUCTURE INCLUDING: 1. REPAIRING CRACKS AND DETERIORATED CONCRETE IN ABUTMENT STEMS AND BRIDGE SEAT 2. REPLACING EXISTING DECK AND PARAPET 3. REPLACING PILASTERS		

APPENDIX B: SPMT SPECIAL PROVISION

CATEGORY 400
STRUCTURES

TRANSPORTING EXISTING BRIDGE SUPERSTRUCTURES AND ERECTING NEW SUPERSTRUCTURES USING SPMT

DESCRIPTION. This work includes transporting two (2) existing bridge superstructures to the Bridge Staging Area and installing two (2) new superstructures using Self-Propelled Modular Transporters (SPMTs).

Definitions.

Bridge Temporary Works	Any structure which is used to provide temporary support for the bridge.
Bridge Staging Area	The location of the temporary substructure and the area in which the new bridge is constructed.
Electronic Steering	Steering which allows for the SPMTs to drive forward and backward, transversely, diagonally, at any angle and in a carousel motion.
Heavy Lifter	The firm employed by the Contractor to provide heavy lift (SPMT) equipment, operation and engineering. Only heavy lifters prequalified will be allowed on this Project to conduct the bridge moves. The following heavy lifters are prequalified to conduct the bridge moves: **Fagioli, Inc.** 21310 Highway 6 Manvel, TX 77578 **Mammoet, Inc.** 20525 FM 521 Rosharon, TX 77583 **Sarens – Rigging International** 7168 Expressway Missoula, MT 59808
Monitoring	The act of measuring the geometry of the new bridge in the temporary support conditions and the changes in geometry as a result of movement operations.

Reference Points	Fixed points identified on the new bridge which are observed during the move in order to monitor deflections.
Safety Plan	A plan to protect all personnel, spectators and property during construction and movement of the new bridge.
Self-Propelled Modular Transporter	A load-bearing vehicle consisting of a platform supported by numerous pairs of independently steered wheels, each with its own hydraulic jack.
SPMT Blocking	The apparatus between the top platform of the SPMTs and the bottom of the new bridge.
SPMT Support Point	Point where the SPMT blocking attaches to/lifts the new bridge.
SPMT System	The SPMTs, their blocking and any other devices or apparatus used to move the new bridge.
Stroke	The distance the SPMTs can raise or lower their platform.
Temporary Substructure	The temporary supports upon which the new bridge is constructed.
Travel Path	The route along which the SPMTs carry the new bridge from the Bridge Staging Area to the final bridge location.
Wheel Lines	The path along which the wheels of the SPMTs travel.

Change in Longitudinal Gradient Along the Girders – The change in slope experienced along the exterior girders from conditions just prior to lifting and at any point during the lifting and transporting operation.

Change in Transverse Gradient Across the Girder Span – The change in slope experienced along the end diaphragms from conditions just prior to lifting and at any point during the lifting and transporting operation.

Twist – The maximum allowable upward or downward deflection of one corner relative to the plane defined concurrently by the elevations of the other three corners.

Submittals.

All submittals shall be signed and sealed by a Professional Engineer licensed to practice in the State of Maryland and in accordance with Section TC-4.01 of the Standard Specifications.

A schedule addressing the timing and sequence of fabrication and erection of the new superstructure, transporting and demolishing the existing superstructure, construction of temporary substructure, connections with the roadway, road closures and transportation of the superstructure.

Working drawings including complete details and substantiating calculations of the method, materials, and equipment to be used. Do not deviate from the approved working drawings unless authorized in writing.

QA/QC procedures.

Monitoring plan.

Bridge Staging Area and Travel Path.

a. Indicate all ground improvements, soft soil mitigation and utility protection.
b. Verify clearances from above-ground obstacles and provide mitigation.
c. Perform calculations indicating actual loads and actual ground bearing capacities.

Selected Movement System.

a. Design the movement system to lift the existing bridge and proposed bridge at the support points indicated on the Contract Drawings.
b. Design the lifting system to provide wheel loads equal to or less than those indicated on the Contract Drawings.
c. Submit certification that the selected lifting system will possess adequate stroke to negotiate the Travel Path as designed.
d. Indicate any additional systems required to move the structure such as skid rails, climbing jacks, jacking towers, etc.
e. Indicate that the selected lifting system will possess electronic steering capability allowing for movement forward and backward, transversely, diagonally, at any angle, and in a carousel motion.
f. Design the supporting system such that equal support is provided to each girder.
g. Indicate preparatory work necessary for moving personnel, SPMT equipment, supplies, additional equipment and incidentals to the project site before beginning work.

SPMT Blocking.

a. Design SPMT blocking to meet the following specifications in order of precedence.
    1. AASHTO Guide Design Specifications for Bridge Temporary Works, 1st Edition, 2008 Interim Revisions and 2nd Edition 2004.
    2. AASHTO LRFD Bridge Design Specifications, 5th Edition.
b. Calculate all anticipated lateral forces due to, but not limited to, braking, turning, and transporting and provide a system to transfer loads to SPMTs.
c. Provide working drawings for carrier beams.

Movement Plan.

a. Provide schedule for lifting, transporting and placing the existing and proposed superstructures.
b. Indicate all required equipment and operations.
c. Indicate monitoring equipment and operations.

Contingency Plans.

a. Provide a plan addressing potential events which could disrupt the operations of equipment and personnel during the move.
b. Identify any spare parts/equipment required to be on the project site.

MATERIALS.

Provide all materials for the permanent features of the project in accordance with MDSHA Standard Specifications.

Provide all temporary features of the project suitable to sustain applied forces. The Contractor may use timber, steel, concrete or any other material or combination of materials that are in sound condition, capable of safely carrying the specified loads and meet the approval of the Engineer.

SPMTs shall consist of four-axle units or six-axle units with powerpacks and capable of connecting to each other both laterally and longitudinally to create the platform width and length as required to support the applied loads. SPMT units shall be computer linked to act together as one unit to ensure safe transport of the bridge. SPMTs shall have the electronic steering capability allowing for movement forward and backward, transversely, diagonally, at any angle, and in a carousel motion.

The top surface of the unloaded SPMT platform at its lowest position shall be no higher than 4 ft. from the ground surface. The minimum available vertical stroke of the SPMT platform shall be 24 inches.

Each SPMT axle line shall have a minimum load capacity of 25 tons. SPMT units shall be assembled in length and width to accommodate the required bridge size and weight for lifting, transporting, and setting. The SPMTs shall include lifting equipment to equally support all of the girders at each end.

SPMTs shall be capable of traveling with the bridge load on uneven terrain having surface variations up to 18 inches and with a maximum 2,000 pounds per square foot ground pressure (approximated as the load divided by the area of the platform). No axle line of the SPMT shall carry a load greater than 16 tons.

The hydraulic axle compensation shall guarantee equal loads on all wheel sets, independent of the travel path conditions. Series-mounted safety valves shall ensure that upon a hose rupture on the wheel set, the pressure is maintained in the remaining undamaged hydraulic circuit, thus preventing one side of the platform from tilting by redistributing the load to the remaining wheel sets.

In no case shall the platform be out-of-level by more than 6 degrees during lifting, transporting, or setting the bridge, or during equipment malfunction. In addition, the configuration of the SPMT must consider the location of the bridge center of gravity relative to the stability of the combined load such that out-of-level limits are established to safely avoid overturning.

The SPMTs shall have either a three-point or four-point suspension to transport the bridge load safely. The center of gravity must be located within the stability triangle or box to provide a safe move.

Out-of-service situations such as flats and/or failures shall be anticipated and contingencies planned accordingly to ensure that the operators can manually coordinate the units if required to complete the bridge move. The SPMT equipment shall have additional capacity to allow 5 percent of the axles to be out-of-service.

CONSTRUCTION.

Construction of the superstructures in the Bridge Staging Area shall be in accordance with the MDSHA Standard Specifications. The entire superstructure, including but not limited to the steel girders, bearings, diaphragms, connections, shear studs, deck, end diaphragms and parapets shall be erected, cast and cured in the Bridge Staging Area. The posts for the chain link fence shall be installed on the parapets in the Bridge Staging Area. The rails and fabric for the chain link fence shall be installed after the new superstructure is installed, before MD 295 is reopened. All paintings and coatings shall be shop applied. Any touch-ups necessary shall be applied in the Staging Area before the superstructure is installed.

To remove the existing superstructures, remove all connections from superstructure to substructure as required to allow SPMTs to lift the superstructure from the supports.

Check elevations of bearing seats and tops of bearings prior to lifting bridge. Notify the Engineer of any discrepancies between as-built and as-planned bearing elevations and submit proposals for corrective measures.

Lift and transport structure in accordance with the lifting points as established in the Contract Drawings.

The location of support by the SPMTs shall be as shown in the Contract Documents. Any necessary deviation of the support location shall be provided to the Engineer immediately. Any time required for analysis or redesign of the proposed superstructure, analysis of the existing superstructure or additional permanent material required as a result of changing the support location shall be paid for by the Contractor and shall not be a cause for any claim.

Do not exceed the SPMT ground pressures for the supporting capacity of the soil, roadway, or any structure or utility over which the load will travel. Locate and protect all active utilities. Take precautions to mitigate the potential for concentrated or abnormally high bearing pressures at SPMT turning points. Take precautions to mitigate for the potential for loss of traction where SPMTs travel over steep grades or uneven terrain.

Follow approved working drawings for the positioning of SPMTs.

Follow specified allowable limits for loss of support by any pair of wheels or axle lines.

Implement contingency plans in the event of a major breakdown of equipment to complete the installation with minimum disruption to traffic.

Deliver the structure to its final location with no damage or loss of strength, performance, or long-term durability.

Monitor deflection and twist of the structure during lift and transport. Provide measurements to the Engineer for actual deflection and twist during lift, transport and setting.

Halt operations immediately if deflection or twist exceed the allowable limits as provided by the Engineer, returning to temporary supports if necessary.

Tolerances.

a. Do not exceed ½ inch at each end of the span for maximum deviation from longitudinal position after setting.
b. Do not exceed ½ inch maximum deviation from the overall transverse location at each line of bearing.
c. Place the bridge within 1/8 inch vertical tolerance.

Deck Repair.
Deck cracks shall be measured after the bridge is placed and the temporary supports are completely removed and 7 days after bridge placement. The Contractor shall submit a method of repair for all cracks 0.08 inches wide and greater.

MEASUREMENT AND PAYMENT.

Transporting Existing Bridge Superstructures and Erecting New Superstructures Using SPMTs will not be measured but will be paid for at the pertinent Contract lump sum price. The payment will be for full compensation for all SPMT equipment, bracing, blocking, working drawings, permits, mobilization, deck repair, and all material, labor, equipment, tools and incidentals necessary to complete the work.

APPENDIX C: FACTSHEETS

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

May - November 2012

Bridge Facts & Technical Data

Weekend Bridge Replacements Using
Self-Propelled Modular Transporters

Old Bridges:

- Originally constructed in 1948
- 300 tons each (approximate)
- Steel parapets (side walls)
- Two lanes each direction
- No shoulders or bicycle lanes

New Bridges:

- Constructed in three months
- Approximately 70 feet long
- 500 tons each (approximate)
- Concrete parapets (approximately five times heavier than steel, accounting for the weight difference between the old and new bridges)
- Two lanes each direction
- Bicycle-compatible shoulders (Five feet wide)

SPMTs:

- Two lines
- 18 axles per line
- Maximum speed approximately 3 mph
- 175 tons (approximate), plus 110 tons for lattice towers, jack stands and transport beams
- SPMTs delivered and assembled on-site two weeks prior to first bridge move

Figure 38. Factsheet on bridge facts and technical data.

SHA State Highway Administration
Maryland Department of Transportation

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

May - November 2012

Project-In-Brief

Weekend Bridge Replacements Using Self-Propelled Modular Transporters

Project: Replacement of two West Nursery Road bridge superstructures over MD 295.

Cost: $4.6 million (construction).

Contractor: G.A. & F.C Wagman, York, PA.

Timeframe: Bridge replacements will take place the weekends of October 26-28 and November 2-4.

Traffic Impacts: Minimal. Because the new bridges are being constructed in the MD 295 median, traffic continues to flow freely on both MD 295 and West Nursery Road. When the new bridges are moved into place, West Nursery Road will be closed and a short detour will be in effect.

Contact:
Bob Rager
Maryland State Highway Administration
District Community Liaison
410-841-1020
rrager@sha.state.md.us

Figure 39. Factsheet on project.

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

Bridge Move Timeline

Bridge Replacements October 26-28 and November 2-4 using Self-Propelled Modular Transporters (SPMTs)

All times are approximate and apply to both weekends. One bridge replacement per weekend.

Friday-Saturday

8:00 pm	MD 295 - left lane closed in both directions
10:00 pm	West Nursery Road - closed at MD 295
10:00 pm	MD 295 - all lanes closed, ramp detour in effect
10:00 pm to 1:00 am	SPMT - move into position
1:00 am to 2:00 am	SPMT - secure and lift existing bridge
2:00 am to 3:00 am	SPMT - remove existing bridge to staging/demolition area
2:00 am to 10:00 pm	Form and pour bearing pads (all day Saturday)
4:00 am to 6:00 am	MD 295 - reopen all lanes

Saturday-Sunday

8:00 pm	MD 295 - left lane closed in both directions
10:00 pm	West Nursery Road - closed at MD 295
10:00 pm	MD 295 - all lanes closed, ramp detour in effect
10:00 pm to 3:00 am	SPMT - move new bridge into position
3:00 am to 5:00 am	SPMT - return to staging area
6:00 am to 8:00 am	MD 295 - reopen all lanes
8:00 am (approximate)	West Nursery Road - reopen at MD 295

Figure 40. Bridge move timeline.

State Highway Administration

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

May - November 2012

SPMTs - Making the Move

How self-propelled modular transporters (SPMTs) will remove the existing West Nursery Road bridges

Step 1	SPMTs are assembled in the construction staging area (MD 295 median). Two lines of 18 axles each are linked together and controlled by a single remote control power pack unit. Lattice/ jacks are placed atop the SPMT assembly.
Step 2	The SPMT assembly is guided down MD 295 and positioned under the first West Nursery Road bridge to be removed.
Step 3	The SPMT assembly is raised to meet the existing bridge. The bridge is secured to the SPMT assembly.
Step 4	The final bridge retaining bolts are removed. (Most of the bridge removal preparation has been accomplished prior to placement of the SPMTs.)
Step 5	The old bridge is lifted from its anchor points, driven to the median staging area and placed on temporary supports for demolition.

See reverse for installation steps

Figure 41. Factsheet on use of SPMTs to remove existing superstructure.

Replacement of the West Nursery Road Bridges over MD 295 (Baltimore-Washington Parkway)

May - November 2012

SPMTs - Making the Move

How self-propelled modular transporters (SPMTs) will install the new West Nursery Road bridges

Step 1 The SPMT assembly is positioned under the new bridge in the median staging area.

Step 2 The operator raises the SPMT hydraulic assembly to meet the new bridge. The bridge is secured to the SPMT using tie-down straps.

Step 3 The operator guides the SPMT out of the staging area, onto MD 295 and down to the West Nursery Road interchange. Sensors on the bridge monitor movement and changes in terrain and provide constant feedback to the remote control unit. Adjustments are made automatically to keep the bridge at a constant elevation all the way to the interchange area.

Step 4 The new bridge is positioned at the interchange, carefully lowered into place and fastened to the anchor points. Tie-down straps are removed.

Step 5 The SPMT assembly is returned to the median staging area.

See reverse for removal steps

Figure 42. Use of SPMTs to install new superstructure.

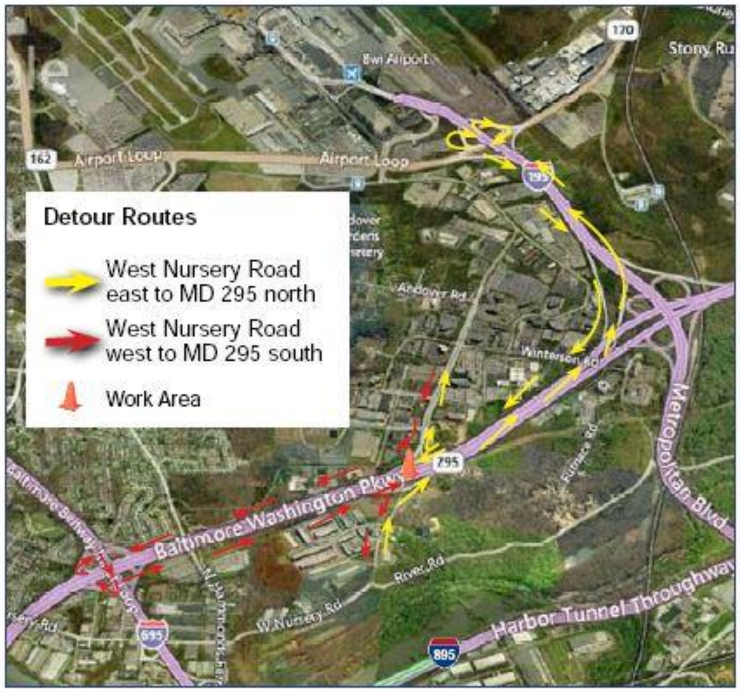
State Highway Administration
Maryland Department of Transportation

West Nursery Road Detour

West Nursery Road will be CLOSED for construction the weekends of October 26-28 and November 2-4. These closures will go into effect at 10 p.m. Friday and remain in effect through 10 a.m. Sunday each weekend. Detour signs will be posted.

** See reverse for more information **

511 Know before you go!



West Nursery Road Will Be Closed at MD 295 October 26-28 and November 2-4

WHAT: Closure and detour of West Nursery Road at MD 295 for two weekends.
WHEN: The weekends of October 26-28 and November 2-4. West Nursery Road will close at 10 p.m. Friday and remain closed through 10 a.m. Sunday each weekend.
WHY: SHA will replace the West Nursery Road bridges over MD 295.

WEST NURSERY ROAD DETOURS (See map on reverse)

From the BWI Thurgood Marshall Airport hotel district east of MD 295 (red arrows on map) to:

- MD 295 north (Baltimore) - proceed to MD 295 and use the right lane exit to MD 295 NORTH.
- MD 295 south - proceed to MD 295 and use the right lane exit to MD 295 NORTH. Continue approximately one mile to I-695. Take the I-695 WEST exit. Remain in the exit lane and return to MD 295 in the southbound direction. Follow signs for MD 295 SOUTH.
- West Nursery Road west of MD 295 - follow directions for MD 295 SOUTH, exiting at West Nursery Road.

From west of MD 295 (yellow arrows on map) to:

- MD 295 south - proceed to MD 295 and use the right lane to exit to MD 295 SOUTH.
- MD 295 north - proceed to MD 295 SOUTH and use the right lane to exit to MD 295 SOUTH. Continue approximately one mile and merge to the left lane. Exit at I-195 EAST toward BWI Thurgood Marshall Airport. This is a LEFT exit only. Follow I-195 to MD 170. Exit at MD 170 NORTH and remain in the exit lane to return to I-195 in the westbound direction. Follow I-195 to MD 295 NORTH.
- West Nursery Road east of MD 295 - follow directions for MD 295 NORTH, exiting at West Nursery Road.

Expect CLOSURES AND DELAYS on MD 295 during overnight hours. See *www.roads.maryland.gov*

Figure 43. Detour card.

APPENDIX D: ROAD RENTAL SPECIAL PROVISION

ROAD RENTALS

DESCRIPTION. It is the intent of the Administration to complete the removal and replacement of each bridge superstructure as quickly as possible and to minimize the time period when West Nursery Road and MD 295 are closed and traffic detours are in place. For these reasons, road rentals are included as part of this Contract. For a rental fee charged by the hour, the Contractor will be allowed to close the roadways during two predetermined weekends. The Contractor will have a specific time period during these weekends, as specified herein, in which to rent road closures on West Nursery Road and MD 295 to complete the critical bridge move portions of the contract (TCP Stages 3A and 3B), which, when completed, all roadways will be open to traffic. The Contractor is alerted that the least amount of time for the roadway closure is of prime importance.

NOTICE OF ROADWAY CLOSURE. In advance of the proposed closure of West Nursery Road and portions of MD 295 to perform the bridge superstructure replacements, the Contractor shall notify the Engineer and Assistant District 5 Engineer for Traffic forty-five (45) calendar days prior to the intended date of closure. The Contractor may not proceed with any closures for this work until receiving written approval from the Assistant District 5 Engineer for Traffic.

The removal and replacement of each bridge superstructure shall take place on two consecutive weekends (weather permitting) per the Traffic Control Plan.

DEFINITIONS.

MD 295 Southbound Roadway Closure Period. The periods of time designated for removal and replacement of the bridge superstructure over MD 295 Southbound shall start no earlier than 11 pm on Friday night and end no later than 6 am the following Saturday morning and shall restart no earlier than 11 pm that same Saturday night and end no later than 8 am the following Sunday morning. These time periods shall occur over one (1) weekend (weather permitting).

MD 295 Northbound Roadway Closure Period. The periods of time designated for removal and replacement of the bridge superstructure over MD 295 Northbound shall start no earlier than 12 am (midnight) on Friday night and end no later than 6 am the following Saturday morning and shall restart no earlier than 12 am (midnight) that same Saturday night and end no later than 8 am the following Sunday morning. These time periods shall occur over one (1) weekend (weather permitting).

West Nursery Roadway (both directions) Road Closure Period. The periods of time designated for removal and replacement of one of the bridge superstructures shall start no earlier than 10 pm on Friday night and end no later than 8 am the following Sunday morning. This period shall occur over two (2) consecutive weekends (weather permitting).

Road Open to Traffic. The road (MD 295 NB, MD 295 SB and both directions of traffic on West Nursery Road) shall be considered open to traffic provided the following conditions are met.

(a) All construction equipment and construction debris has been removed from the roadway and is safely protected behind temporary or permanent barrier.
(b) There are no obstructions / equipment / debris adjacent to the roadway that would pose a safety hazard to errant vehicles.
(c) At least two (2) lanes on MD 295 in each direction (NB & SB) are open to through traffic. Any portion of the roadway damaged during the bridge moving operation is completely repaired.
(d) Both lanes of West Nursery Road are open to through traffic with temporary roadway markings in place.

Road Rental. The removal and replacement of the superstructures of each bridge shall occur over two (2) consecutive weekends (weather permitting). The following chart outlines the rental rates associated with closing the roadways.

ROADWAY	RENTAL RATE (per hour – all lanes)
MD 295 Southbound	$175
MD 295 Northbound	$125
West Nursery Road (both directions)	$1,500

Road rental charges shall apply concurrently for each traffic impact (MD 295 and West Nursery Road).

Road rental charges will be assessed once road closures are in place, whether or not work is in progress and regardless of weather conditions. The Engineer, in his / her sole discretion, reserves the right to waive road rental charges in documented extenuating circumstances. All reductions and extensions of Contract duration will be made in conformance with the provisions of Section 109.

Lane closures permitted in Special Provision 104.01 not associated with the bridge superstructure removal and the installation of the replacement superstructure will not be required to be rented.

FAILURE TO REOPEN ROADS. The Road Rental rate listed above does not include lane closure deductions for failure to reopen the roadways at the end of the allowable closure periods. These deductions will be assessed in accordance with the fee schedule per minute outlined in special provision 104.01, copied below for reference.

ASSESSED DEDUCTIONS FOR MD 295	
ELAPSED TIME, (MINUTES)	**DEDUCTION**
1 – 10	$ 2,000.00
Over 10	$1,000.00 per minute (In addition to the original 10 minute deduction)

ASSESSED DEDUCTIONS FOR WEST NURSERY ROAD	
ELAPSED TIME, (MINUTES)	**DEDUCTION**
1 – 10	$ 300.00
Over 10	$150.00 per minute (In addition to the original 10 minute deduction)

IT IS IMPORTANT TO NOTE THAT ROADWAY RENTAL TIMES AND ASSESSED DEDUCTIONS WILL BE EVALUATED INDEPENDENTLY FOR EACH WEEKEND. RENTAL TIMES FROM EACH WEEKEND WILL NOT BE ADDED TOGETHER FOR DETERMINING ASSESSED DEDUCTIONS (i.e. finishing four hours earlier one weekend and four hours late the following weekend does not result in finishing on time for determining assessments).

MEASUREMENT AND PAYMENT. Road rentals will be charged against the Road Rental lump sum item. A preestablished price of $106,550, equaling the roadway closure rental rates for full closure of the roadways for the complete times allowed, has been designated for this item.

Roadway Location	**Allowed Closure (hrs)**	**Road Rental Rate ($/hr)**	**Total Rental Cost**
MD 295 Southbound Roadway	16	175	$2800
MD 295 Northbound Roadway	14	125	$1750
West Nursery Road	68	1500	$102,000
		Total =	**$106,550**

The Engineer will record Road Rental assessments for each weekend closure and submit a tabulation to the Contractor the following week. The Contractor must submit to the Engineer any disputes of the Road Rental assessments within one week of receipt of the tabulation.

No direct payment will be made for the Road Rental lump sum. At the conclusion of the project, the Contractor shall receive an incentive payment or disincentive monetary deduction equal to the lump sum Road Rental amount minus the amount of the total of all Road Rental assessments and any incurred lane closure deductions for the entire Project. Any deduction greater than the preestablished price will be deducted from the Contractor's monthly billing (see example below).

Example: During weekend no. 1 when moving the existing bridge over MD 295 SB into the median, MD 295 SB is opened at 9 am Saturday instead of 6 am. All other time constraints in weekend no. 1 are met.

Weekend	**Roadway Location**	**Closure (hrs)**	**Road Rental Rate ($/hr)**	**Exended Closure (min.)**	**Exended Closure Deduction ($)**	**Total Rental Cost ($)**
1	MD 295 Southbound Roadway	16	175			$2,800
1	MD 295 Southbound Roadway			180	$2,000 (first 10 minutes) + 170 x $1,000 =	$172,000
1	West Nursery Road	34	1500			$51,000
					Total =	**$225,800**

During weekend no. 2 when moving the new bridge over MD 295 NB into place, West Nursery Road is opened at 6 am Sunday instead of 8 am. All other time constraints in weekend no. 2 are met.

Weekend	Roadway Location	Closure (hrs)	Road Rental Rate ($/hr)	Exended Closure (min.)	Exended Closure Deduction ($)	Total Rental Cost ($)
2	MD 295 Northbound Roadway	14	125			$1,750
2	West Nursery Road	32	1500			$48,000
					Total =	**$49,750**

<u>Summary</u>

Weekend no. 1 rental total = - $225,800
Weekend no. 2 rental total = - $ 49,750
<u>Pre established price = $106,550</u>
Total = $169,000

Total Amount to be deducted from the Contractor's monthly billing = **$169,000**.

APPENDIX E: USER SATISFACTION SURVEY

WEST NURSERY ROAD BRIDGE REPLACEMENT PROJECT WRAP-UP AND SURVEY

February 2013

The replacement of two West Nursery Road bridges over MD 295 is complete except for minor landscaping, touch-up, and cleaning. The Maryland State Highway Administration's (SHA's) goal was to construct the new bridges in the MD 295 median and move them into place over two weekends, with as little impact on traffic and local businesses as possible.

As a member of the SHA project e-mail list, you are receiving this survey. Your responses to a few questions will help SHA evaluate our efforts to communicate this work to area stakeholders, and will help guide future communication efforts.

NOTE: SHA only replaced the two bridges over MD 295. A private developer constructed turn lane and signal improvements on West Nursery Road and that work was NOT related to the bridge replacements. This survey asks you to consider only the bridge replacement work and the weekend closures/detours on West Nursery Road and MD 295.

This 15 question, multiple-choice survey should take about 3 minutes to complete. Use your mouse to check the appropriate boxes. Please SAVE this survey when completed and e-mail to rrager@sha.state.md.us. Thank you!

1) Which one of these statements best describes you?

8 ☐ I commute/work along West Nursery Road
0 ☐ I own or manage a business along West Nursery Road
2 ☐ I live near West Nursery Road
2 ☐ I work in a customer service business along West Nursery Road (e.g., hotel, restaurant)
1 ☐ Other

2) How did the bridge work affect your commute/driving?

9 ☐ Not at all
4 ☐ Minor delays (up to 30 minutes additional travel time)

0 ☐ Major delays (more than 30 minutes additional travel time)

3) How did the bridge work affect your business (if applicable)?

3 ☐ Minor business impact
2 ☐ Major business impact
7 ☐ No impact

4) If your business or employment was impacted by the bridge work, which of these best describes the impact? (Please check all that apply)

0 ☐ Fewer customers
0 ☐ Loss of sales
3 ☐ Employees late for work
1 ☐ Meetings postponed or cancelled
4 ☐ Customers asking for directions

5) If your work along or near West Nursery Road involves customer service, do you recall if any customers complained about the bridge work, road closures or detours?

4 ☐ Yes, I heard a few complaints
0 ☐ Yes, there were many complaints
3 ☐ No, I was not aware of any complaints

6) How did you first learn about this project?

0 ☐ Radio or Television
0 ☐ Newspaper
1 ☐ Community newsletter
2 ☐ Internet
0 ☐ Social media (Twitter, Facebook)
10 ☐ Personal contact with SHA representative

7) Did you or your business receive any of the following materials from SHA regarding the bridge work? (Please check all that apply)

5 ☐ Bridge project presentation video
8 ☐ Detour card/map
6 ☐ Project factsheet
7 ☐ FAQ
7 ☐ Project timeline

8) Which of these resources was the MOST useful/helpful?

5 ☐ Detour card/map
1 ☐ Bridge project presentation video
2 ☐ Project factsheet
4 ☐ FAQ
3 ☐ Project timeline
2 ☐ SHA Web site (www.roads.maryland.gov)

9) Overall, how useful was the detour card/information?

6 ☐ Very useful
4 ☐ Somewhat useful

3 ☐ Not useful at all

10) Overall, how useful was the SHA Web site in providing project, road closure, or detour information?

6 ☐ Very useful
5 ☐ Somewhat useful
1 ☐ Not useful at all

11) Overall, how effectively did SHA communicate the road closures and detours?

12 ☐ Very effectively
1 ☐ Somewhat effectively
0 ☐ Not effectively at all

12) Did you have direct contact with SHA staff during this project? If so, please rate your experience:

8 ☐ Very positive
3 ☐ Somewhat positive
1 ☐ Neither positive or negative
0 ☐ Somewhat negative
0 ☐ Very negative

13) What could SHA have done better in communicating road closure and detour information?
(Please check all that apply)

0 ☐ Use more/better direct contact with area residents and businesses
0 ☐ Use more/better printed materials
10 ☐ Nothing–good job
2 ☐ Use more radio and television
2 ☐ Put more information on the Internet
0 ☐ Use more social media

14) Were you aware that this project used special bridge moving technology ("self-propelled modular transporters") to replace the bridges?

12 ☐ Yes
1 ☐ No

15) Please include any additional comments here:

See Below

THANK YOU!

Please save this completed survey and attach it to an e-mail to rrager@sha.state.md.us

Comments

I found the e-mail notifications very useful. For the scope of the work that was done, I must say that you did an awesome job with very little disruption to travelers.

It seems that SHA's priority in choosing detour routes is to minimize the total impact on the neighboring roads. But my personal goal in choosing a detour route is how to get to and from work the fastest. These two goals were in direct conflict. Personally I would NEVER have chosen SHA's detour routes, nor recommended them to anyone else, simply because there were always better options, no matter which direction you were going from or coming to.

Although you said contractors were responsible for lanes and lights, I have to say the turn arrows are not visible when coming up the ramp heading north on 295 and turning east on West Nursery. Many drivers are ignoring the NO TURN ON RED sign. In fact some are proceeding from the second and third turn lanes. I think larger no turn on red signs are needed and also adjustments on the turn arrow signals.

Good job!

APPENDIX F: WEBINAR

West Nursery Road Over MD 295/Baltimore-Washington Parkway Bridge Replacement

AGENDA
January 10, 2013

Moderator: Ian Cavanaugh, Area Engineer–FHWA Maryland Division
Facilitator: Tim Cupples, Bridge and Tunnel Construction Engineer–Federal Highway Administration

12:30 p.m.–12:40 p.m.	**Welcome**
12:40 p.m.–1:00p.m.	**Project Overview** Jeff Robert, Senior Project Manager–MDSHA
1:00 p.m.–1:40 p.m.	**SPMT Presentation** Donald Tusing, Senior Project Engineer–RK&K Consultants
1:40 p.m.–2:05 p.m.	**MOT/Lane Rentals** Scott Crumley, Senior Traffic Engineer–RK&K Consultants
2:05 p.m.–2:35 p.m.	**Public Outreach** Robert Rager, District Community Liaison–MDSHA
2:35 p.m.–2:45 p.m.	**Break**
2:45 p.m.–3:30 p.m.	**Project Engineering** Donald Tusing, Senior Project Engineer–RK&K Consultants
3:30 p.m.–4:30 p.m.	**Lesson Learned** Todd Becker, Vice President of Operations–G.A. & F.C. Wagman, Inc. Jeff Robert, Senior Project Manager–MDSHA Donald Tusing, Senior Project Engineer–RK&K Consultants
4:30 p.m.	**Adjourn**

ATTENDEE LIST

Name	Company Name	State	Viewers
Richard Brown	WBCM	Maryland	1
Frank Kaul	Dewberry	Maryland	1
John Barefoot	Mead & Hunt	Virginia	1
Amar Bhajandas	Applied Research Associates	Illinois	1
Phillip Bobitz	FHWA	Maryland	1
Sudipta Ghorai	Syracuse University	New York	1
Eva Del Valle-Valentin	FHWA	Virginia	1
Carlos Figueroa	FHWA Georgia Division	Georgia	5
Robert Mihalek	FHWA	District of Columbia	1
Mary Milcic	Illinois DOT	Illinois	1
Ewa Flom	FHWA	District of Columbia	1
Jay Shah	DPWT Prince Georges County	Maryland	1
Benjamin Hokuf	MDSHA Office of Structures	Maryland	1
Rajan Patel	Eastern Federal Lands Highway Division	Virginia	1
Michael Allen	USACE	Virginia	1
Kathryn Weisner	FHWA-RC	Const TST	1
Douglass Robb	Delaware DOT	Delaware	1
Maurice Agostino	MDSHA-OOS	Maryland	1
Xiaohua "Hannah" Cheng	New Jersey DOT	New Jersey	1
Depankar Debnath	Sabra-Wang & Associates	Maryland	1
Chien Ming Chu	USACE	Pennsylvania	1
David Mraz	FHWA-NE	Nebraska	1
Tiffany Brase	Illinois DOT	Illinois	8
Ryan O'Donoghue	FHWA	DelMar	1
Jeri Shell	T2	Florida	1
Nathaniel Benoit	Maine DOT	Maine	1
Megan Carter	Department of State	Virginia	1
Melinda Roberson	FHWA	Georgia	1
Christopher Lynch	FHWA	Idaho	1
Victor Dang	FHWA	Georgia	1
Matthew DiGiovanni	FHWA	Maryland	1
Ben Beerman	FHWA	Georgia	1
Michael Pritchett	Illinois DOT	Illinois	1
Phil Ciha	Wisconsin DOT	Wisconsin	1
David Ross	Colorado DOT-Staff Bridge	Colorado	1
Mikhail Lozovatsky	AECOM	Maryland	1

Tim Armbrecht	Illinois DOT	Illinois	1
Mick Syslo	Nebraska Department of Roads	Nebraska	2
Shiuli Mahmud	Syracuse University	New York	1
Steve Gaston	Georgia DOT	Georgia	1
John Holt	TxDOT Bridge Division	Texas	1
Daniel Slanina	FHWA	Washington	1
Billie Owen	Illinois DOT	Illinois	1
Joshua Cunningham	FHWA	District of Columbia	1
David Fish	Rhode Island DOT	Rhode Island	1
Raymond Kirchner	URS Corporation	Maryland	1
Eunice Usher	Florida DOT	Florida	1
Ian Cavanaugh	FHWA	Maryland	1
Eric Mueller	Illinois DOT	Illinois	10
Patrick Kennedy	FHWA	Delaware	1
Daniel Montag	FHWA	Delaware	1
Shararehp Pirzadeh	Syracuse University	New York	1
Mary Ridgeway	FHWA	Delaware	1
Michael Hyzak	TxDOT Bridge Division	Texas	1
David Depolo	USACE	Pennsylvania	1
Kellie Boulware	MDSHA	Maryland	1
Beny Berlanga	Florida DOT	Florida	1
Raymond Valido	Florida DOT	Florida	1
Jaime Carreon			1
Rebecca Tharp	Illinois DOT	Illinois	1
Barry Benton	Delaware DOT	Delaware	1
David Platz	FHWA	Wisconsin	1
Julie Fahy	Ohio DOT D2	Ohio	1
Patti LeBeau	Illinois DOT	Illinois	2
Marc Dixon	FHWA DelMar Division	Delaware	1
Mary Huie	FHWA	District of Columbia	1
Hari Kalla	FHWA	District of Columbia	1
		Total Attended:	**89**

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 Maryland State Highway Administration engineers Jeff Robert, James Folden, and James Dembowski; Communications Director Valerie Burnette Edgar; District Community Liaison Robert Rager; FHWA Division Administrator Gregory Murrill; and FHWA Engineers Benjamin Beerman, Dennis Oshea, Ian Cavanaugh, and Tim Cupples for their advice, assistance, and coordination during this project.