Massachusetts Demonstration Project: Reconstruction of Fourteen Bridges on I-93 in Medford Using Accelerated Bridge Construction Techniques

FINAL REPORT
OCTOBER 2014

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

U.S.Department of Transportation
Federal Highway Administration

FOREWORD

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

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

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

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Abstract

As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Massachusetts Department of Transportation (MassDOT) was awarded a $1 million grant to demonstrate the use of proven, innovative technologies to deliver a $91.0 million project in less time than conventional construction.

This report documents the use of accelerated bridge construction techniques and Design-Build (D-B) contracting to replace 14 bridges on Interstate 93 in Medford, Middlesex County. The bridge superstructures were installed during a 55-hour weekend closure over 10 weekends between June 3 and August 15, 2011. This report describes project/site challenges, construction details, D-B contract administration, fabrication, shipping and installation of prefabricated modular steel elements, traffic operations management, and MassDOT's extensive public outreach and communication efforts to minimize the impacts of weekend closure on I-93 motorists and adjacent detour routes.

Under traditional construction methods, the project would have taken 48 months (4 years) to build all 14 bridges. With five stages of construction and the placement of single-lane closure, the project would have impacted I-93 traffic for the full 48 months. Using accelerated bridge construction and D-B contracting, the project was completed 39 months earlier, with only 550 hours of travel impacts to motorists. The Design-Build contracting allowed MassDOT to overlap design and construction phases and issue a notice to proceed for construction 17 months earlier than the anticipated issue date.

The use of innovations resulted in savings of $1.75 million in construction costs and $8.45 million in user delay costs. The use of accelerated bridge construction instead of traditional staged and cast in-place construction also resulted in user cost savings of approximately $136 million.

Key Words	Distribution Statement
Highways for LIFE, prefabricated modular steel bridge elements, innovative construction, Design-Build project delivery, incentives and disincentives, economic analysis	No restriction. This document is available to the public through the Highways for LIFE website: http://www.fhwa.dot.gov/hfl/

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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	Pound force	4.45	Newtons	N
lbf/in^2 (psi)	Pound force per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
DENSITY				
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2

ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	Newtons	0.225	poundforce	lbf
kPA	kiloPascals	0.145	poundforce per square inch	lbf/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)

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

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND SYMBOLS

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
ABC	Accelerated bridge construction
ADT	Average daily traffic
ARAN	Automatic Road Analyzer
CCP	Comprehensive Communications Plan
CHIPS	Computerized Highway Information Processing
CM/GC	construction manager/general contractor
CPI	Consumer Price Index
D-B	Design-Build
dB(A)	A-weighted decibel
DOT	Department of Transportation
ECI	Employment Cost Index
EDC	Every Day Counts
FHWA	Federal Highway Administration
HfL	Highways for LIFE
Hz	Hertz
IAP	Incident Action Plan
IRI	International Roughness Index
ITS	Intelligent Transportation System
MBTA	Massachusetts Bay Transportation Authority
MOTT	Massachusetts Office of Travel and Tourism
MassDOT	Massachusetts Department of Transportation
MIVIS	Massachusetts Interagency Video Information System
MUTCD	Manual on Uniform Traffic Control Devices
NCAT	National Center for Asphalt Technology
OBSI	Onboard sound intensity
OSHA	Occupational Safety and Health Administration
PBES	Prefabricated bridge elements and systems
PCMS	Portable changeable message sign
PCU	Projects Control Unit
PMSE	Prefabricated modular steel bridge elements
QA	Quality Assurance
QC	Quality Control
QMP	Quality Management Plan
RTTM	Real-time traffic management
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SRTT	Standard reference test tire
TWG	Traffic Working Group
VHB	Vanasse Hangen Brustlin, Inc.
VOC	Vehicle operating cost

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

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

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

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

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

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

Project Solicitation, Evaluation, and Selection

FHWA issued open solicitations for HfL project applications in fiscal years 2006 through 2013. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, then contacted applicants to discuss technical issues and obtain commitments on project issues. Documentation of these questions and comments was sent to applicants, who responded in writing.

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

- Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
- Use innovative technologies, manufacturing processes, financing, contracting practices, and performance measures that demonstrate substantial improvements in safety, congestion, quality, and cost-effectiveness. An innovation must be one the applicant State has never or rarely used, even if it is standard practice in other States.
- Include innovations that will change administration of the State's highway program to more quickly build long-lasting, high-quality, cost-effective projects that improve safety and reduce congestion.
- Will be ready for construction within 1 year of approval of the project application. For the HfL program, FHWA considers a project ready for construction when the FHWA Division authorizes it.
- Demonstrate the willingness of the applicant department of transportation (DOT) to participate in technology transfer and information dissemination activities associated with the project.

HfL Project Performance Goals

The HfL performance goals focus on the expressed needs and wants of highway users. They are set at a level that represents the best of what the highway community can do, not just the average of what has been done. States are encouraged to use all applicable goals on a project:

- Safety
    - Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
    - Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported on Occupational Safety and Health Administration (OSHA) Form 300.
    - Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.
- Construction Congestion
    - Faster construction—Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
    - Trip time during construction—Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
    - Queue length during construction—A moving queue length of less than 0.5 miles in a rural area or less than 1.5 miles in an urban area (in both cases at a travel speed 20 percent less than the posted speed).
- Quality
    - Smoothness—International Roughness Index (IRI) measurement of less than 48 in/mi.
    - Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test method.

- User satisfaction—An assessment of how satisfied users are with the new facility compared to its previous condition and with the approach used to minimize disruption during construction. The goal is a measurement of 4 or more on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This report documents the Massachusetts Department of Transportation's (MassDOT) demonstration project to replace 14 structurally deficient bridges on I-93 in Medford, approximately 5 miles north of Boston. The goal of this project was to rapidly replace 14 superstructures. Presented herein are project details relevant to the HfL program, including the use of prefabricated modular steel elements, accelerated bridge construction (ABC) techniques, Design-Build (D-B) project management, and incentive/disincentive clauses applied to produce a superior product, safely and in less time than traditional construction. HfL performance metrics measurement, economic analysis, and lessons learned also are discussed.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The MassDOT demonstration project replaced seven structurally deficient overpasses on I-93. Each overpasses has two superstructures, for a total of 14 separate bridges which each carry 4 lanes of traffic. Tagged as the *Fast 14* project by MassDOT, the goal of this project was to replace all of the superstructures during just one construction season. This ambitious project required innovative approaches in construction, contracting, and project management, such as the use of prefabricated modular steel elements, ABC techniques, D-B project management, and incentive/disincentive clauses. Figure 1 shows a map of the project location in Medford, approximately 5 miles north of Boston.

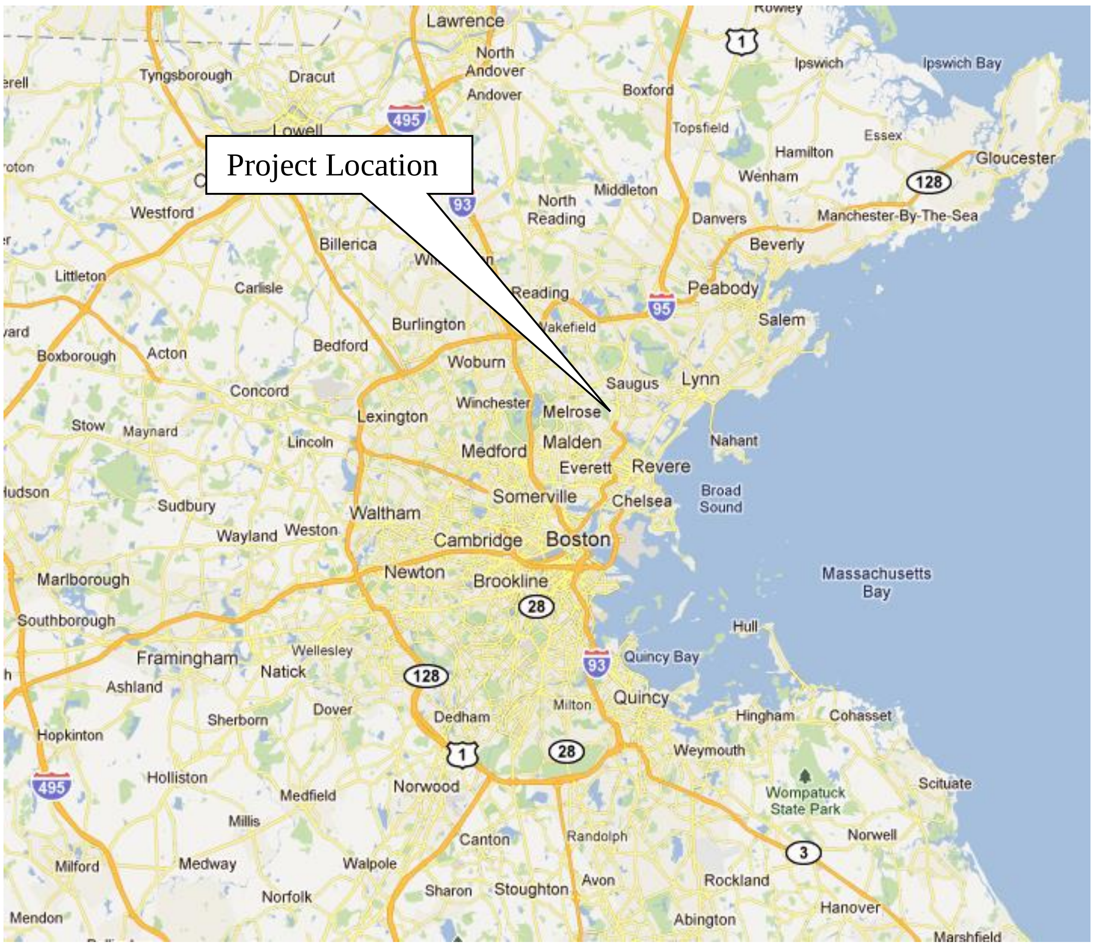


Figure 1. Map of project location.

HFL PERFORMANCE GOALS

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

- **Safety**
  - Work zone safety during construction—The HfL goal of achieving a work zone crash rate equal to or less than the preconstruction rate was not met, since the work zone crash rate was higher than the preconstruction crash rate; however, with ABC, the reduction in the duration of work zone exposure from 4 years to 550 hours was significant for reduction in work zone safety risks.
  - Worker safety during construction—The contractor achieved a score of 0.0 on the OSHA Form 300, meeting the HfL goal of less than 4.0.
  - Facility safety after construction—There were no significant safety improvements on this facility, except to upgraded barriers and guardrail transitions. The net effect that these safety improvements will have on the HfL goal of 20 percent reduction in fatalities and injuries in 3-year crash rates compared to preconstruction rates is yet to be determined.

- **Construction Congestion**
  - Faster construction—With the use of accelerated construction methods, the duration of construction was shortened from 48 months to 9 months. The traffic impact time due to construction was drastically reduced from 48 months to 550 hours (10 weekend closures each 55 hours long). This meets the HfL goal of a 50 percent reduction in the time traffic is impacted compared to traditional construction methods.
  - Trip time—The average delay time ranged between 7 and 15 minutes in the northbound direction on I-93 over the weekend, and approximately 4 to 8 minutes in the southbound direction. This did not meet the HfL goal of no more than a 10 percent increase in trip time compared to the average preconstruction conditions.
  - Queue length during construction—The shortest average measured queue length was 1.6 miles, while the average measured queue length was 2.8 miles. This did not meet the HfL goal less than a 1.5-mile queue length in an urban area.

- **Quality**
  - Smoothness—The average IRI value for the bridges dropped from 294 to 103 inches/mile. This represents a 65 percent reduction in IRI and reflects the increase in both ride and construction quality. However, the HfL goal for IRI of 48 inches/mile—typically expected to be attainable on long, open stretches of pavement—was not met on this project.
  - Noise—The average value of the bridges dropped 4.0 dB(A) from 100.8 to 96.7 dB(A). While not meeting the HfL goal of 96.0 dB(A), the bridges were quieter than the old bridges.
  - User Satisfaction—Seventy-eight percent of the motorists surveyed were satisfied with the condition of the finished highway, while 83 percent of the survey participants indicated their satisfaction with the way the project was carried out.

Overall, the survey indicated that the user satisfaction met the performance goal of 4 or more points on a 7-point Likert scale.

ECONOMIC ANALYSIS

The costs and benefits of this innovative project approach were compared with those of a project of similar size and scope delivered using a more traditional approach. The economic analysis revealed that MassDOT's approach realized a cost savings of $1.75 million, or 1.96 percent of the total project, over conventional construction practices. User cost savings were $8.45 million.

LESSONS LEARNED

Through this project, MassDOT gained valuable insights on the innovative processes deployed—both those that were successful and those that need improvement in future project deliveries. The following points highlight the lessons learned on this project:

- Teamwork and coordination between and within the Design-Builder and MassDOT teams contributed to the project's success.
- When selecting D-B method for project delivery, an owner agency should evaluate its internal resources at varying levels across disciplines to ensure good preparation for procurement and project administration.
- Assigning an owner's engineer for reviews of design submittal and construction support was effective.
- Utilization of a SharePoint site for exchanging documents between the D-B team and the owner agency was effective in terms of time, cost, and convenience. The electronic document management system facilitated access to plans and submittals and allowed for more effective tracking of changes.
- Outreach and coordination activities with State agencies, local government, transportation partners, and other organizations were important before and during construction.
- The use of incentives/disincentives was effective. The contractor opened the roadway to traffic on or before 5:00 a.m. Monday on each of the 10 weekend closures to receive the maximum incentive amount of $7 million.
- Setting up a State Police mobile command at the job site allowed for real-time monitoring of live traffic using video feeds and helped provide rapid response to incidents.
- Use of two-way radios allowed MassDOT, the contractor, and police to communicate on one channel. With two-way radios, all parties were kept aware of the progress and incidents on the field. The two-way radios also helped to minimize phone usage costs.
- Instead of shipping separately, the materials for each panel were shipped together. Not only did this trucking arrangement saved shipping time and costs, but it also provided workers with immediate access to materials.
- Deployment of a zipper barrier allowed the traffic operations at the crossovers to be more efficient.
- Deployment of modular element technology allowed construction to be flexible and adaptable.

- Co-location, over-the-shoulder review, and weekly progress meetings between the Design-Builder and MassDOT teams helped with thorough review and faster release of design submittals.
- Revising the requirements to deliver materials at the job site well before the installation time would provide adequate time for the construction crew to work with the materials.
- Allowing more time for project development would help the Design-Builder with the design efforts, material procurement, and construction planning.
- It is valuable for the contractor to have a good working relationship with other partners, including police, as well as the emergency and fire department, to facilitate faster and better response to incidents.
- Better estimation and allocation of resources is important to keep pace with the project schedule.

CONCLUSIONS

This project successfully replaced all 14 bridges over 10 weekend closures within a shorter period of time than would have been required using traditional approaches. The use of innovations, i.e. accelerated bridge construction and Design-Build project delivery helped MassDOT to complete the project in a timely manner with minimal disruption to the public. The Design-Build contracting allowed MassDOT to overlap design and construction phases and issue a notice to proceed for construction 17 months earlier than the anticipated issue date, while the use of accelerated construction methods saved 39 months of traffic impact time. This project also demonstrated the importance of outreach, communication and coordination not only with partners and stakeholders but also with the general public. MassDOT used a combination of various traffic control, incident and emergency management, safety management, and communication strategies to ensure mobility and safety of motorists during construction. This project also efficiently utilized the incentive and disincentive clauses in the construction contract to ensure on-schedule completion. The success of this project underlines the importance of early coordination and working relationship among various parties, i.e. MassDOT, FHWA, Design-Builder, consultants, local agencies, public transit and police, involved in construction.

PROJECT DETAILS

BACKGROUND

The overpasses were built in the early 1960s, and at the time of this project each one was reaching the end of its service life, although the substructures were in repairable condition. Since the bridges are located on a major artery, they carry a very high volume of traffic—up to 181,000 vehicles per day. Figure 2 shown each overpass location and is labeled with the MassDOT identification number, crossroad, average daily traffic (ADT), year built, and previous rebuild year.

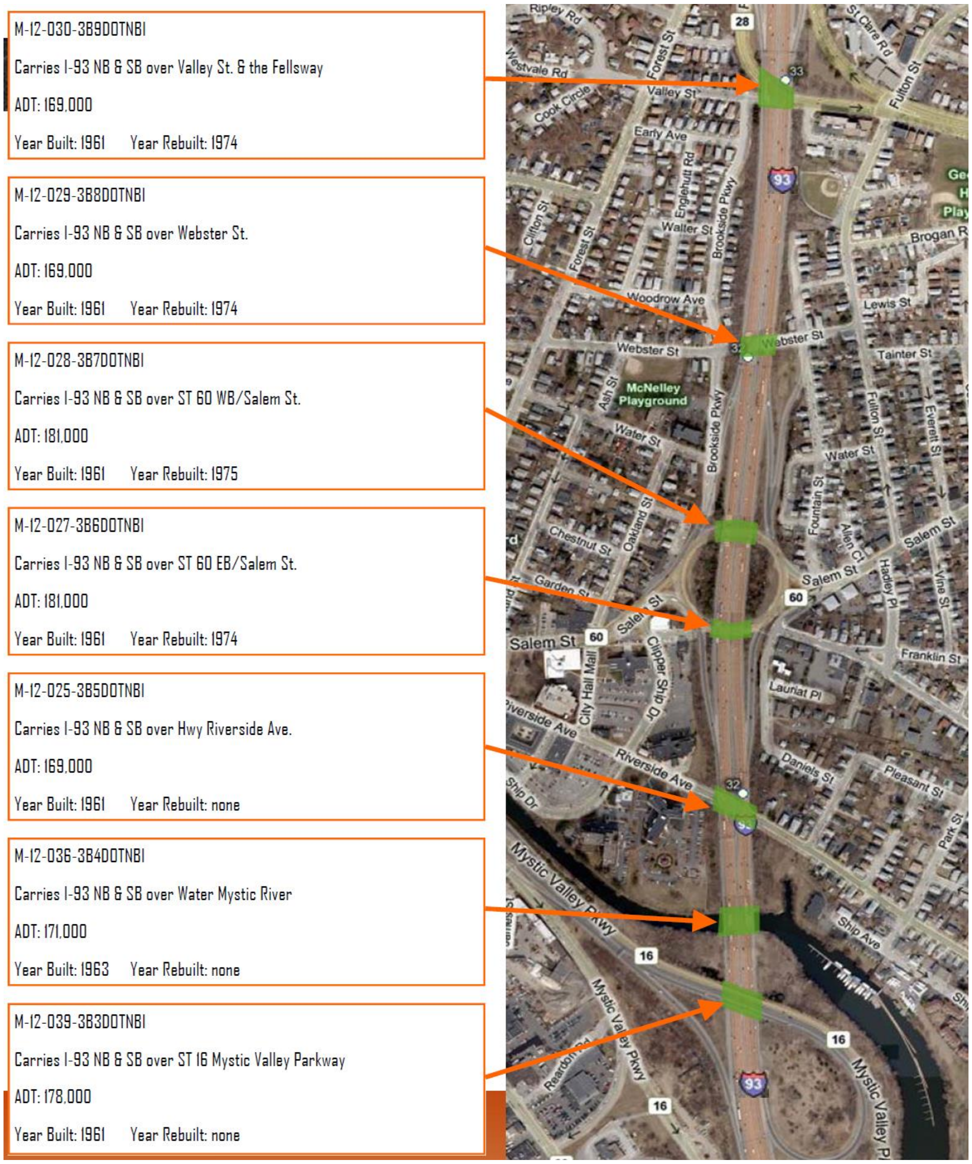


Figure 2. Map. Bridge locations.

During a scheduled highway resurfacing project in 2008, MassDOT observed significant deterioration in the condition of the concrete bridge decks (see Figure 3). The decks were in poor condition for reasons including old age and chloride intrusion from the use of deicing materials. In addition, the steel beams that support the bridge deck were corroded and were painted with lead paint. However, the substructures (foundations and piers) were in good condition and needed only minor repairs. **Error! Reference source not found.** presents condition ratings of he bridge deck, substructure, and superstructures recorded during a 2010 bridge inspection.

Figure 3. Photo. Deck condition on I-93 over Valley Street prior to construction.

Table 1. Bridge condition ratings from 2010 inspection.

Bridge Location	**Year Built**	**2010 Bridge Condition Rating**		
		Deck	**Superstructure**	**Substructure**
I 93 over Riverside Avenue	1961	5	3	5
I 93 over Route 60 WB/Salem Street	1961	5	6	6
I 93 over Route 60 EB/ Salem Street	1961	5	6	6
I 93 over Webster Street	1961	6	7	6
I 93 over Valley Street and Fellsway	1961	5	7	6
I 93 over Route 16 Mystic Valley Parkway	1960	6	7	6
I 93 over Mystic River	1963	5	6	6

PROJECT DESCRIPTION

The I-93 Fast 14 project replaced 14 deteriorated bridge superstructures over 10 weekends using accelerated construction techniques and the D-B project delivery method. The goals of the project were to replace the bridges faster using cutting-edge innovations while keeping the

Interstate and local traffic on the move to minimize impacts to travelers and communities with no compromise in the quality of the constructed product.

The project rehabilitated the bridges by demolishing and replacing the superstructures with prefabricated modular steel elements (PMSEs)—composite units made of two weathering steel beams and a precast concrete deck. Using link slab technology, the composite units provide a jointless deck for each structure. The beams were designed as simple spans with longitudinal post-tensioning to connect the concrete slabs above them. The pier caps were repaired and adjusted as necessary to support the superstructure replacement. The new decks were design with a spray-applied membrane waterproofing and a bituminous pavement overlay. The precast decks had a rough surface to allow vehicular use prior to installing the wearing surface.

The composite units were designed to be erected by crane during short closures of one barrel of I-93—either overnight or on weekends. Traffic crossovers were used to maintain two directions of traffic on the remaining open barrel of I-93. MassDOT issued the D-B notice to proceed in February 2011 and realized substantial completion in August 2011. The ambitious schedule, accomplished with multiple innovations, is expected to revolutionize high volume highway bridge construction in Massachusetts. Using conventional methods, such a project would typically take a minimum of four construction seasons in five construction stages, causing years of unacceptable congestion and safety issues.

MassDOT enhanced safety by installing a new 42-inch-tall median barrier. The new barrier matched the existing median barriers located off of the bridges. The parapets conformed to the current edition of the MassDOT bridge manual.

The horizontal alignment, lane width, lane locations, median shoulder, and median width remained the same before and after construction. To accommodate the new superstructures, only minor profile adjustments were needed, along with a slight widening of the outside shoulder as a result of barrier upgrades.

The following sections provide details of the innovations included in this project.

Accelerated Bridge Construction Techniques

In the planning phase of the project, MassDOT decided to use ABC techniques to replace all 14 bridges on the I-93 corridor. The decision to use ABC was made primarily to reduce the duration of construction to minimize traffic impacts and improve work zone safety. With traditional cast-in-place construction, MassDOT estimated that the project would entail at least five construction stages for a minimum duration of 4 years. High traffic volumes on the I-93 corridor precluded any long-term closure. Furthermore, there were concerns over durability of the existing decks.

During the preliminary engineering phase, MassDOT and its consultants, CME Associates, Inc., conducted an alternative analysis to select a preferred ABC alternative for the project. The following alternatives were considered:

- Alternative 1: Full Bridge Self-Propelled Modular Transporter Bridge Move or Lateral Slide-in—This option was ruled out because the I-93 corridor is a congested area, and it was deemed difficult to do multi-span bridges in a weekend.
- Alternative 2: Precast NEXT Beams—This option was not selected due to span limitations of the NEXT beams. There were constraints with substructure capacities to support higher span-depth ratios. Other roadway geometry issues, including cross slope issues and large skews on several bridges, precluded their selection as well.
- Alternative 3: New Beams with Separate Precast Concrete Decks—A single-span bridge has been constructed this way in New Hampshire; however, this option was ruled out due to concerns with the construction of a four-span bridge in a single weekend. There were skew-related issues with precast decks as well.
- Alternative 4: Modular Steel Stringer/Girder Systems—This option was selected. Each prefabricated unit was made of a composite concrete deck with two weathering steel stringers underneath it. This system is based on a simple span jointless design (i.e., link slab technology) that offered continuous spans with no bolted splices. Figure 4 shows a crane lift of the modular beam/deck system. The modular beam/deck system offered the following advantages for this project:
    - Pre-topped steel beam units were adaptable for complex geometries involving skews and vertical curves. The sections can also be made shallow to accommodate vertical clearances.
    - Since the weights of modular units were same as the existing structure, there were no limitations with substructure capacities and crane lift capacities.

From a design perspective, the compressed schedule was a challenging factor. The appropriate design and details needed to be worked out for each of the 10 work periods, for items including bridge deck closure, diaphragms, crane lifts, and tolerances.

For bridge deck closure, small, medium, and wider pours were considered. The wider pour option with lapped bars and high early strength concrete was selected, as this option allowed for reduced width of precast decks, which in turn helped with transporting and crane lifting. In addition, wider pour also facilitated installation because it allowed more room for splicing of interfering steel bars. Figure 5 shows the wider pour for bridge deck closure. Figure 6 is a schematic diagram of closure pour details including the splicing of interfering steel bars. Each closure pour was designed for 2 feet, 8 inches wide in longitudinal direction and 3 feet wide in the transverse direction. As a precautionary measure, contingency plans were developed for closure pour with 1.5-inch longitudinal pour plates.

Figure 4. Photo. Modular beam/deck system.

Figure 5. Photo. Wider closure pour for bridge decks.

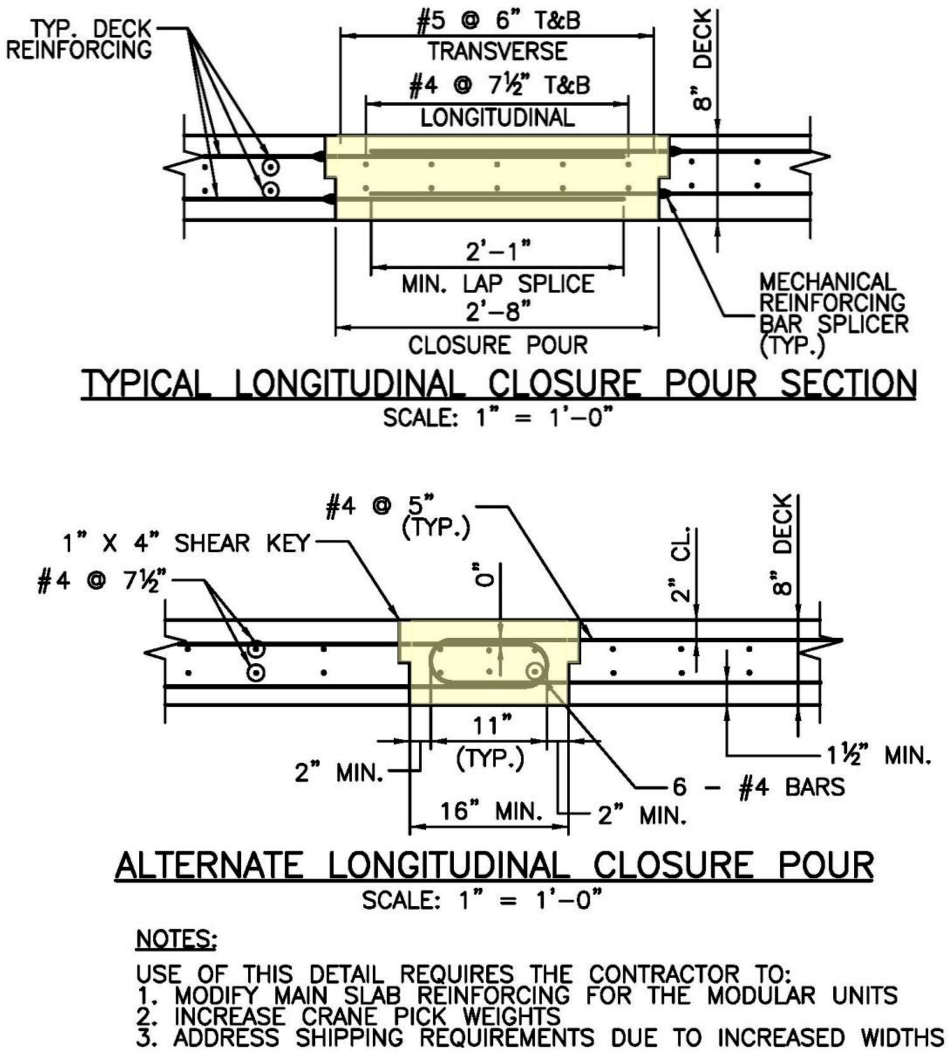


Figure 6. Diagram. Details of longitudinal closure pour.

The steel diaphragms were provided between the steel stringers to provide stability to the bridge decks. The diaphragm layout had to be consistent with MassDOT requirements of a maximum 25-foot spacing. Figure 7 shows the installation of both single and double diaphragms under the closure pour area. In addition, the design and detailing considered potential tolerance issues with precast elements, oversized diaphragm connections, rebar length, and splice requirements.

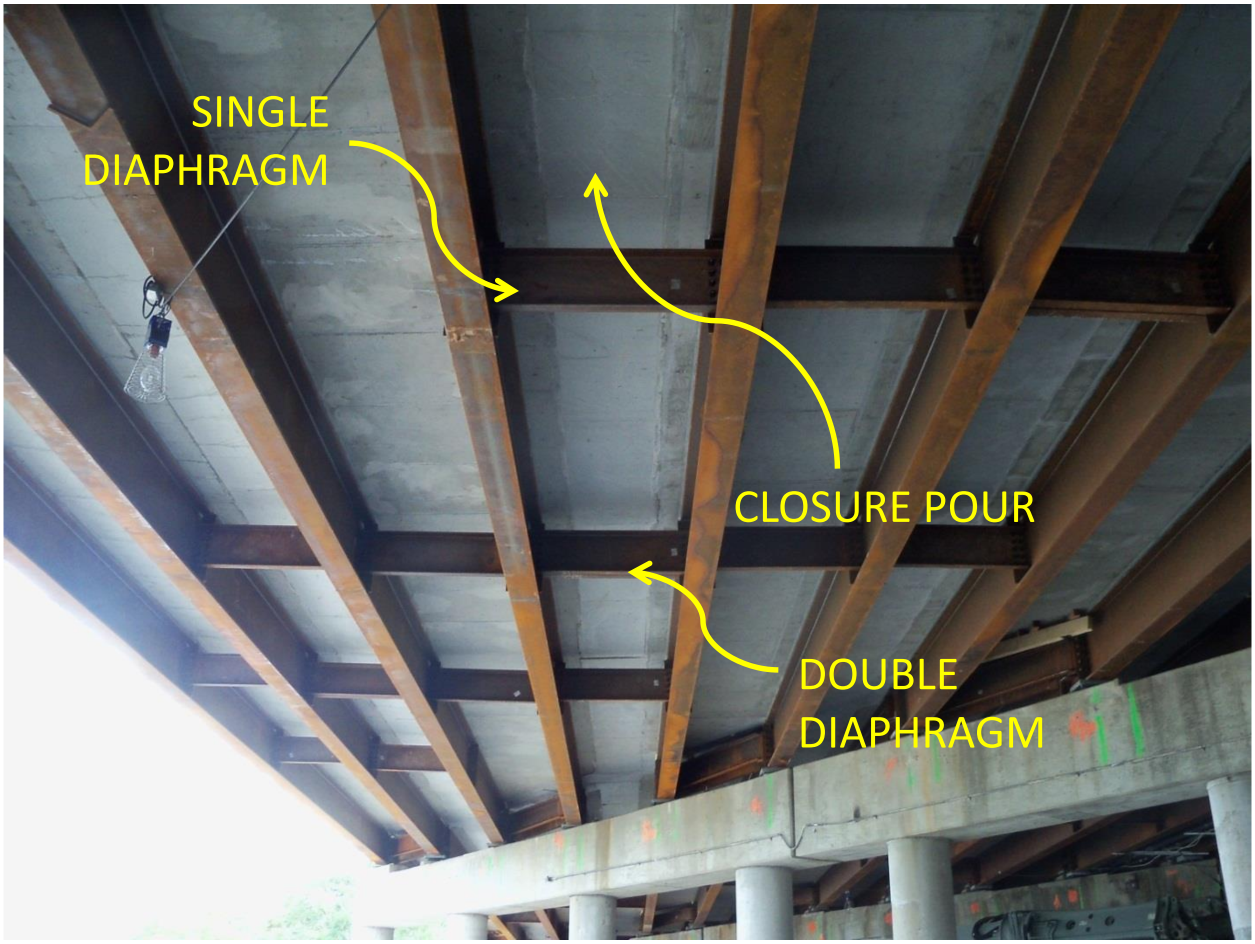


Figure 7. Photo. Use of single and double diaphragms to provide lateral support under the closure pour.

Prefabricated Modular Steel Elements

A total of 252 PMSE units were used for replacement of the 14 bridge superstructures. Each bridge had a deck width of three spans long and six units wide (a total of 18 units per bridge). Each unit had an 8-inch-thick composite concrete deck over two steel girders, and each PMSE unit weighed an average of 50 tons. The length of each unit ranged from 40 to 106 feet, while the width of each unit ranged between 8 feet, 7.5 inches to 11.75 feet. A typical unit measured about 75 feet long by 9.5 feet wide. Each PMSE unit rested on elastomeric bearings and acted as a simple span for dead loads. Figures 8 and 9 present the typical modular layout plan and transverse section of the bridge, respectively.

The steel girders were first fabricated by Structal at its facility in Point of Rocks, Maryland. The steel girders were then transported to the precaster, Jersey Precast Casting Yard, of Hamilton, New Jersey. Upon delivery at the precast facility, each steel member was inspected for material and welding defects. The steel members were then assembled.

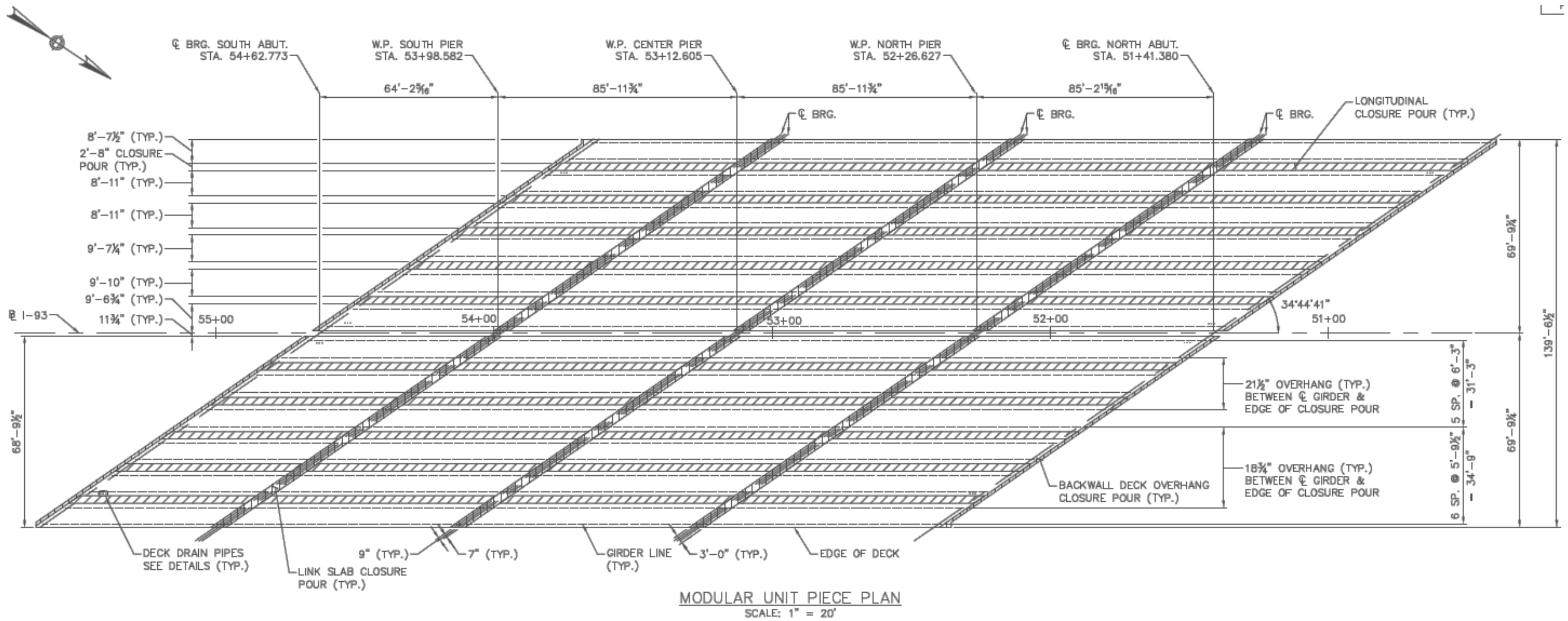


Figure 8. Diagram. Typical modular unit piece plan.

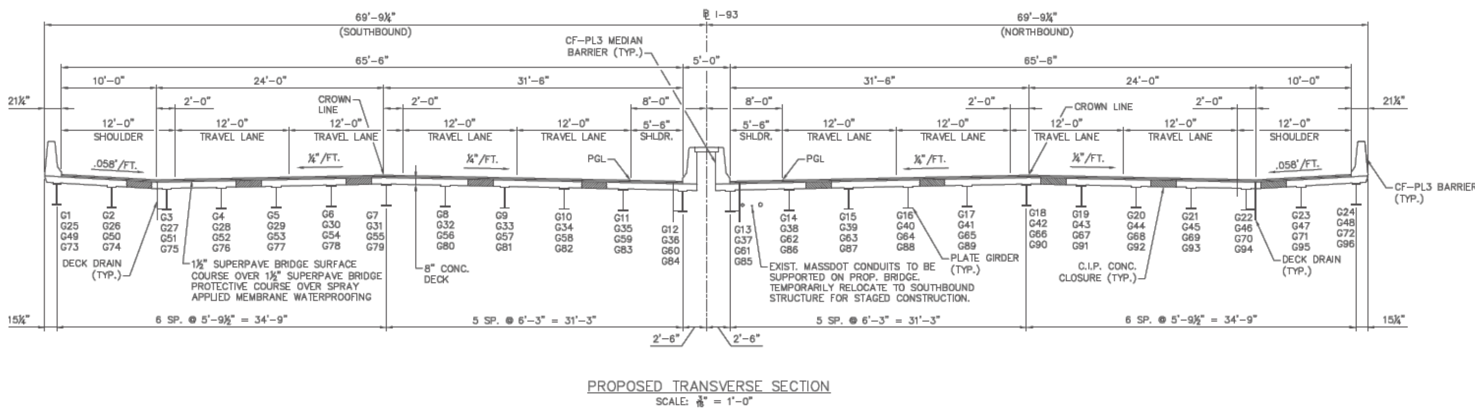


Figure 9. Diagram. Typical transverse section of a bridge.

The steel members are set in line and graded. Diaphragm bolts are fixed, followed by shear stud welding (see Figure 10) and installation of form support angles (see Figure 11).

Following the steel assembly, the girders were transferred to the form tables. The girders were then set in line and graded to provide support to the form table. A typical form table typically supports three PMSE units. Steel frame, rebar mats, and dowel bar splicers are installed before portland cement concrete is placed to form a composite concrete deck. Figure 12 presents a typical form table assembly. Note that the figure shows the steel girders supporting the form tables on either side and the fabrication crew assembling rebars on form tables.

When the concrete in the form table gains adequate strength, the PMSE units are transferred to the curing area. The design strength of concrete to lift the modular unit out of form table was 2,600 psi. Each PMSE unit is water cured for 7 days. Figure 13 shows the water curing of PMSE units at the precast facility.

After 7 days of water curing, the finished PMSE units were transported from the precast facility to a staging area in Wilmington, Massachusetts. The design strength of concrete prior to shipping to the job site was 4,000 psi. Figure 14 shows the transportation of PMSE units to the staging area using truck trailers. The PMSE units were delivered 1 week in advance. Figure 15 shows the storage of PMSE units at the laydown area.

Figure 10. Photo. Shear stud welding.

Figure 11. Photo. Form support angles.

Figure 12. Photo. Typical form table assembly.

Figure 13. Photo. Water curing of PMSE units at the precast facility.

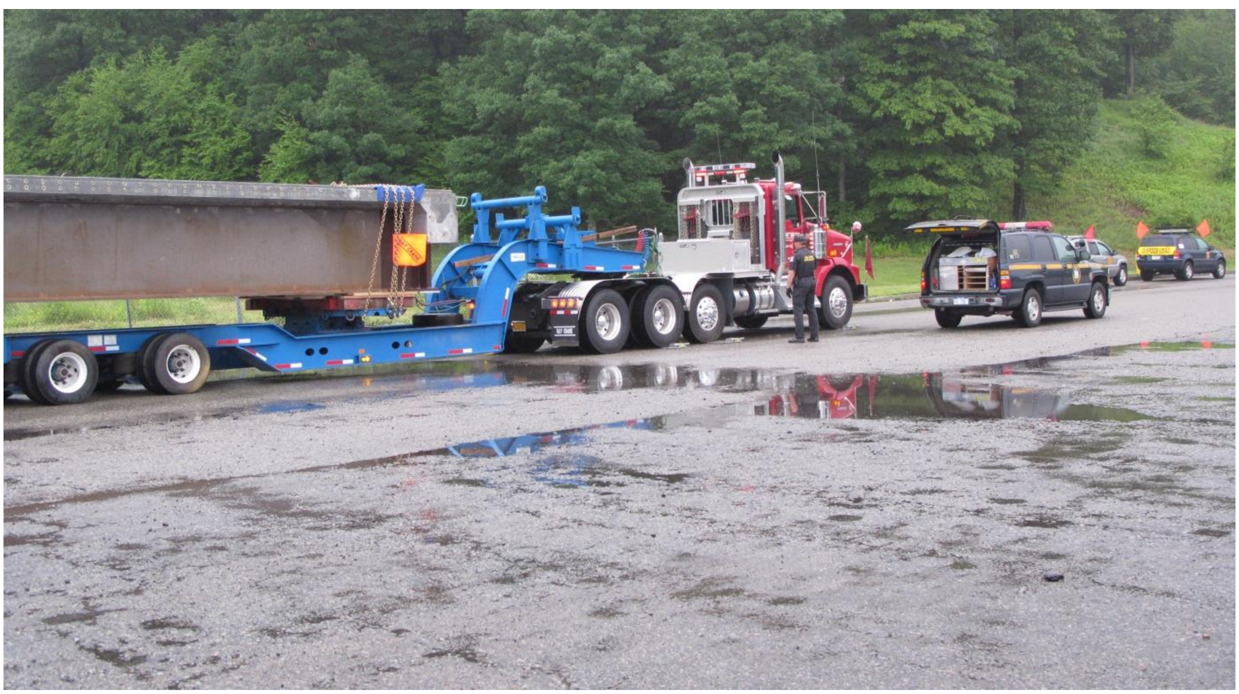


Figure 14. Photo. Transportation of PMSE units to staging area.

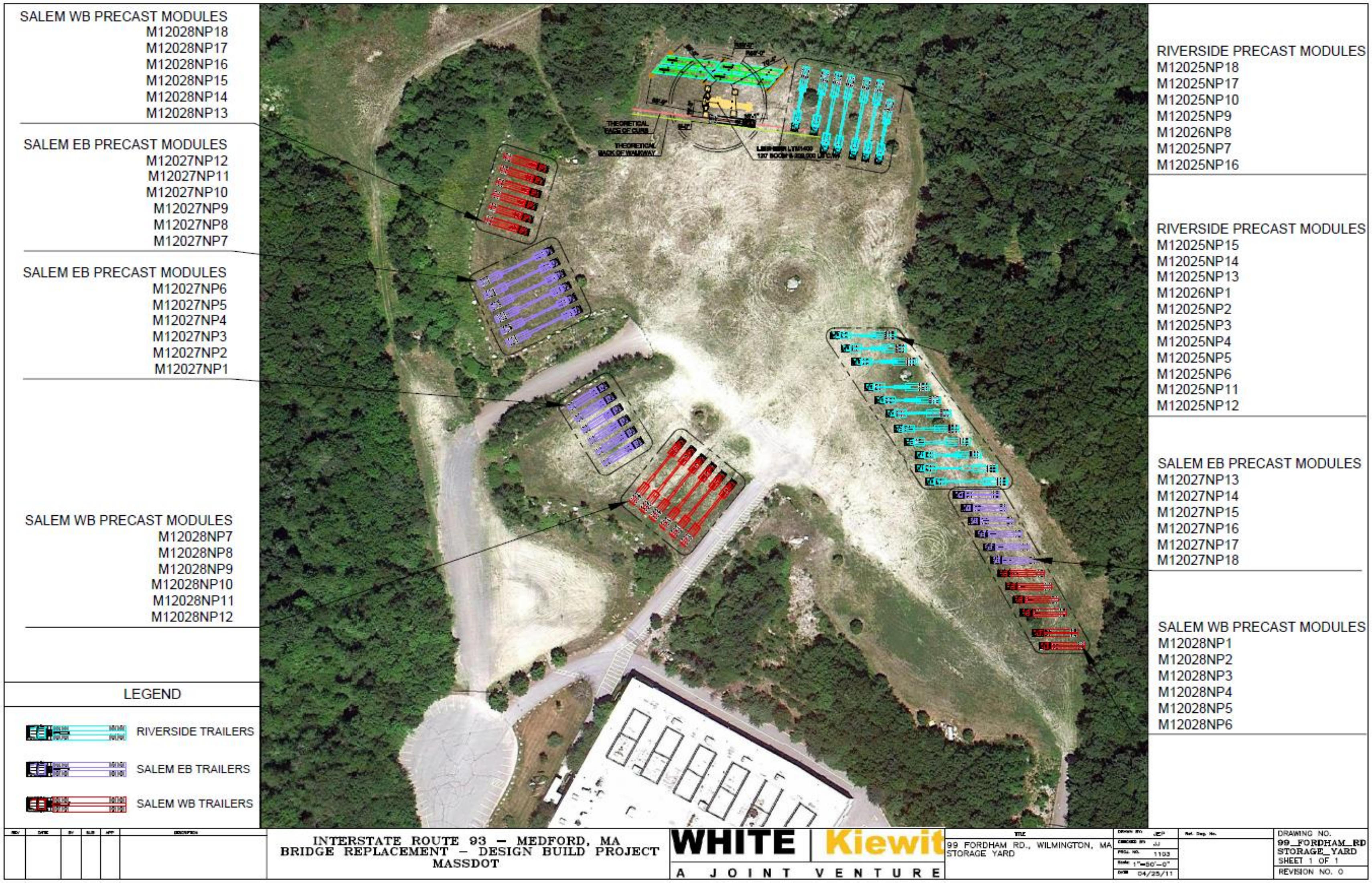


Figure 15. Photo. Storage of PMSE units at laydown yard.

Prior to the erection of PMSE units, the bridge substructures underwent minor repair work to support the new superstructures. A total of 684 beam ends were de-lead, shored, jacked, and coped to provide access for beam seat work (see Figure 16). Similarly, 1,008 beam sets were prepared with new pedestal to support the new superstructures (see Figure 17).

Figure 16. Photo. Shoring and coping of beam ends.

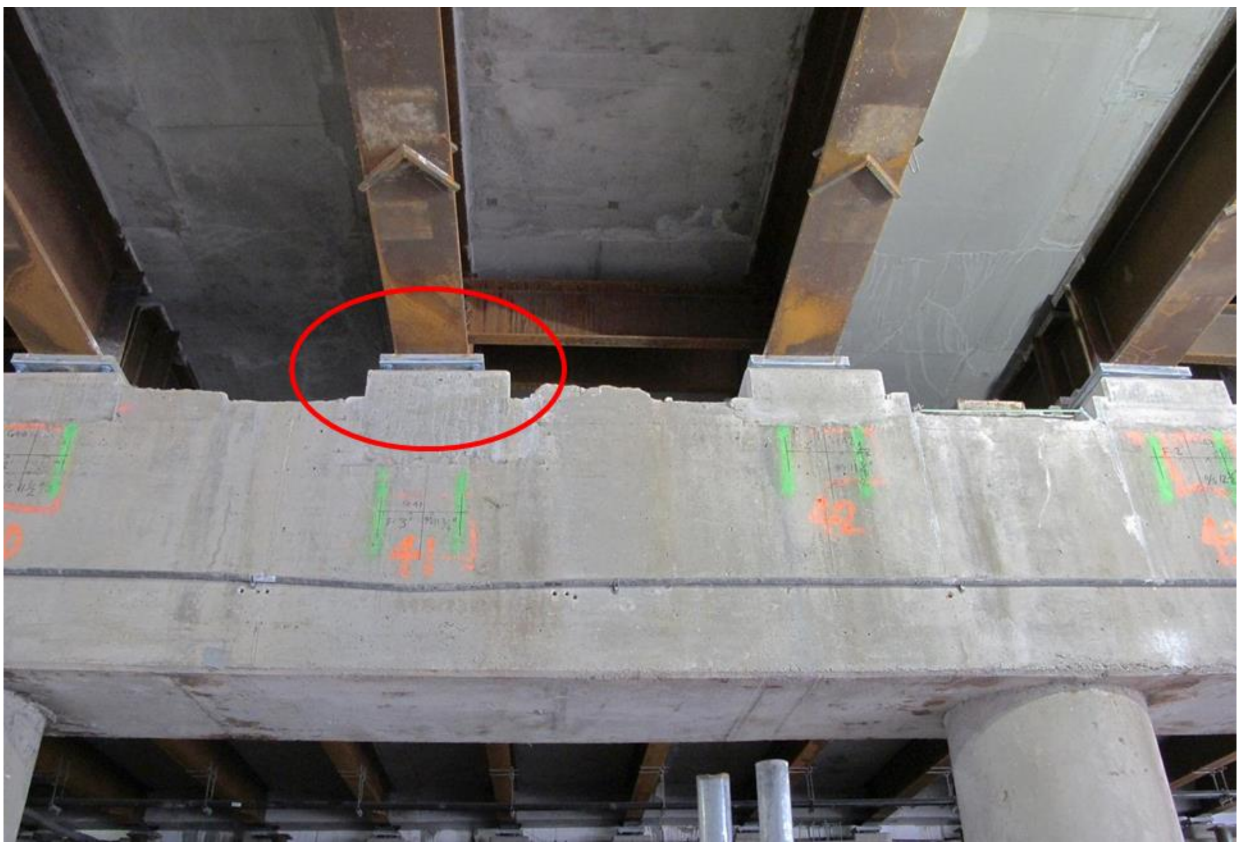


Figure 17. Photo. Pedestal placement for beam seats.

The existing bridge superstructure was demolished on the Friday night during each weekend closure. Figure 18 shows the demolition of the superstructure of an existing bridge. Figure 19 shows the clean-up and preparation activities on a Saturday morning after the demolition of the existing bridge superstructure.

Figure 20 shows the placement of PMSE units on the substructure. Each PMSE unit was rested on elastomeric bearings. The 32-inch bridge deck closures between two PMSE units were poured with high early or rapid strength concrete. The concrete was designed to reach a target compressive strength of 2,000 psi within 4 hours of placement. The rebars from two adjacent units were connected using dowel bar splicer during the closure pour.

The rapid strength concrete required immediate curing and protection. Figure 21 shows the curing and protection of concrete poured at the bridge deck closures. Shortly after the curing of closure concrete was complete, the concrete samples were tested at the mobile lab to ensure the attainment of minimum strength before the bridge was opened to traffic.

The follow-up work included the installation of cast-in-place parapet walls, application of waterproofing membrane, and placement of 3 inches of hot mix asphalt overlay.

Figure 18. Photo. Demolition of existing bridge superstructure.

Figure 19. Photo. Clean-up and preparation activities.

Figure 20. Photo. Erection of PMSE units at night.

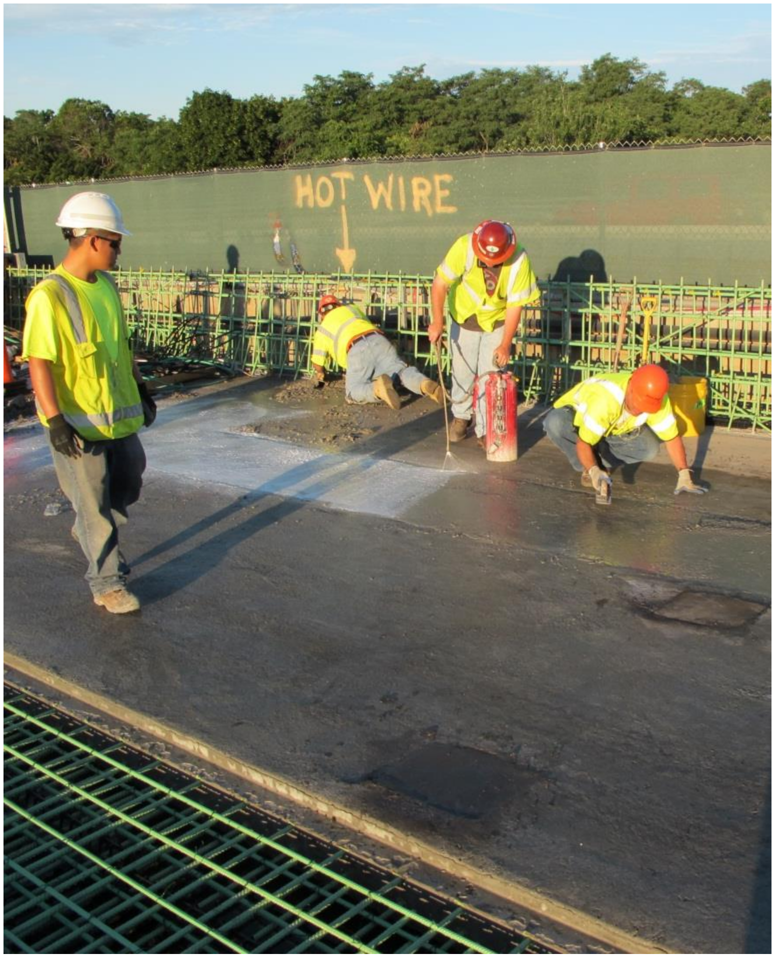


Figure 21. Photo. Curing and protection of concrete at bridge deck closure pours.

Design-Build Project Management

Massachusetts statutes allow for the use of D-B on public works projects with values in excess of $5 million, and particularly, on Accelerated Bridge Program projects of any value. This project was delivered under MassDOT's Accelerated Bridge Program.

The goals of this project, particularly the need for expedited delivery, clearly indicated the preference for D-B as the project delivery method. The choice of D-B method provided both flexibility and cost certainty to MassDOT. Since the services for both design and construction are procured through a single contract, D-B facilitates a higher level of integration between both phases. In addition, due to the extent and magnitude of traffic impacts, this project provided opportunities for incorporating innovative and creative inputs from the Design-Builder into the project development process.

MassDOT outlined the reasons for using D-B for this project:

- Need for an aggressive schedule required.
- Completion date must be fixed.
- Well-defined project scope.
- Project complexity.
- Need/opportunities for innovation
- Risks can be managed by others.
- Limited agency resources.

Project Timeline and Milestones

The project was initiated in August 2010. The request for proposal was out in late October 2010. After the procurement of the D-B contract was complete, MassDOT issued the notice to proceed to the Design-Builder on February 7, 2011. The preparatory work began the week of March 14, 2011. The superstructure replacement of all 14 bridges occurred over 10 weekends between June 3 and August 15, 2011. All work related to the bridge and highway was complete in November 2011. **Error! Reference source not found.** lists the milestones of the I-93 Fast 14 project.

Table 2. I-93 Fast 14 project milestones.

Date	Project Milestone
9/20/2010	First Public Information Session for Bidders
9/27/2010	Second Public Information Session for Bidders
10/1/2010	Letters of Interest from Contractors Due
10/4/2010	Issue request for Qualifications
10/6/2010	Third Public Information Session for Bidders
10/19/2010	Fourth Public Information Session for Bidders
10/22/2010	Statement of Qualifications from Contractors Due
10/29/2010	Post Short List of Contractors
11/1/2010	Issue Request for Proposal
11/10/2010	Mandatory Pre-bid Meeting for Contractors
12/22/2010	Technical Proposals from Contractors Due
1/11/2010	Oral Presentations from Contractors
1/19/2010	Bid Openings and Apparent Selection
2/2/2011	Issue Notice to Proceed
3/14/2011	Preparatory Construction Begins
4/14/2011	Design Public Hearing
6/3/2011	WEEKEND CONSTRUCTION BEGINS
6/3-6/6/2011	First Weekend: Riverside Ave
6/10-6/13/2011	Second Weekend: Salem Street E+W
6/17-6/20/2011	Third Weekend: Route 16
6/24-6/27/2011	Fourth Weekend: Mystic Valley River Center Span + Valley street/Fellsway
7/8-7/11/2011	Fifth Weekend: Webster Street + Mystic River Back Span

Date	Project Milestone
7/15-7/18/2011	Sixth Weekend: Salem Street E+W
7/22-7/25/2011	Seventh Weekend: Mystic River Center Span + Valley Street/Fellsway
7/29-8/1/2011	Eighth Weekend: Webster Street + Mystic River Back Span
8/5-8/8/2011	Ninth Weekend: Riverside Ave
8/12-8/15/2011	Tenth Weekend: Route 16
8/19-8/22/2011	Contingency Weekend 1
8/26-8/29/2011	Contingency Weekend 2
8/29/2011	Contractor Milestone 1: Complete the erection of all replacement superstructure units; all superstructures replaced.
10/14/2011	Contractor Milestone 2: Substantial completion of the 14 superstructures, including additional work such as parapet wall construction, permanent barrier construction, and paving
11/15/2011	Contractor Milestone 3: Final Acceptance of the 14 bridges; all bridge replacement work items were complete, including lighting, site clean-up, etc.
6/24/2012	Contractor Milestone 4: Complete Noise Barrier
7/2/2012	Contractor Milestone 5: Final Acceptance and Project Completion

Work Zone Traffic Management

Existing Conditions

With four lanes in each direction, the I-93 roadway section in the Medford area carried between 169,000 and 181,000 vehicles per day. Figure 23 presents the existing roadway configuration on I-93. It appeared that any reduction in lane capacity during construction would lead to severe congestion. Regardless of whether traditional staged or accelerated construction methods were used, MassDOT's plan was to use counter-flow crossover for traffic maintenance (see Figure 23), which would facilitate full closure in one direction while allowing use of the opposite direction to provide two lanes each for both northbound and southbound traffic in a single barrel.

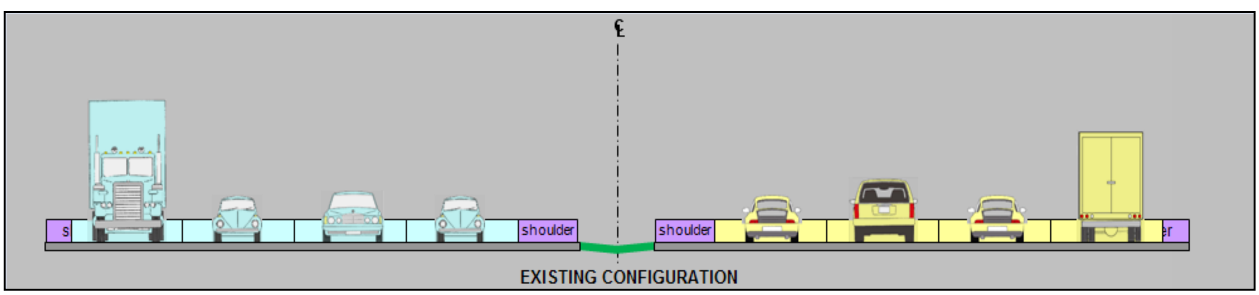


Figure 22. Diagram. Existing roadway configuration on I-93.

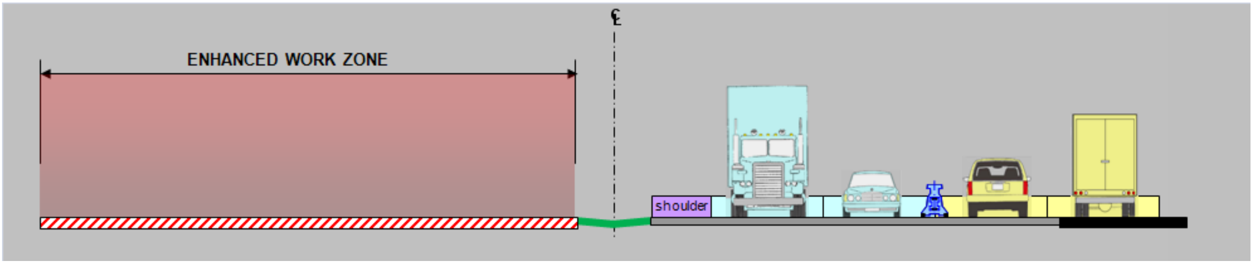


Figure 23. Diagram. Proposed counter-flow crossover for traffic maintenance on I-93.

In the preliminary design phase of the project, MassDOT conducted an evaluation of historical traffic count data of only summer months to study the possible impacts of lane reduction. Reducing the number of lanes from four to two would provide an estimated capacity of 2,960 vehicles per hour, which would be fairly adequate for the I-93 peak-hour traffic demand during weekends; however, with this smaller difference between roadway capacity and traffic demand, a single traffic incident can trigger potentially significant traffic disruptions and unsafe conditions. Therefore, some threshold level of traffic diversion was deemed necessary to effectively manage the traffic flow on I-93.

Furthermore, it was anticipated that the construction on I-93 would encourage local traffic to divert and use other local roadways, including Route 1, Route 16, Route 38, Route 60, Route 128/95, I-495, and I-90. The potential diversion of I-93 traffic would impact the existing traffic conditions significantly on these already congested local routes and require retiming of traffic signals on these routes. A majority of traffic signals along these roadways are under the control of local and other State agencies, and MassDOT would have had to undertake significant coordination activities with these agencies to retime the traffic signals.

Traffic Management Goals

MassDOT outlined the following goals for effective traffic management on this project:

- Use of ABC to reduce the duration of construction.
- Make work zone safety is a priority.
- Minimize traffic impacts to motorists and local communities.
- Stress need to encourage route diversion.
- Effectively communicate travel delays and detour routes to the public at large.
- Sell the overall benefits of ABC.

Traffic Working Group

To achieve the above-mentioned goals, MassDOT established a Traffic Working Group (TWG) to develop strategies, discuss alternatives, coordinate with other stakeholders, and review all associated activities. The TWG consists of members from MassDOT, its preliminary design consultant, Vanasse Hangen Brustlin, Inc. (VHB), and other stakeholders including State police, local police, local fire department, department of public works, and transit agencies. Various activities undertaken by the TWG are summarized as follows:

- August 25, 2010 – First internal meeting of the traffic team from MassDOT.
- September 23, 2010 – Meeting with Medford Major Michael McGlynn and city officials to brief them on the project scope and potential impacts.
- September 30, 2010– Kick-off meeting of the TWG.
- March 30, 2011 – First tabletop exercise for project contingency planning.
- May 5, 2011 – Incident action plan review for test barrier crossover deployment.
- May 23, 2011 – Weekend 1: Riverside Avenue incident action plan review.
- May 25, 2011 – Second tabletop exercise to drill final contingency plans.

MassDOT held as many as 10 working group meetings prior to the first weekend closure.

Traffic Management Plan

MassDOT used the following specific strategies to effectively manage work zone traffic and minimize impacts to motorists and local communities:

- During each weekend closure, I-93 was restricted to two lanes in each direction, from Friday night at 8 p.m. until Monday at 5 a.m. (at the latest). Traffic was diverted to the opposite side via crossover, and full access was provided to one barrel of I-93 for bridge superstructure replacement.
- I-93 remained accessible for local use, where feasible, with all on and off ramps opened on the active side of the highway.
- Traffic diversion from I-93 to alternate routes was encouraged through outreach activities to achieve a desirable level of demand reduction on I-93.
- Route 28/Fellsway served as the primary local access detour route, while Route 16 (Mystic Valley Parkway), Route 38 (Mystic Avenue), Route 60 (Salem Street), and Riverside Avenue provided alternate detour travel routes.
- MassDOT took control of 16 traffic signals, conducted an inventory of the key signalized intersections within the project area, and prepared a progression timing plan for each location.
- MassDOT deployed several strategies for traffic operations, demand management, and incident management, including a real-time traffic management (RTTM) system and mobile command center, to manage traffic impacts.
- MassDOT engaged other stakeholders early in the process, including State and local police, to support traffic operations and follow incident command structure for quick clearance.

Traffic Diversion Requirements

MassDOT anticipated that some rate of traffic diversion would ease the traffic flow on I-93 during the weekend closures. The agency conducted a spreadsheet-based traffic demand-capacity analysis to estimate delay times and queue length with various diversion rates expected during a weekend closure.

Error! Reference source not found. and **Error! Reference source not found.** present the timated queue length and average delay with various diversion rates expected during a weekend closure for I-93 northbound and southbound traffic, respectively. As indicated in the tables, achieving a diversion rate of 15 percent in the northbound direction would ease the I-93 traffic to manageable levels. Similarly, for the southbound direction, achieving a diversion rate of 35 percent would ease the traffic to manageable levels.

Based on this analysis, MassDOT established traffic diversion goals of 15 and 35 percent for the northbound and southbound traffic, respectively, to achieve desirable performance levels during the weekend closure.

Table 3. Diversion factors for I-93 northbound traffic during the 55-hour weekend closure.

Day	Diversion Rate (Percent)	Queue Length (miles)	Average Delay (minutes)
Saturday	0	20	172
	10	11	94
	20	3	29
	30	0	0
	40	0	0
	50	0	0
Sunday	0	18	158
	10	9	80
	20	2	15
	30	0	0
	40	0	0
	50	0	0

Table 4. Diversion factors for I-93 southbound traffic during the 55-hour weekend closure.

Day	Diversion Rate (Percent)	Queue Length (miles)	Average Delay (minutes)
Saturday	0	43	460
	10	31	327
	20	19	206
	30	9	100
	40	1	15
	50	0	0
Sunday	0	47	512
	10	29	313
	20	19	202
	30	9	94
	40	1	8
	50	0	0

Traffic Control – Crossovers and Movable Barriers

I-93 was restricted to two lanes in each direction using a 4.3-mile crossover starting Friday night at 8 p.m. and ending no later than 5 a.m. on Monday. While all on and off-ramps on the active side of the highway remained open, one travel lane was provided for local access where possible to ramps on the closed side of the highway. Two emergency access points were assigned in the work zone.

The crossover was designed in accordance with Manual on Uniform Traffic Control Devices (MUTCD) standards. The crossovers were designed for a speed of 65 mph while accommodating shifting tapers and curve radii of the roadway. The crossovers were also designed to minimize conflicts with existing elements such as bridge piers, interchanges, and sign bridges. Figure 24 presents the schematic of the crossover configuration on I-93.

Figures 25 through 28 illustrate the installation and use of movable barriers. Moveable barriers were used in the crossovers to channelizing devices to separate opposing vehicular traffic, as well as in providing access to ramps and at emergency access points. Movable barriers were particularly used to provide positive protection to run counter-flow traffic and also increased efficiency in the deployment of a Quick Change® barrier system. These barriers can be installed quickly at speeds up to 5 mph, creating zipper lanes and work spaces in a matter of minutes.

In this project, movable barriers were installed for an approximate length of 22,715 feet, or 4.3 miles. This includes 2,015 feet of barriers for the northern crossover, 1,450 feet of barriers for the southern crossover, 18,250 feet of contra-flow distance between the two crossovers, and 1,000 feet (i.e., 250 feet each) on each approach and departure end for tapers and protection. By including 4,680 feet of taper on either side of crossovers, the total impact length of movable barrier installation was 32,075 feet, or about 6 miles.

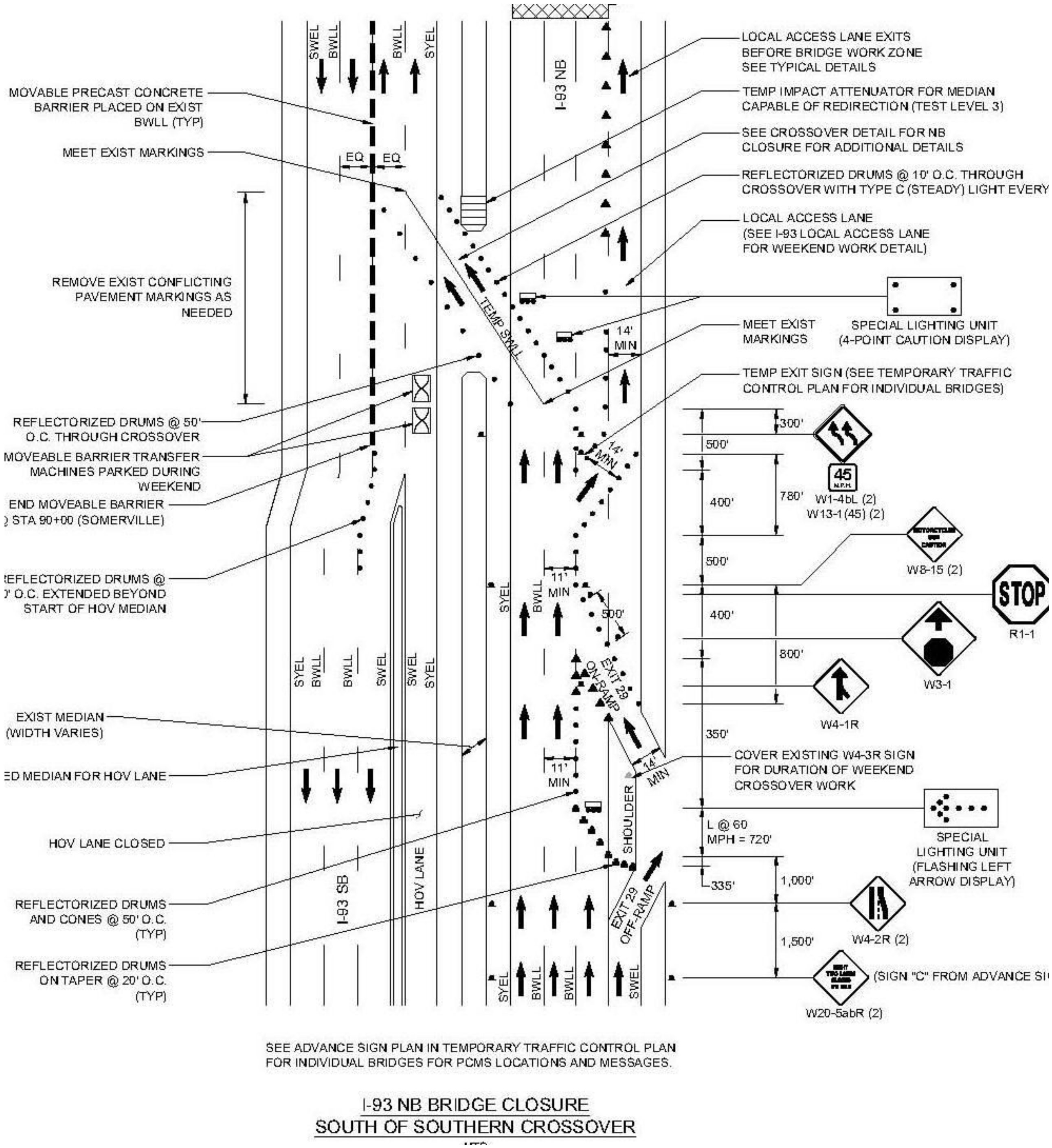


Figure 24. Diagram. Crossover configuration on I-93.

Figure 25. Photo. Installation of movable barriers.

Figure 26. Photo. Movable barriers facilitating counter-flow traffic at crossovers.

Figure 27. Photo. Movable barriers providing access at ramps.

Figure 28. Photo. Movable barriers at emergency access points.

Detour Routes

Figure 29 shows the potential traffic impact area in the vicinity of the project location. As indicated by the different colors on the map, the magnitude of traffic impacts varied based on the proximity to project location:

- Yellow Zone—For travel within the area just outside of Route 128 to 495 and beyond.
- Metro Zone—For travel within the metropolitan area, but not within Medford or the abutting communities.
- Core Zone—For travel within the work zone, Medford, and abutting communities.

MassDOT developed detailed transportation operation strategies for each traffic impact zone.

Figure 29. Map. Traffic impact area around the project location.

Yellow Zone – Greater Boston Area

MassDOT proposed several strategies for travelers in the Greater Boston area:

- Commuter rail and bus through MassDOT's MassRIDES, Massachusetts Bay Transportation Authority (MBTA), and other transit options.
- Free parking at the Anderson Regional Transit Center.
- Alternative routes for road users traveling north and south of the Greater Boston area, including Route 2, Route 9, Route 1, Route 24, Route 25, I-95, I-195, and the Mass Turnpike (I-90).

Metro Zone – Metropolitan Area

MassDOT proposed several strategies for travelers in the metropolitan area to avoid the I-93 construction area in Medford:

- Commuter rail and bus through MassRIDES, MBTA, and other transit options.
- Free parking at the Anderson Regional Transit Center.
- Alternative routes for motorists traveling in the metropolitan area, including Route 128, Route 24, Route 9, Route 3, I-90, and I-95.

Core Zone – Medford Area

In the Medford area, during each weekend closure, the following streets near the project location were closed at 8:00 p.m. on Friday and fully reopened by 5:00 a.m. on the following Monday:

- June 3-6, 2011: Riverside Avenue was closed.
- June 10-13, 2011: Salem Street/Route 60 was closed.
- June 17-20, 2011: Route 16 was closed.
- June 24-27, 2011: Valley Street and Route 28 were closed. Mystic River was closed for nautical travel.
- July 8-11, 2011: Webster Street was closed. Mystic River was closed for nautical travel.
- July 15-18, 2011: Salem Street / Route 60 was closed.
- July 22-25, 2011: Valley Street and Route 28 were closed. Mystic River was closed for nautical travel.
- July 29-August 1, 2011: Webster Street was closed. Mystic River was closed for nautical travel.
- August 5-8, 2011: Riverside Avenue was closed.
- August 12-15, 2011: Route 16 was closed.

Route 28/Fellsway served as the primary local detour route during the weekend closures. Traffic signals along Route 28/Fellsway were modified to accommodate the increased traffic demands. Figure 30 presents a map of the Medford area showing Route 28 and the location of traffic signals that were modified. Depending on the closure, other local routes also served as detour routes.

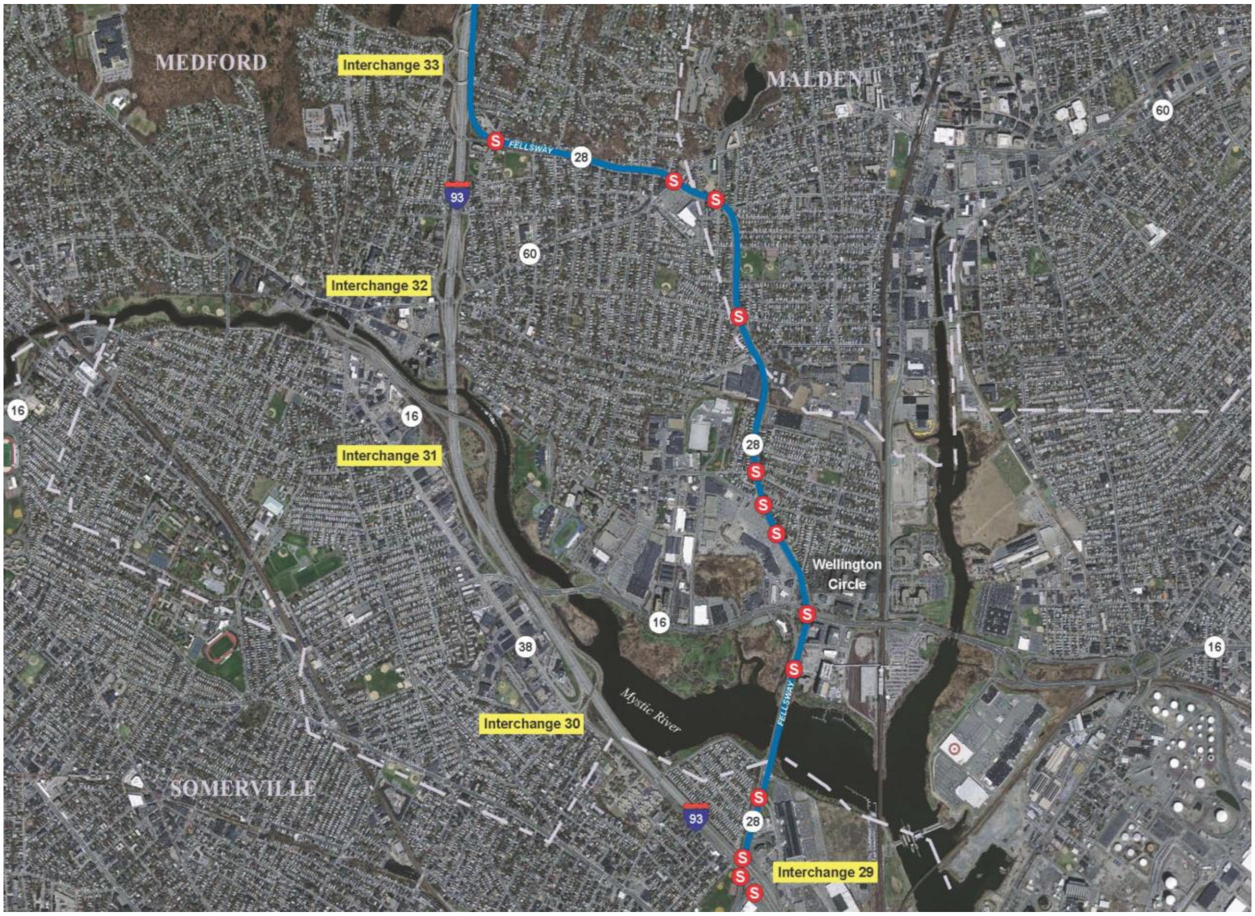


Figure 30. Map. Route 28 (Fellsway) and location of traffic signals.

Work Zone Safety Management

Work Zone Speed Limit

The speed limit in the work zone was restricted to 45 mph. Speed monitoring boards were installed to capture work zone speed, which was shared with State police in real time.

Work Zone Safety

The I-93 work zone was set up with zipper lanes and perimeter fencing to prevent vehicle incursions. Figure 31 shows perimeter fencing installed to prevent rubbernecking of motorists. Figure 32 shows work zone protection measures implemented in this project. In addition, MassDOT installed live cameras using EarthCam to remotely monitor the work activities at the job site.

Figure 31. Photo. Perimeter fencing to avoid rubbernecking.

Figure 32. Photo. Work area protection.

Worker Safety

Several worker safety measures were implemented in this project:

- White-Kiewit JV developed a checklist for reviewing the lift plan.
- White-Kiewit JV coordinated with subcontractors and crane suppliers to ensure worker safety
- Engineering controls, such as guardrails and pre-installed tie-off points and cables, were installed.
- Employees were issued harness and fall protection equipment, Personal Fall Arrest Systems.
- Orientation, training, accountability, and discipline were employed.
- Two full-time project safety managers and four additional project safety managers were employed.

Incident Management and Enforcement

Real-Time Traffic Management

MassDOT implemented an RTTM system in its first large-scale “smart work zone” project. The RTTM provides the project team the ability to monitor traffic and travel conditions in real time. The RTTM system website was easy to use and understand and provided a public face to the agency. The RTTM system included the following smart work zone elements:

- Thirty-five portable changeable message signs (PCMS).
- Four portable camera trailers.
- Sixty-seven traffic sensor trailers.
- Three Bluetooth sensors.
- Computerized Highway Information Processing (CHIPS) operating system.
- Bluetooth travel-time origin and destination.

Figure 33 shows a picture of the RTTM dashboard. Prior to the beginning of construction, MassDOT provided training to its employees on how to use the RTTM system. The agency also provided training to the State police on reading the system and camera operations. MassDOT set up a full-time field operation center that was active during the entire 55-hour closure on each of the 10 weekends. Figure 34 shows the RTTM dashboard on the video wall of the field operation center.

The purpose of the operation center was to coordinate and provide directives on work zone operations such as changing message boards, moving traffic cameras, providing response to work zone incidents, and monitoring travel times on detour routes and I-93 through lanes. Figure 35 shows the nighttime live video feed-in on the RTTM system. The bottom right picture on this figure shows an incident being cleared off to the shoulder at night. Figure 36 presents speed readers and live video feeds on the RTTM system.

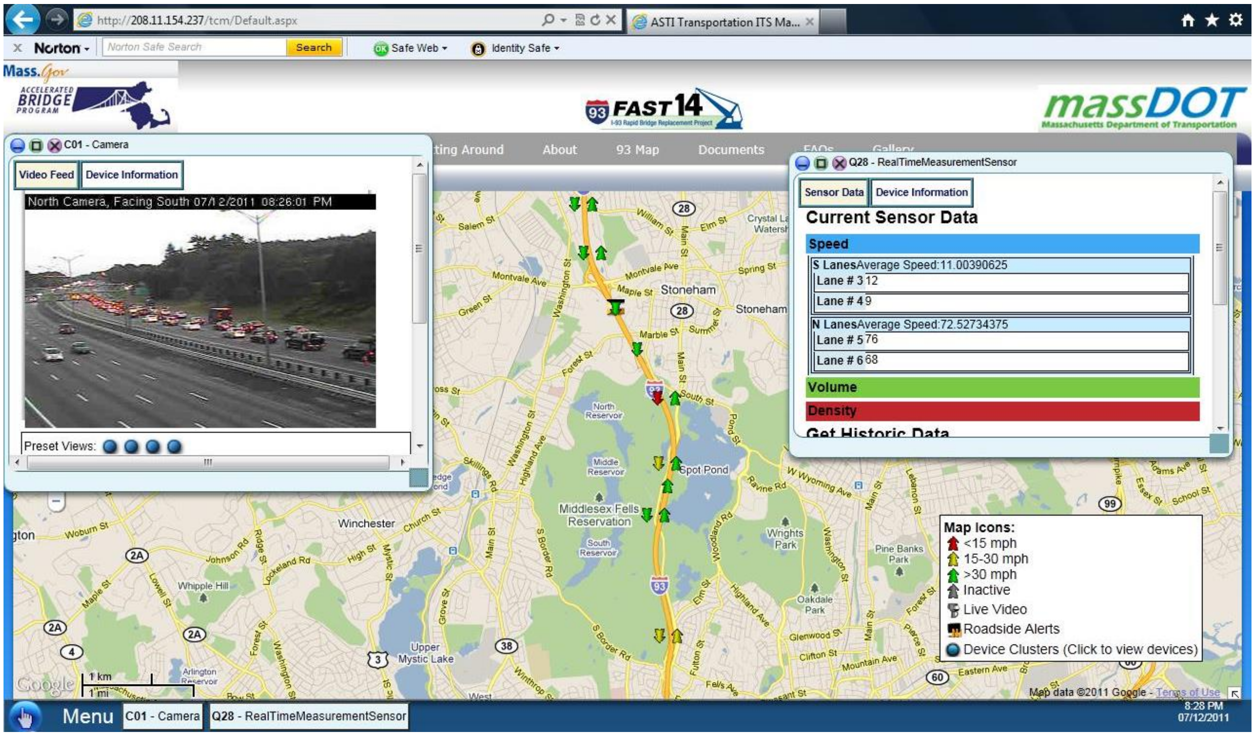


Figure 33. Screen shot. RTTM dashboard.

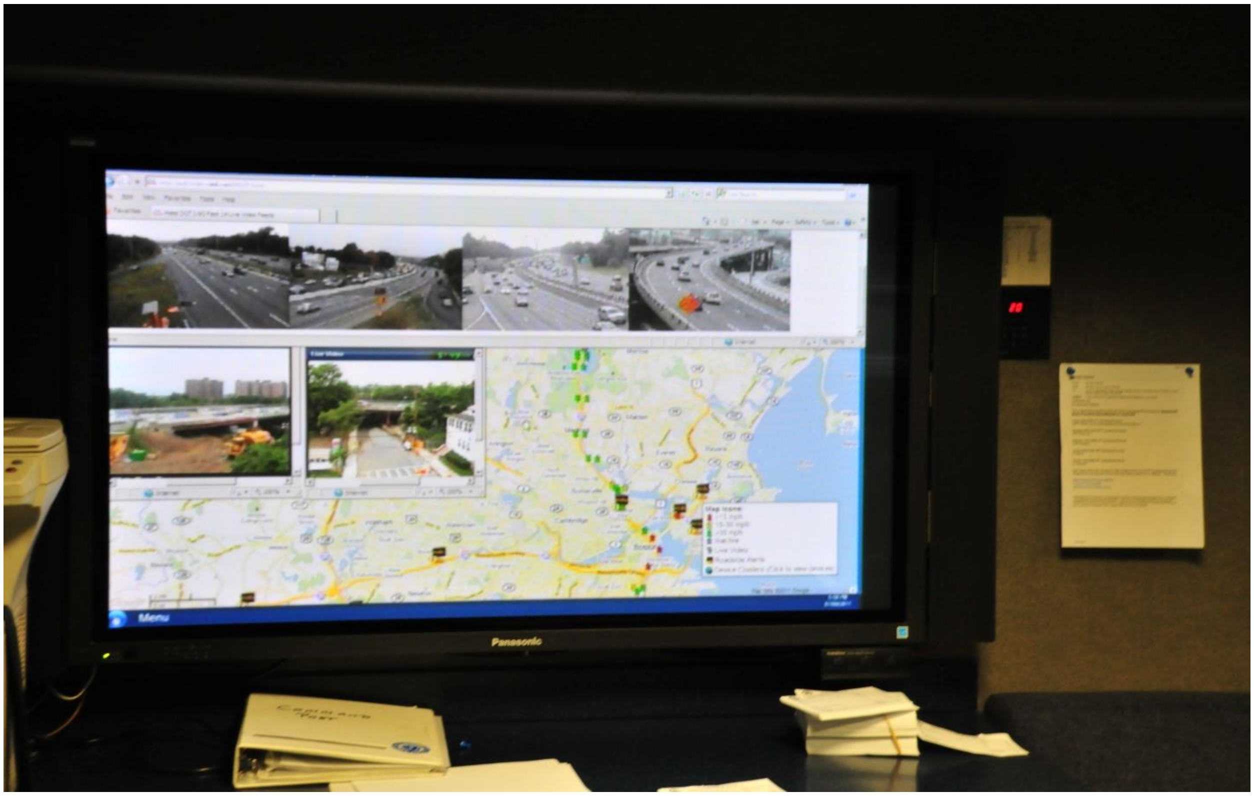


Figure 34. Photo. Video wall at command post.

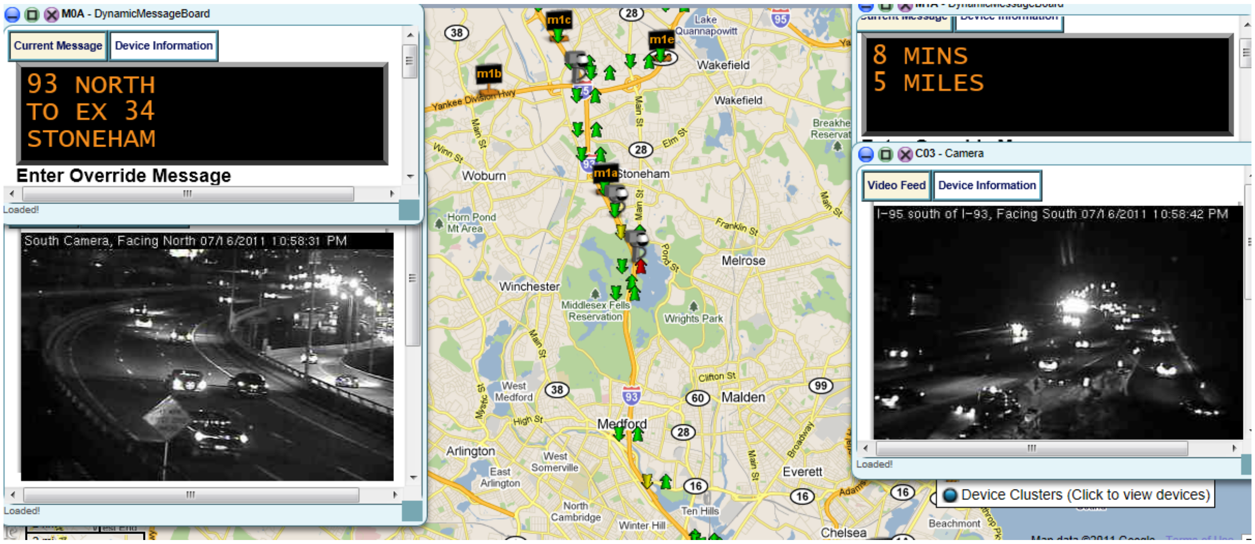


Figure 35. Screen shot. Nighttime live coverage on RTTM system.

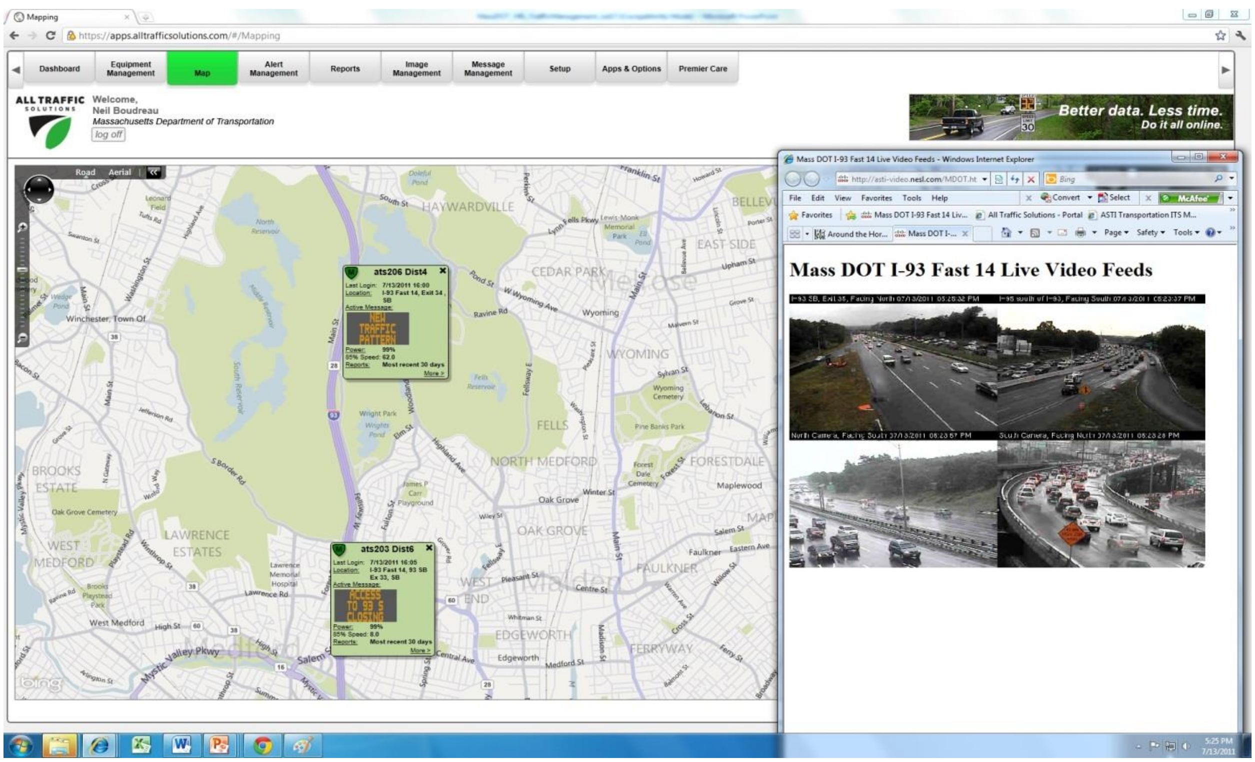


Figure 36. Screen shot. Speed readers and live video feeds on RTTM system.

To communicate effectively with its partners, MassDOT deployed the Massachusetts Interagency Video Information System (MIVIS) that integrated video feeds from remotely installed cameras at key locations. The MIVIS facilitates video feeds to MassDOT, the Boston Transportation Department, the MBTA, and the State police.

MassDOT also deployed six highway advisory radio units at 1700 AM frequency on key alternate routes to broadcast messages, as necessary, based on prevailing travel conditions and delays. Seven to 10 messages were prerecorded for broadcasting. MassDOT also utilized a 511 system for construction updates. The agency sent specific text messages on upcoming construction alerts. In addition, the agency prepared voiceover messages to cover the roadway detour plans.

Incident Command Center

MassDOT decided to treat each weekend work schedule as an incident and began engaging incident responders, such as State police, local police, emergency medical services, and the fire department. As a result, an incident management structure was set up, in accordance with National Incident Management System guidelines, to provide systematic and proactive guidance to all pertinent stakeholders on incident management. Furthermore, the State police had a mobile command center (see Figure 37) that served as the focal point of communications between work zone traffic details, intersection control, construction operations, local police/fire, and regional emergency services. On-site towing service units were deployed to facilitate faster clearing of vehicle breakdowns.

The project team also created simple, site-specific layouts of the traffic management plan for each bridge to assist State police with fixed post assignment and quick emergency response. The command center also had a list of police officers assigned on the job and their exact location of posting for effective response to incidents. This provided the command center staff to whom exactly incident-related calls should be made and the potential backups that would be required, when necessary.

Figure 37. Photo. State police incident command center.

Emergency Response

The I-93 Fast 14 project team held four meetings with 16 local police departments to develop an emergency response plan. The outcomes of these meetings were the Contingency Plan and Incident Action Plan (IAP). Figure 38 shows a draft copy of the IAP prepared for the first weekend closure and replacement of the I-93 bridge over Riverside Street. The project team also conducted a regional meeting with Armstrong Ambulance, a private ambulance company that provides emergency management services in the greater Boston area. The project team also held coordination meetings with representatives from both emergency management and medical services.

The Massachusetts State Police Truck Team Commander held several discussions with the truck team, Coady's, and the Department of Environmental Protection to ensure that an agreement on an expedited version of the hazardous materials clean-up protocol was reached. State Police Troop A worked with the Accident Recon Team to develop an expedited accident reconstruction protocol to ensure very quick clean-up and clearance for any accident involving a serious injury or fatality occurring within the Fast 14 project boundary.

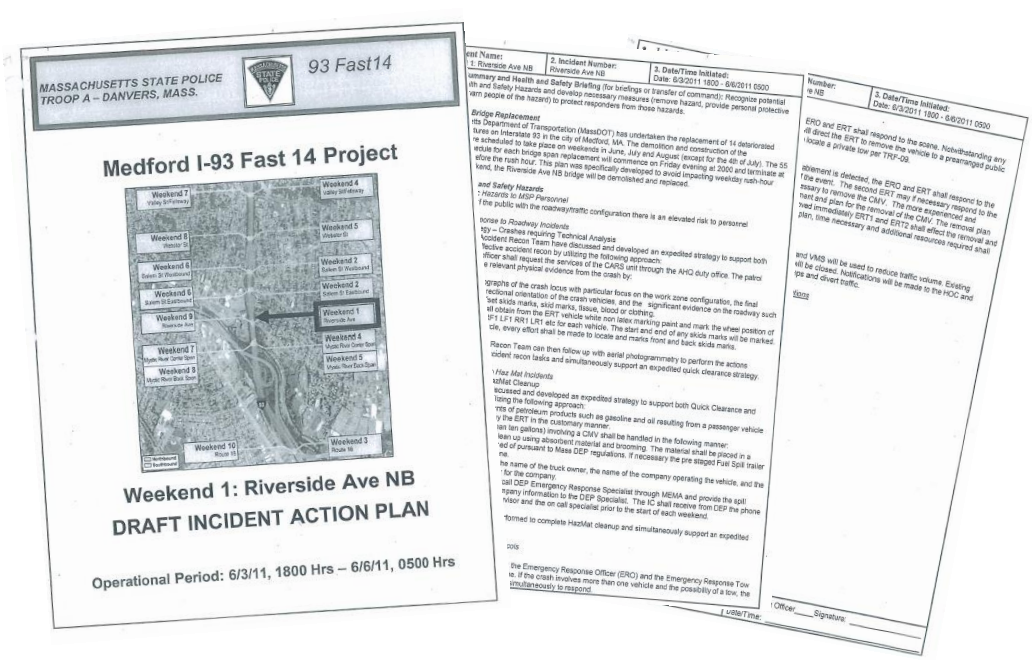


Figure 38. Picture. Draft copy of MassDOT's IAP for the first weekend closure.

Outreach and Communications Plan

Because of the complexity of the project, the aggressive schedule, and the anticipated extent of impacts, "getting the word out" to the people was critical to the success of the project. Outreach and communications efforts were not only a part of best practices for MassDOT from customer service perspective but an absolute necessity to achieve MassDOT's traffic management goals. MassDOT had the following specific goals to achieve through its outreach efforts:

- Manage Interstate traffic with half the capacity each weekend.
- Encourage diversion to alternate routes by providing real-time travel time information.
- Monitor alternate routes to ensure that capacity is available.
- Communicate work schedule to the public effectively.
- Make safety a priority.

MassDOT prepared a Comprehensive Communications Plan (CCP) in September 2010 to communicate to stakeholders (particularly road users and the community at large) the need for the project and the benefits of the innovations to be utilized. The goal of the CCP was to provide the best possible customer service by giving people the information they need to make good decisions. The CCP drew best practices from the Highways for LIFE *Guide to Creating an Effective Marketing Plan* and plans of similar projects, such as Utah's I-15 CORE project.

Concurrently, MassDOT convened as many as 75 meetings with its project stakeholders. The agency reached out to key stakeholders, including elected officials, State legislature, and local governments, in the early months of the project. During the same period, the I-93 Fast 14 project team convened the TWG meetings with the project partners to brainstorm, discuss, and develop traffic management strategies.

The communications team involved the following entities:

- I-93 Fast 14 project team.
- White-Keiwit JV.
- MassDOT.
- MassDOT Public Affairs & Legislative Affairs.
- Information Technology.
- Partners including police agencies, MBTA, MassPORT, Massachusetts Office of Travel and Tourism (MOTT), Office of Outdoor Advertising, etc.
- External networks.

Outreach and communications efforts included the following:

- Dedicated website for the project: http://93fast14.dot.state.ma.us (see Figure 39). This website served as a single stop for all project-related information and updates.
- Email network consisting of more than 1,200 members of the public.
- Press releases and advisories through traditional print media.
- Social media such as Twitter, Flickr, YouTube, and MassDOT blogs.
- Partner websites including MBTA and MassRIDES.
- Email lists of external networks including MassCommute and Red Sox.
- Other resources including fast lane reminders, posters at Massachusetts Registry of Motor Vehicles offices and visitor centers, billboards, posters/signs on buses, highway advisory radio, AM 1700, changeable message boards, 511, State payroll, toll tickets, and toll booth stickers.
- Service advisories for bus route changes.

Figure 39. Screen shot. I-93 Fast 14 website.

Incentive/Disincentive Clauses

MassDOT introduced incentive/disincentive clauses in the D-B contract to encourage on-time (or early) completion. The contractor was eligible for $7 million of incentive payments if all three milestones related to the bridge replacements were achieved on or before the scheduled dates. The milestones and associated incentive/disincentive payment mechanisms are as follows:

- *Milestone 1: Completion of Superstructure of 14 Bridges*. The contractor must open all weekend shutdowns by 5:00 a.m. on Monday in order to obtain the maximum incentive of $6.45 million. This milestone stipulated that all 14 bridges must be opened before September 2, 2011.
    - Incentive payments were designed based on how many weekend shutdowns the contractor opened (or failed to open) the entire roadway (all four lanes) to traffic by 5:00 a.m. Monday. The contractor would receive the maximum incentive

amount when the roadway was opened to traffic on time on all weekend shutdowns. No incentive would be if paid if the contractor failed to open the roadway on time on three or more weekend shutdowns. **Error! Reference source ot found.** presents the incentive payment schedule for Milestone 1.

  - Disincentives were designed based on how long the contractor took to open all four lanes to traffic on Monday. Failure to open all four lanes to traffic by 5:00 a.m. on a Monday would cost the contractor a disincentive of $450,000. Additional disincentives were to be applied in 15-minute increments to a maximum of $1,150,000 for delays in opening the roadway on any weekend shutdown. Disincentives would accumulate up to a maximum of $6.45 million for a total delay of 5.61 hours over six weekends. **Error! Reference source not ound.** presents the disincentive schedule for Milestone 1.

- *Milestone 2: Substantial Completion*: "Substantial completion" was defined as the completion of Milestone 1 plus all remaining work associated with the roadway and bridges, except for the sound barriers, by October 15, 2011. The incentive/disincentive payment available for Milestone 2 was $450,000.

- *Milestone 3: Final Acceptance*. This is defined as the final Acceptance of all 14 bridges by MassDOT for an incentive/disincentive payment of $100,000 by November 15, 2011.

Table 5. Incentive payment schedule for Milestone 1.

Scenario	Incentive Reduction	Incentive Payment
All four lanes of all weekend shutdowns opened to traffic by 5:00 a.m. Monday	No penalty	$6,450,000
Failure to open all four lanes to traffic by 5:00 a.m. on Monday once	50%	$3,225,000
Failure to open all four lanes to traffic by 5:00 a.m. on Monday twice	25%	$1,612,500
Failure to open all four lanes to traffic by 5:00 a.m. on Monday thrice	0%	$0

Table 6. Disincentive schedule for Milestone 1.

Scenario	Disincentive
Failure to open all four lanes to traffic by 5:00 a.m. Monday	$450,000
Failure to open all four lanes to traffic by 5:15 a.m. Monday	$550,000
Failure to open all four lanes to traffic by 5:30 a.m. Monday	$700,000
Failure to open all four lanes to traffic by 5:45 a.m. Monday	$900,000
Failure to open all four lanes to traffic by 6:00 a.m. Monday	$1,150,000
Total weekly disincentive	$1,150,000
Total maximum disincentive	$6.450,000

Road User Cost Projections

During the early phases of the project, MassDOT conducted an analysis to evaluate the impacts of delay in scheduled lane opening in terms of motor vehicle operator costs. **Error! Reference ource not found.** presents the road user cost estimates based on the measured increase in I-93 traffic volumes in 15-minute intervals on Monday mornings. These estimates were used in devising the incentive/disincentive schedule specified in the D-B contract. The agency used a value of $18.97 per hour (in 2011 dollars) as the cost of a vehicle driver's travel time in road user cost calculations.

Table 7. MassDOT's road user cost projections.

Time of Day	Delay Time (Hours)	Volume (Vehicles/Hour)	Incremental Road User Cost at Each 15-Minute Interval*	Total Road User Cost at Each 15-Minute Interval
Mon., 5:00 a.m.	0.5	6,549	$62,117	$62,117
Mon., 5:15 a.m.	1.5	7,000	$199,185	$261,302
Mon., 5:30 a.m.	2.5	8,000	$379,400	$640,702
Mon., 5:45 a.m.	3.5	10,000	$663,950	$1,304,652
Mon., 6:00 a.m.	4.5	11,036	$942,088	$2,246,740
Mon., 6:15 a.m.	5.5	11,150	$1,163,335	$3,410,076
Mon., 6:30 a.m.	6.5	11,400	$1,405,677	$4,815,753
Mon., 6:45 a.m.	7.5	11,600	$1,650,390	$6,466,143
Mon., 7:00 a.m.	8.5	11,847	$1,910,270	$8,376,412

Note: Based on travel time delay value of $18.97/per person/per hour

Quality Assurance

In the I-93 Fast 14 project, Quality Assurance (QA) presented unique challenges, particularly due to the complexity of project, the aggressive schedule, and the involvement of many stakeholders. The QA program had to be rigorous and efficient, and it needed to work as intended the first time for both the design and construction phases of the project.

Under the QA program, the contractor was responsible for Quality Control (QC) of both the design and construction phases, while MassDOT was responsible for Acceptance. To execute the quality functions for this project, the contractor developed a Quality Management Plan (QMP) in coordination with the MassDOT and FHWA. The development process involved weekly meetings with participation from the D-B QC team, D-B design team, and D-B construction team, as well as representatives from MassDOT Central Office, District Office, and FHWA Division Office. The QMP described and defined the roles and organizational responsibilities of the various participants, instructions for document management and control, and quality requirements and review activities of various work items. The manual included the following components:

- Organization and Roles.
- Document Management and Control.

- Design Quality Control.
- Construction Quality Control.

Organization and Roles

The contractor's QC activities were led by the Quality Control Administrator who was responsible for the overall management and implementation of the QMP. The organizational structure included two separate teams for design and construction Quality Control. The design quality was managed by the Design QC team that included a Design Quality Control Manager and members representing each of the 14 design components. The construction quality was managed by a team that included a Construction Quality Control Manager, field inspectors, shop inspectors, and independent testing firms.

Document Management and Control

The contractor maintained an electronic filing system using Microsoft SharePoint to file, organize, track, and maintain project-related documents. The SharePoint system helped MassDOT and the D-B team to have easy access and distribution of submissions/information. With this system, both parties were able to post review comments and track document revisions effectively.

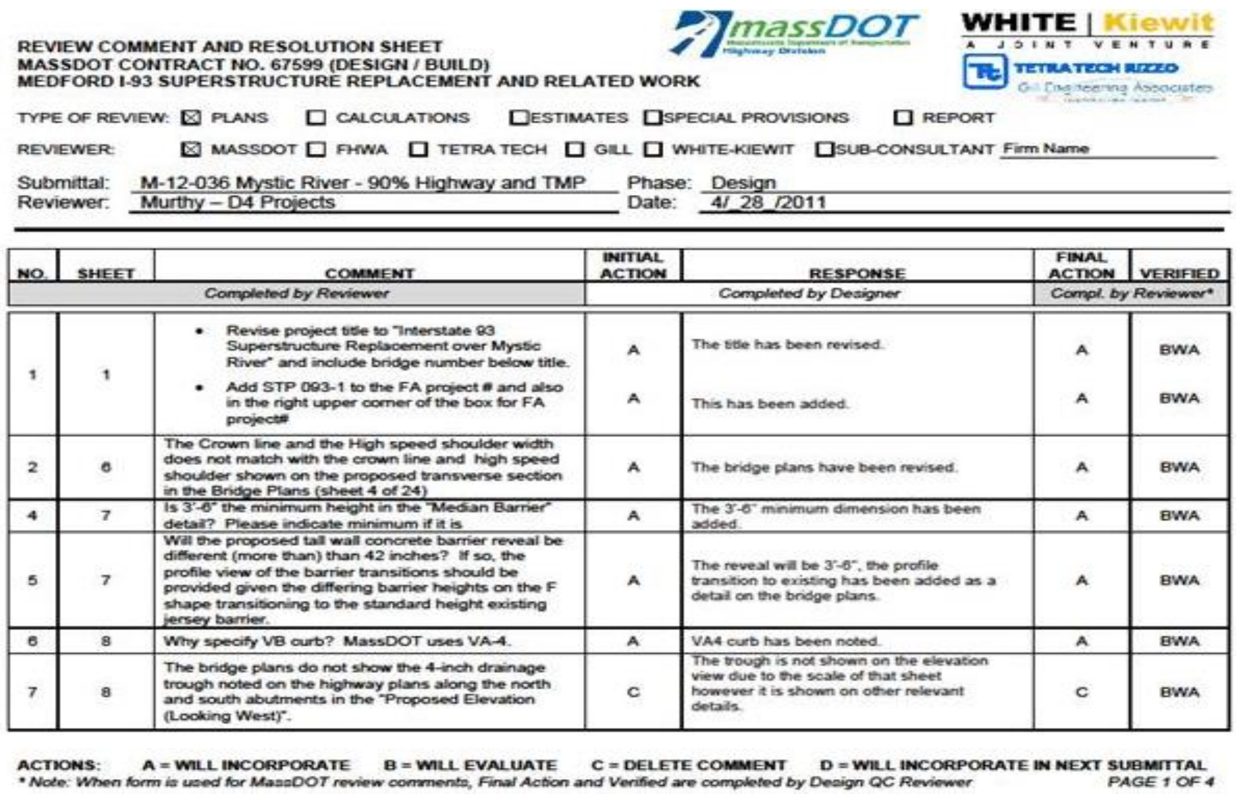
MassDOT had two separate teams under the Project Manager and District Construction Engineer for design and construction Acceptance, respectively. The design Acceptance team had three separate subteams for bridge, highway, and traffic-related design submittals. The construction Acceptance team included the District Materials Engineer, Resident Engineer, Field Control Engineer, lab technicians, and construction inspectors.

Design Quality Control

Design Quality Control involves target review procedures for various work items. The documents, including shop drawings, were subjected to rigorous procedures that involved both technical and constructability reviews. Each review included a QC checklist and comments resolution forms for design review, discipline coordination, and construction review. Unnecessary review steps were eliminated to facilitate early release of certain noncritical work packages, where applicable. Early release of work packages, such as structural steel and bearings, beam seats and substructure repairs, temporary crossover, highway lighting, sawcutting, and median barrier deployment, involved only limited review for the contractor to proceed at risk.

MassDOT's design Acceptance involved streamlined, fast-paced review and acceptance of designs. The design Acceptance procedure included weekly meetings, over-the-shoulder reviews, and formal reviews of design submittals. Weekly working group meetings were held at a field office with the key personnel of the D-B design team. Over-the-shoulder reviews facilitated informal and in-depth discussion of design concepts, incorporating inputs from construction personnel, and reviewing and revising designs in advance of formal submissions. Thus, these informal reviews helped avoid redesign and minimized review time. During formal submittal reviews, MassDOT turned in all the reviews to the D-B design team within the agreed timeframe. The agency's project manager verified the completeness of each submittal prior to review and actively monitored the progress of reviews. Comments resolution forms were used to provide formal feedback on design submittals. Figure 40 presents a sample review comment and resolution sheet.

Upon final Acceptance, MassDOT released the design submittals for construction.


REVIEW COMMENT AND RESOLUTION SHEET
MASSDOT CONTRACT NO. 67599 (DESIGN / BUILD)
MEDFORD I-93 SUPERSTRUCTURE REPLACEMENT AND RELATED WORK

massDOT | WHITE | Kiewit A JOINT VENTURE | TETRA TECH RIZZO | Gill Engineering Associates

TYPE OF REVIEW: ☒ PLANS ☐ CALCULATIONS ☐ ESTIMATES ☐ SPECIAL PROVISIONS ☐ REPORT

REVIEWER: ☒ MASSDOT ☐ FHWA ☐ TETRA TECH ☐ GILL ☐ WHITE-KIEWIT ☐ SUB-CONSULTANT Firm Name

Submittal: M-12-036 Mystic River - 90% Highway and TMP   Phase: Design
Reviewer: Murthy – D4 Projects   Date: 4/ 28 /2011

NO.	SHEET	COMMENT	INITIAL ACTION	RESPONSE	FINAL ACTION	VERIFIED
Completed by Reviewer			Completed by Designer		Compl. by Reviewer*	
1	1	• Revise project title to "Interstate 93 Superstructure Replacement over Mystic River" and include bridge number below title. • Add STP 093-1 to the FA project # and also in the right upper corner of the box for FA project#	A A	The title has been revised. This has been added.	A A	BWA BWA
2	6	The Crown line and the High speed shoulder width does not match with the crown line and high speed shoulder shown on the proposed transverse section in the Bridge Plans (sheet 4 of 24)	A	The bridge plans have been revised.	A	BWA
4	7	Is 3'-6" the minimum height in the "Median Barrier" detail? Please indicate minimum if it is	A	The 3'-6" minimum dimension has been added.	A	BWA
5	7	Will the proposed tall wall concrete barrier reveal be different (more than) than 42 inches? If so, the profile view of the barrier transitions should be provided given the differing barrier heights on the F shape transitioning to the standard height existing jersey barrier.	A	The reveal will be 3'-6", the profile transition to existing has been added as a detail on the bridge plans.	A	BWA
6	8	Why specify VB curb? MassDOT uses VA-4.	A	VA4 curb has been noted.	A	BWA
7	8	The bridge plans do not show the 4-inch drainage trough noted on the highway plans along the north and south abutments in the "Proposed Elevation (Looking West)".	C	The trough is not shown on the elevation view due to the scale of that sheet however it is shown on other relevant details.	C	BWA

ACTIONS: A = WILL INCORPORATE B = WILL EVALUATE C = DELETE COMMENT D = WILL INCORPORATE IN NEXT SUBMITTAL
* Note: When form is used for MassDOT review comments, Final Action and Verified are completed by Design QC Reviewer   PAGE 1 OF 4

Figure 40. Picture. Sample review comment and resolution sheet used for design submittals.

Construction Quality Control

The QMP included separate QC procedures for project produced materials, fabricated materials, and standard manufactured work items. Construction Quality Control included field inspection, independent field testing, and laboratory testing for project-produced materials such as earthwork, bridge substructure repairs, bridge deck closure, and roadway materials. For fabricated materials, such as bridge bearings, structural steel, and bridge modular elements, the Quality Control followed the quality procedures of fabricators with additional inspection of fabrication shops by the contractor's inspectors. The manufacturers' quality system manuals were followed for standard manufactured work items, with additional inspection and testing at the project site.

MassDOT's construction Acceptance activities included the following:

- The construction Acceptance team conducted inspections of prefabricated structural components at the Jersey precast concrete yard plant during fabrication and the staging area in Wilmington upon delivery.
- The agency conducted field inspections during closure pour of bridge decks. Figure 41 shows MassDOT personnel conducting field inspection during bridge deck closure pour. Figure 42 is a photo of a mobile laboratory deployed to facilitate the sampling and testing of concrete used in the closure pours.
- The agency also conducted inspection of materials and construction activities for conformance with contract documents. Sampling and testing were conducted in accordance with the MassDOT *Guide Schedule for Sampling and Testing Materials* typically used in design-bid-build projects.
- The agency also monitored QC activities of the contractor for conformance with the specific construction Quality Control Plans for bridge structural elements, hot mix asphalt, etc., as identified in the Quality Management Plan.

Specifically for acceptance of precast elements, the agency conducted cylinder breaks prior to their standard 28-day breaks. This was done based on the design strength attained through fabricator's 7-day wet cure to facilitate Acceptance based on shipping release at 7 days.

The QMP also specified the use of nonconformance reports, where applicable, that included the nature of nonconformance, disposition, corrective action, verification, and sign-off by the D-B Quality Control Administrator, D-B design engineer, and MassDOT. Separate protocols were in place for field and fabrication-related nonconformance issues.

Figure 41. Photo. MassDOT personnel conducting inspection during bridge deck closure pour.

Figure 42. Photo. Mobile laboratory at project site.

DATA ACQUISITION AND ANALYSIS

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

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

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

SAFETY

Steps toward making this project safe began before starting construction by making PMSEs in a controlled factory setting away from the project location. During construction, ABC methods and a high early strength concrete used for the longitudinal closure pours helped to minimize the time the contractor spent erecting the structures. By closing the portion of the interstate necessary for ABC, MassDOT ensured a much safer work zone than would be present if conventional methods such as staged construction were used. After construction was completed, the upgraded bridge and median barriers should improve safety and further decrease the possibility for fatalities on Massachusetts roads.

The project included the HfL performance goal of achieving a work zone crash rate equal to or less than the existing conditions. Work zone safety was ensured by weekend closure, extensive public outreach, accelerated construction, and use of prefabricated bridge components. MassDOT's Geonetics web-based crash query tool was used to obtain the crash statistics: http://services.massdot.state.ma.us/crashportal/CrashMapPage.aspx?Mode=Adhoc. Crash statistics were obtained using both map-based and attributes-based filters.

Error! Reference source not found. presents a Medford area map showing the influence area of he I-93 Fast 14 project assumed for obtaining crash statistics. The influence area was a geospatially constrained area between I-93 north of Middlesex Avenue in Somerville and south of Marble Street/Forest Street in Stoneham. A wider-influence area was considered due to the fact that alternate detour routes were extensively used during the closure. The following attributes were used in the filter:

- Crash date.
  - Between June 1, 2008, and May 31, 2011 (before construction).
  - Between June 3, 2011, and August 15, 2011 (during construction) — only weekend closure times (i.e., 55 hours /closure * 10 closures) were considered.
- Reported into the system by MA State police.
- Occurred in Medford, Stoneham, or Somerville.

- Roadway is like "93," Exit route is like "93," or Mile marker route is like "93."

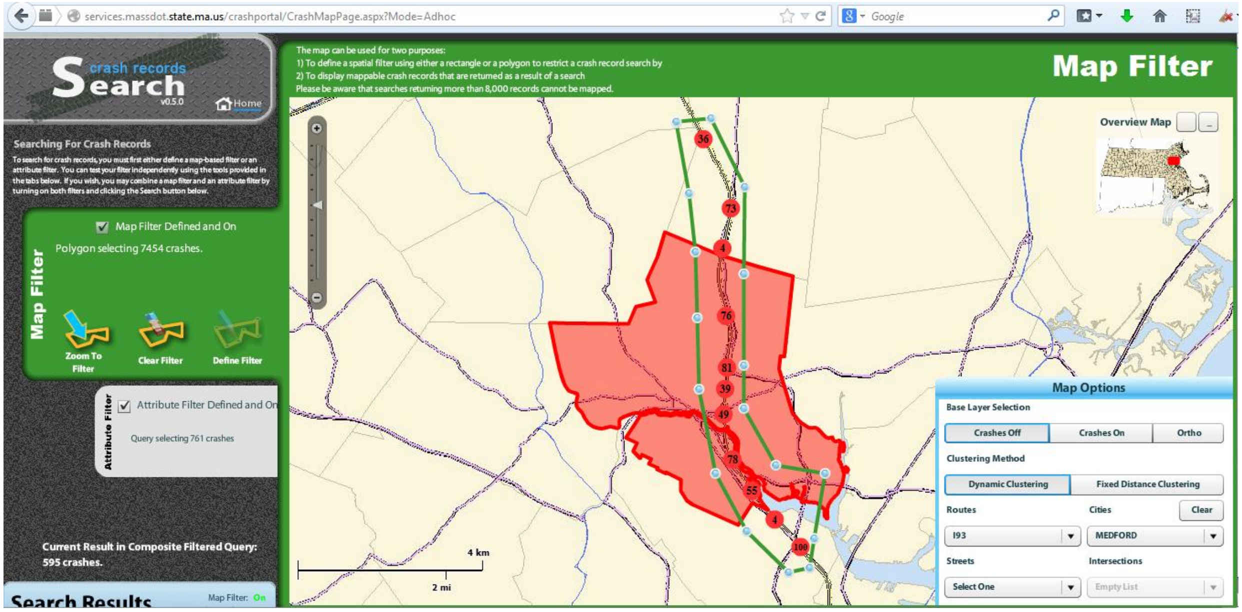


Figure 43. Map. Influence area assumed for obtaining crash statistics.

Crash statistics were collected for the entire influence area, as well as for the I-93 corridor only. **Error! Reference source not found.** presents the crash statistics reported in the web portal by everity type during the 3-year period before construction and during weekend closure times. **Error! Reference source not found.** presents a comparison of average crashes per year by everity type. As indicated, the number of crashes during the weekend closures, after normalization for the period of observation, was higher than the number of crashes that before construction; however, with ABC, the reduction in the duration of work zone exposure from 4 years to 550 hours was significant for reducing work zone safety risks.

No work-related injuries occurred during construction, resulting in an OSHA Form 300 score of 0.0. Although the bridge barriers were upgraded during construction, the new facility did not include any significant features, such as geometric re-alignment or widening that would improve the future safety performance of the facility.

Table 8. Number of crashes reported by severity type before and after construction.

Crash Severity	**Influence Area**		**I-93 only**	
	Before Construction	**During Construction**	**Before Construction**	**During Construction**
Property damage only	1035	31	372	24
Not reported	194	3	13	1
Non-fatal injury	531	17	205	9
Fatal injury	6	0	5	0
Total	1766	51	595	34

Crash Severity	Influence Area		I-93 only	
	Before Construction	**During Construction**	**Before Construction**	**During Construction**
Days of coverage	1095	22.9 (550 hours)	1095	22.9 (550 hours)

Table 9. Comparison of average crashes per year by severity type before and after construction.

Crash Severity	Influence Area		I-93 only	
	Before Construction	**During Construction**	**Before Construction**	**During Construction**
Property damage only	345.0	493.7	124.0	382.2
Not reported	64.7	47.8	4.3	15.9
Non-fatal injury	177.0	270.7	68.3	143.3
Fatal injury	2.0	0.0	1.7	0.0
Total	588.7	812.2	198.3	541.4

CONSTRUCTION CONGESTION

The innovations used in this project enabled MassDOT to deliver a complete project in just one construction season, far exceeding the HfL performance goal of a 50 percent reduction in the duration of construction-related congestion. Traditional methods would take at least 3 years and result in unacceptable traffic impacts. The D-B method allowed MassDOT to select the entity whose proposal provided the highest level of efficiency, economy, safety, and durability. Since the designer and builder work as a single team, fabrication and construction could overlap with portions of the design, considerably advancing and compressing the construction schedule and increasing efficiency.

Because the portion of I-93 within the project limits carries between 169,000 and 181,000 vehicles each day, severe construction-related congestion was unfortunately inevitable. Queue lengths and trip times would have been markedly increased regardless of whether traditional or accelerated construction methods were used. MassDOT's goal was to shorten the duration of the impact as much as possible. By using PMSEs, a large portion of the work was moved out of the roadway. The PMSE units were quickly staged, erected, and made ready for vehicular passage. The modular nature of the PMSE units, their lane-sized width, and connections allowed the contractor to erect the superstructures rapidly, section by section.

TRAVEL TIME

MassDOT utilized moveable barrier technology to create crossovers at both ends of the project limits (south of the Highway 16 interchange and north of the Valley Street interchange) so that traffic could be easily moved onto the remaining open direction and operate as a four-lane, two-way facility with barrier separation between the two directions over the weekend. A total of 10 weekends were scheduled to complete this work.

To assess the impacts of the construction project upon motorists, researchers conducted a series of travel time runs to determine the additional travel time required to traverse I-93 during the crossover weekends, as well as an adjacent parallel arterial alternate route. A preconstruction study was performed in May 2011. A during construction study was performed August 12-14, 2011. The travel time data were then supplemented with spot speed and volume data obtained from a work zone intelligent transportation system (ITS). The system was developed and deployed to provide motorists with real-time delay and congestion information throughout the corridor. However, these data were also helpful in determining the duration of queuing and congestion that resulted each weekend. Figure 44 illustrates the locations of the spot sensors from that system.

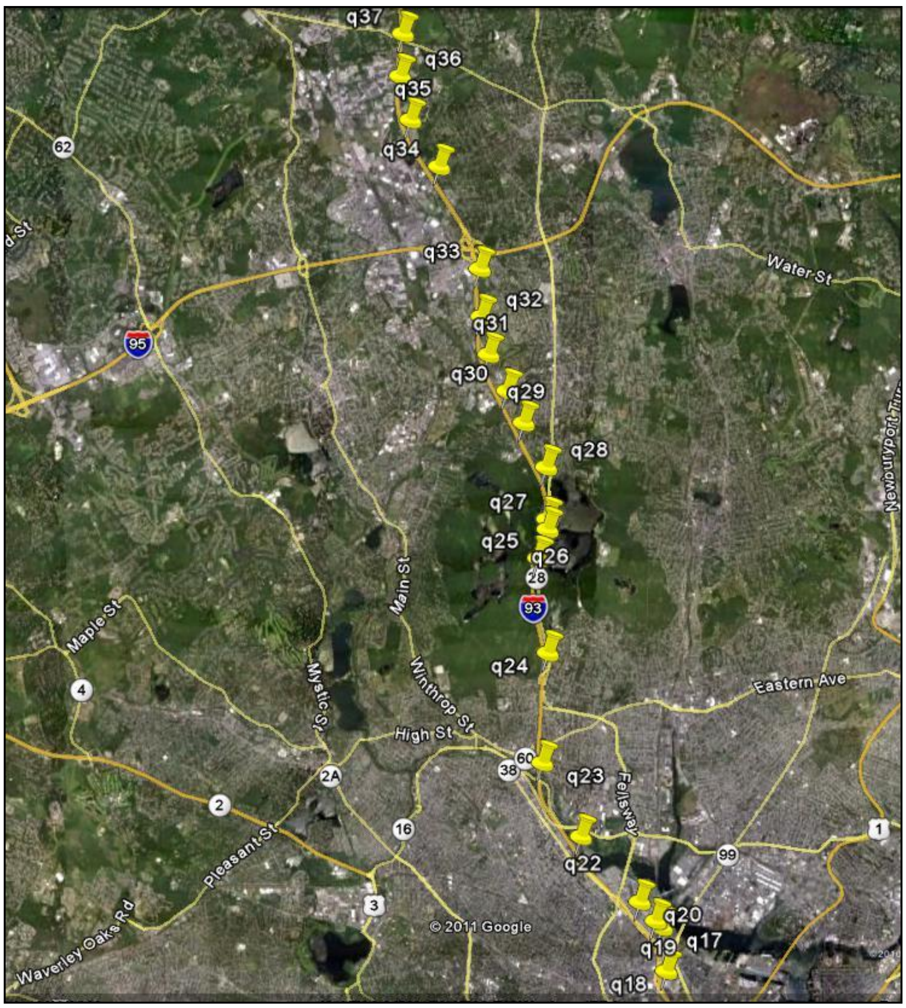


Figure 44. Map. Work zone ITS spot sensor locations (source: Google).

Data Collection

Researchers utilized the floating vehicle methodology to collect travel times, attempting to mimic the "typical" driving speed of other vehicles along the various roadway segments of the detour route. Data were collected Friday night and Saturday in the preconstruction condition. During that time, it was verified that traffic normally operated at near free-flow conditions during the weekends, so additional data were not needed from Sunday. During construction, however, data were collected on Friday night, as well as daytime and nighttime both Saturday and Sunday.

Upon further review of the work zone ITS data, researchers noted that many of the sensor stations experienced sporadic data archive issues over the weekends, so could not by themselves always yield a useful speed profile or full volume count over the entire weekend. Researchers were able to identify a sensor at the north end of the project, in the middle of the project, and at the south end of the project that provided good and mostly complete data for analysis purposes.

Travel Time Comparison Results

The travel time runs performed in the preconstruction condition (May 2011) indicated that travel speeds consistently averaged 60 mph in both directions along I-93 on a typical weekend. On Highway 28 (a nearby arterial street), speeds averaged 28 mph in both directions on the weekend as well. Other smaller arterial routes were also present in the corridor that could be used as an alternative to I-93, depending on the motorist's destination within or beyond the study limits. However, these other routes were not significant enough to warrant monitoring during construction.

The resulting analyses of travel times on the weekend of August 12-14 are presented in Table 10 for I-93 and Table 11 for Highway 28. Delay was calculated against the typical 60 mph operating speed on I-93 and 28 mph operating speed on Highway 28. Queue lengths on I-93 were defined as locations where speeds were below 35 mph. Data collection personnel noted that, in many instances, multiple regions of queued traffic operating below this threshold were encountered prior to and within the crossover section, separated by distances where speeds were closer to 40 to 50 mph. The cumulative distance of these queued regions is documented in Table 10. The shortest measured queue length was 1.6 miles, which means the moving queue length during construction did not meet the HfL goal less than 1.5 miles in an urban area.

Overall, delays averaged 10 to 15 minutes in the northbound direction on I-93 over the weekend, and approximately 6 to 8 minutes in the southbound direction. Delays exceeded 20 minutes northbound on only one occasion during the entire weekend, but they were near 20 minutes for a substantial period of time on Sunday. Southbound, maximum delays documented peaked at about 14 minutes on Friday evening and then did not exceed 12 minutes the rest of the weekend.

Interestingly, delays along Highway 28 over the weekend were likewise fairly small, generally 5 minutes or less. MassDOT had anticipated significant diversions from I-93 would adversely affect Highway 28 operations, and plans were made to alter the traffic signal timing along the route during the weekend crossovers on I-93. Based on the travel time studies performed, it appears that the modifications made were successful in mitigating the impacts of the crossover strategy on travel times.

Table 10. Delays and queues on I-93 during construction.

Time	Delay, Minutes	Queue Length, Miles
I-93 Northbound:		
Aug 12, 8:00 p.m.	10.3	3.8
Aug 12, 9:44 p.m.	9.3	3.4
Aug 12, 10:38 p.m.	5.7	3.5
Aug 12, 11:23 p.m.	5.3	2.7
Aug 12, 11:59 p.m.	4.8	3.1
Fri, Aug 12 Average	7.1	3.3
Aug 13, 11:06 am	19.4	3.2
Aug 13, 12: 15 p.m.	37.6	5.6
Aug 13, 2:17 p.m.	---	5.6
Aug 13, 3:26 p.m.	13.9	4.5
Aug 13, 5:04 p.m.	8.1	3.0
Aug 13, 5:41 p.m.	5.8	3.3
Aug 13, 6:14 p.m.	3.7	1.3
Sat, Aug 13 Average	14.8	3.8
Aug 14, 12:55 p.m.	3.6	1.2
Aug 14, 2:53 p.m.	19.0	3.5
Aug 14, 3:53 p.m.	18.4	3.9
Aug 14, 4:50 p.m.	12.8	3.4
Aug 14, 5:57 p.m.	6.2	2.7
Aug 14, 7:45 p.m.	5.6	2.7
Sun, Aug 14 Average	10.9	2.9
I-93 Southbound:		
Aug 12, 8:13 p.m.	3.5	1.5
Aug 12, 10:15 p.m.	14.3	4.2
Aug 12, 11:37 p.m.	12.9	4.2
Aug 13, 12:08 am	0.6	0.0
Fri, Aug 12 Average	7.8	2.5
Aug 13, 11:41 am	2.8	0.6
Aug 13, 2: 29 p.m.	10.5	1.1
Aug 13, 3:09 p.m.	3.0	0.9
Aug 13, 4:47 p.m.	0.5	1.5
Aug 13, 5:23 p.m.	11.5	4.0
Aug 13, 6:30 p.m.	3.7	1.6
Sat, Aug 13 Average	6.0	1.6
Aug 14, 1:23 p.m.	4.9	1.6
Aug 14, 3:30 p.m.	9.5	3.7
Aug 14, 5:24 p.m.	5.8	2.2
Aug 14, 6:14 p.m.	5.7	1.6
Aug 14, 7:27 p.m.	4.2	1.5
Aug 14, 8:28 p.m.	6.0	2.2
Sun, Aug 14 Average	6.0	2.1

--- data not available due to equipment problem

Table 11. Travel time delays on Highway 28.

Time	Delay, Minutes
Sat, Aug 13, 2:30 p.m.	1.1
Sun, Aug 14, 2:08 p.m.	3.5
Sun, Aug 14: 2:26 p.m.	4.8
Sun, Aug 14, 6:46 p.m.	5.4

To estimate the duration of queuing periods during each weekend, speed versus time of day plots were generated for three key spot sensor locations from the work zone ITS deployment:

Q19 (south end, north direction).
Q24 (in the crossover, both directions).
Q29 (north end, south direction).

Figures 45 through 47 present these plots. Times of congestion were fairly minimal at the southern end of the project at Q19 northbound. Researchers saw some congestion late Friday into early Saturday morning, and then again Saturday from about noon until approximately 9 p.m. Some congestion was then again evident Sunday evening from about 6 p.m. until 9 p.m. Moving north to the Q24 station, the congestion times on Friday evening and Saturday were approximately the same (albeit with much greater degree of variability in the speed measurements minute-by-minute). However, Sunday showed a longer congestion period, beginning about 9 a.m. and extending until possibly 4 a.m. or so Monday morning. Whether these data represented only motorist speeds or perhaps a mixture of motorists and construction vehicles cannot be ascertained from the documentation available to the researchers.

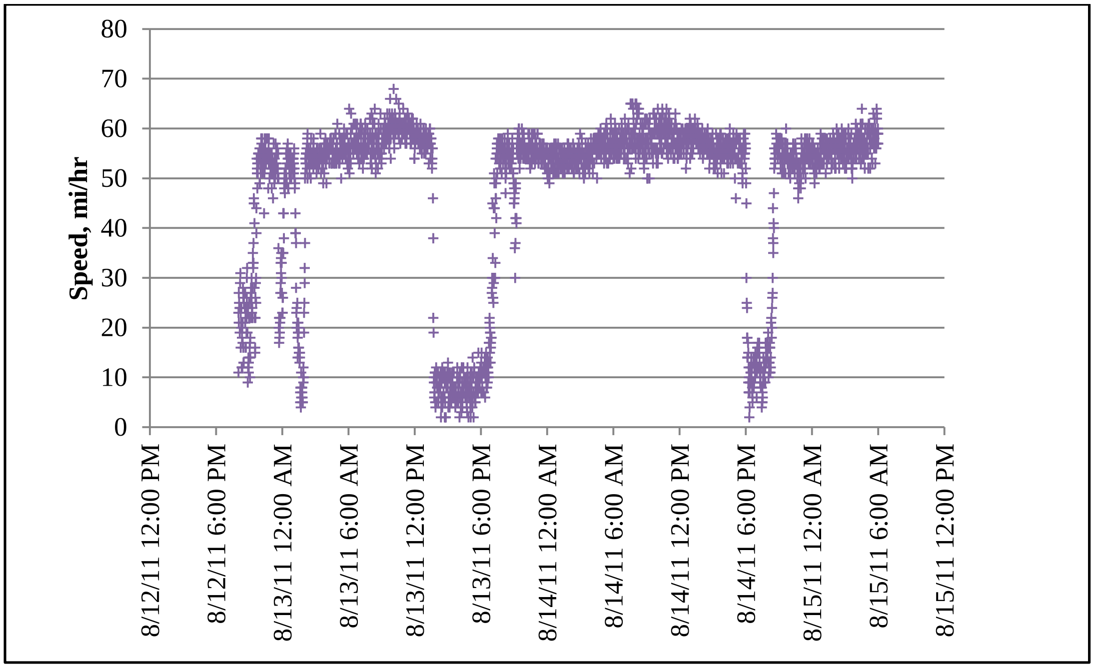
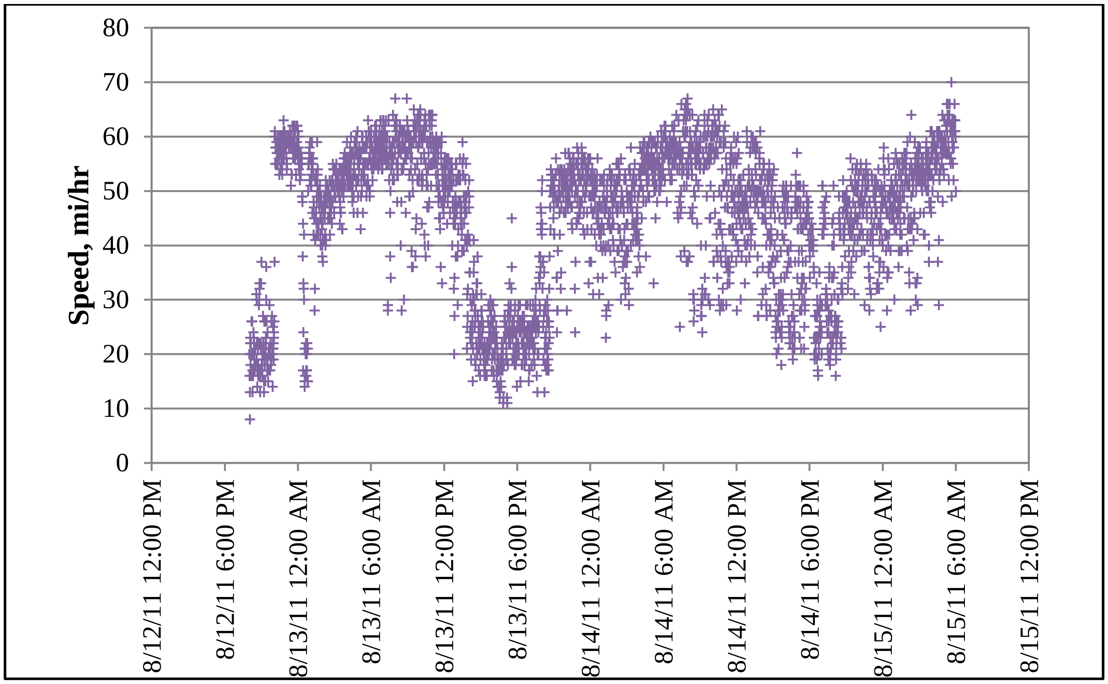
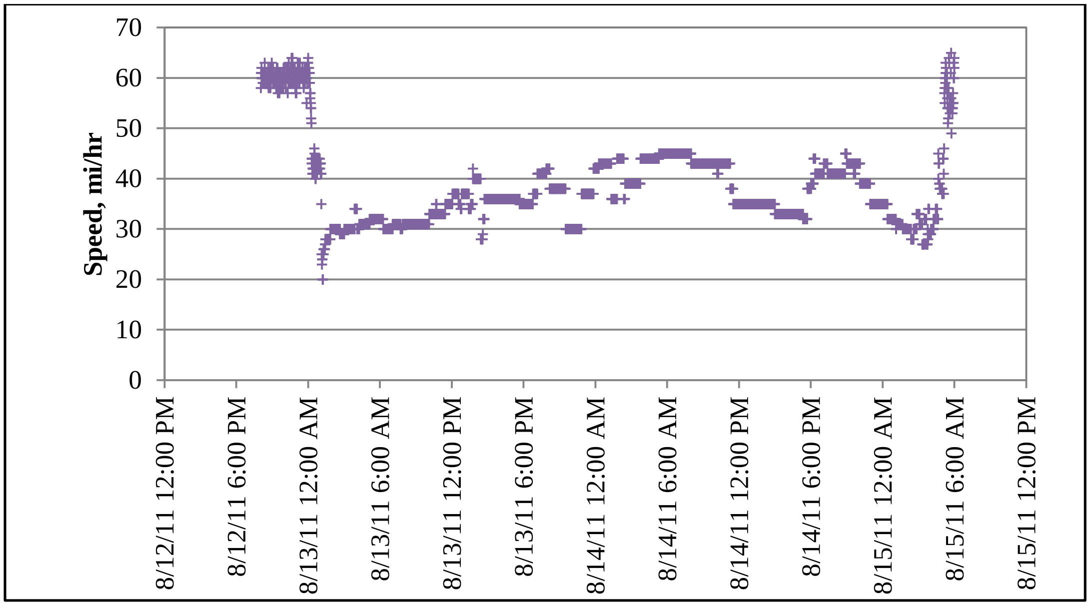


Figure 45. Graph. Speeds versus time northbound at the Q19 sensor location.

Once into the crossover section at sensor Q24, speeds stabilized and flowed smoothly throughout both days and nights, generally right at 30 to 40 mph or so. Data from sensor Q29 illustrate fairly well the time periods where southbound traffic was congested. Speeds are dramatically lower on both Saturday and Sunday afternoons and nights (2 p.m. Saturday to 1 a.m. Sunday, and 3 p.m. Sunday to 1 a.m. Monday).



Northbound



Southbound
Figure 46. Graph. Speeds versus time at the Q24 sensor station.

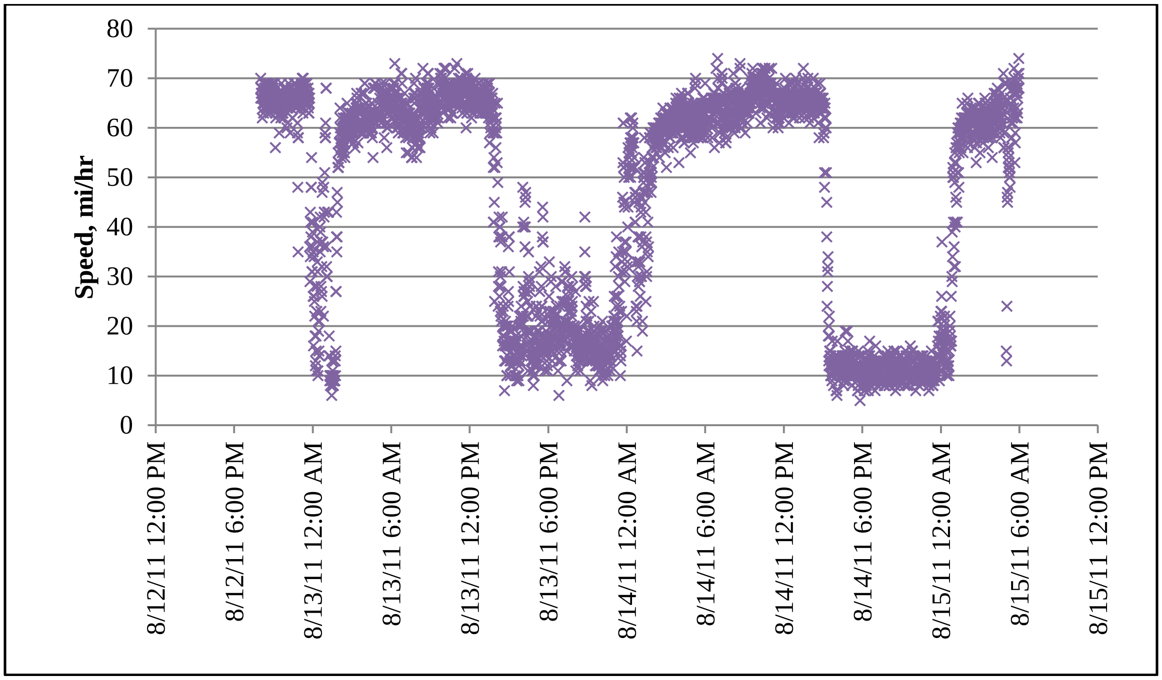


Figure 47. Graph. Speeds versus time southbound at the Q29 sensor station.

Estimates of Diversion and Total Vehicular Delays per Weekend

The length of queues and amount of delay measured during the weekend crossover condition suggest that considerable diversion occurred away from I-93. Queue analysis estimates by MassDOT indicated that 15 to 20 percent of the traffic normally using I-93 on the weekend would need to divert in order to keep delays and queues manageable. The fact that queues were generally less than 2 to 3 miles and delays were less than 30 minutes suggests that this level of diversion did indeed occur. Furthermore, it appears that the diversion was spread among the various alternative routes in the corridor, as conditions on the primary diversion route did not degrade appreciably (delays were kept to less than 5 minutes).

For purposes of this assessment, it was assumed that all traffic that did divert resulted in about the same amount of increased travel time to their destination via an alternative route or to a different destination entirely (this analysis disregards any trips that may have been totally canceled in the corridor due to the construction). Based on this assumption, total delays are simply the average delay per vehicle measured for each time period when delays were occurring multiplied by the total normal volume during those time periods. **Error! Reference source not ound.** summarizes this computation. Overall, data indicate that each weekend that the crossover condition was implemented to replace a structure resulted in 17,962 vehicle-hours of delay to I-93 travelers. While significant, one would expect that alternative methods of reconstruction (i.e., each bridge reconstructed using traditional long-term lane closures) would have resulted in dramatically greater delays than were experienced.

Table 12. Vehicle delay computations per crossover weekend.

	Time Period of Delays	Average Delay per Vehicle, min	Total Vehicles Delayed	Total Vehicle-Hours of Delay
I-93 northbound:				
Friday	8 p.m. – 1 a.m.	7.1	8,382	992
Saturday	12 p.m. – 9 p.m.	14.8	23,772	5,864
Sunday	9 a.m. – 12 a.m.	10.9	35,699	6,485
I-93 southbound:				
Friday	10 p.m. – 12 a.m.	7.8	2475	322
Saturday	2 p.m. – 1 a.m.	6.0	23,167	2,317
Sunday	3 p.m. – 1 a.m.	6.0	19,815	1,982
TOTAL DELAY PER WEEKEND				17,962

QUALITY

Pavement Tests

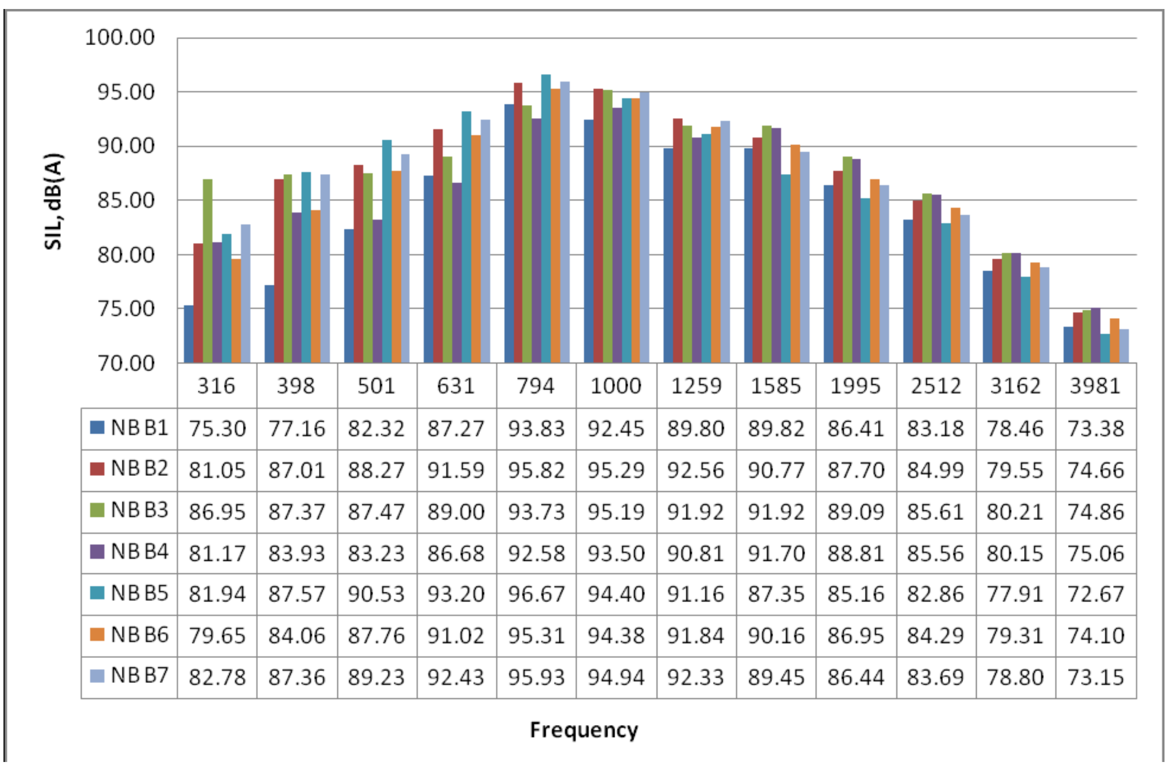
Sound intensity and smoothness test data were collected from each of the bridges before and after construction. Comparing these results provides a measure of quality of the finished project. Data were collected by personnel from the National Center for Asphalt Technology (NCAT) in Auburn, Alabama.

Sound Intensity Testing

Presently, MassDOT does not use the OBSI test method on any projects. Nevertheless, this method was utilized to record sound intensity measurements from where the tire meets the bridge surface. The measurements were made using the currently accepted OBSI technique, American Association of State Highway and Transportation Officials (AASHTO) TP 76-10, which includes dual vertical sound intensity probes and an ASTM recommended Standard Reference Test Tire (SRTT). Multiple measurements were made at 45 mph in the right wheelpath. The sound intensity probes simultaneously captured data from the leading and trailing tire/bridge surface contact areas. Figure 48 shows the dual probe instrumentation and the tread pattern of the SRTT.

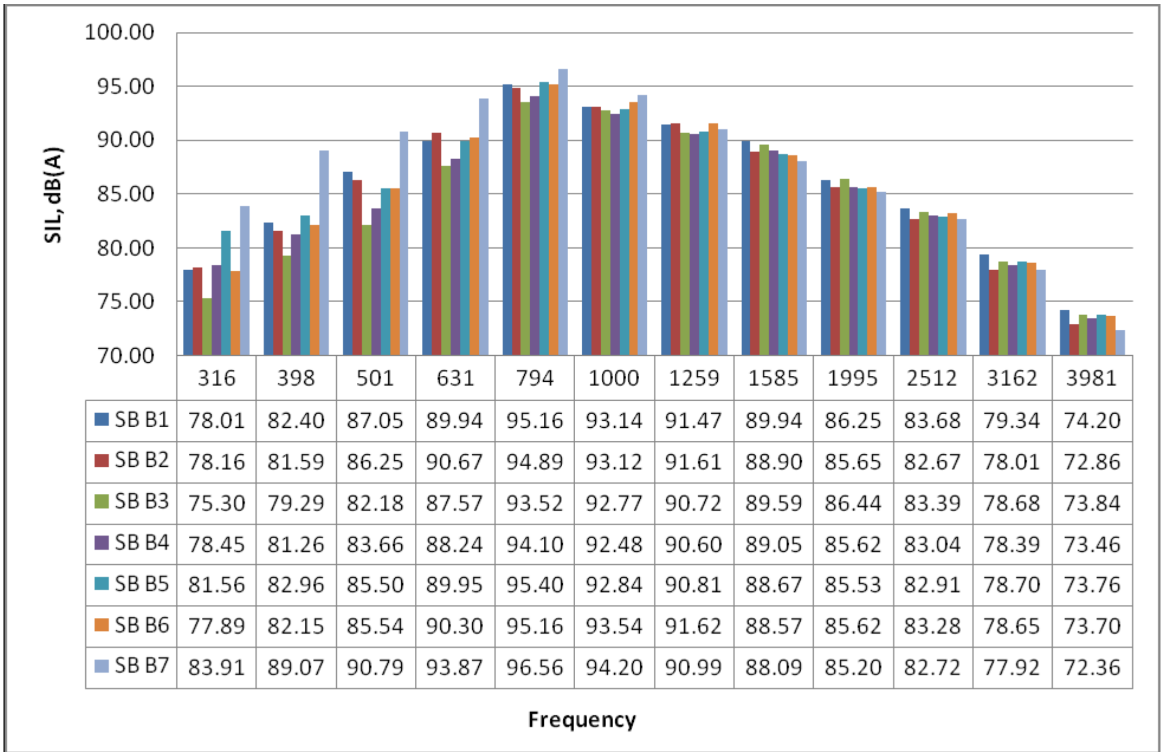
Figure 48. Photo. OBSI dual probe system and the SRTT (source: NCAT).

The average of the front and rear sound intensity values was computed for each of the bridges. Raw data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean sound intensity levels are A-weighted to produce the sound intensity frequency spectra in one-third octave bands. Figures 49 and 50 are frequency plots of the northbound and southbound bridges before construction. Figures 51 and 52 are frequency plots of the northbound and southbound bridges after construction. Generally, the sound intensity spectra show the expected results of the new construction in which the value for nearly all frequencies was reduced.



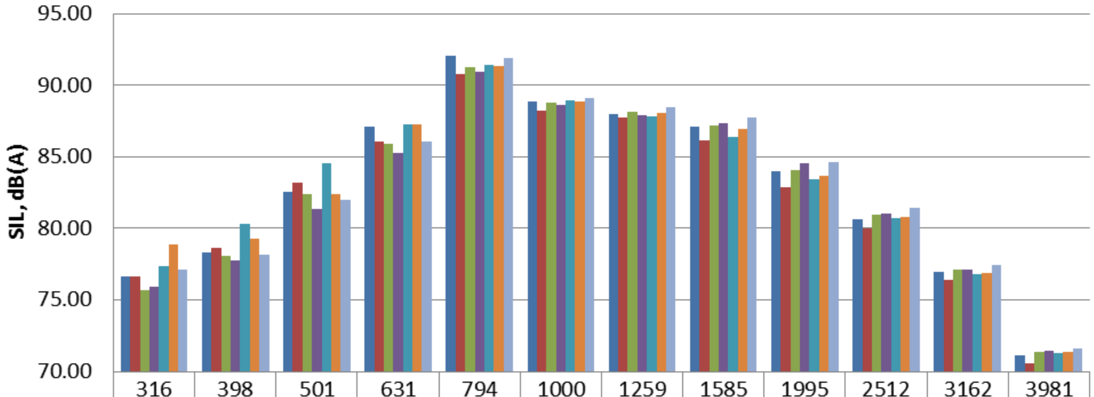
	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
NB B1	75.30	77.16	82.32	87.27	93.83	92.45	89.80	89.82	86.41	83.18	78.46	73.38
NB B2	81.05	87.01	88.27	91.59	95.82	95.29	92.56	90.77	87.70	84.99	79.55	74.66
NB B3	86.95	87.37	87.47	89.00	93.73	95.19	91.92	91.92	89.09	85.61	80.21	74.86
NB B4	81.17	83.93	83.23	86.68	92.58	93.50	90.81	91.70	88.81	85.56	80.15	75.06
NB B5	81.94	87.57	90.53	93.20	96.67	94.40	91.16	87.35	85.16	82.86	77.91	72.67
NB B6	79.65	84.06	87.76	91.02	95.31	94.38	91.84	90.16	86.95	84.29	79.31	74.10
NB B7	82.78	87.36	89.23	92.43	95.93	94.94	92.33	89.45	86.44	83.69	78.80	73.15

Figure 49. Graph. Sound intensity frequency spectra of the northbound bridges before construction.



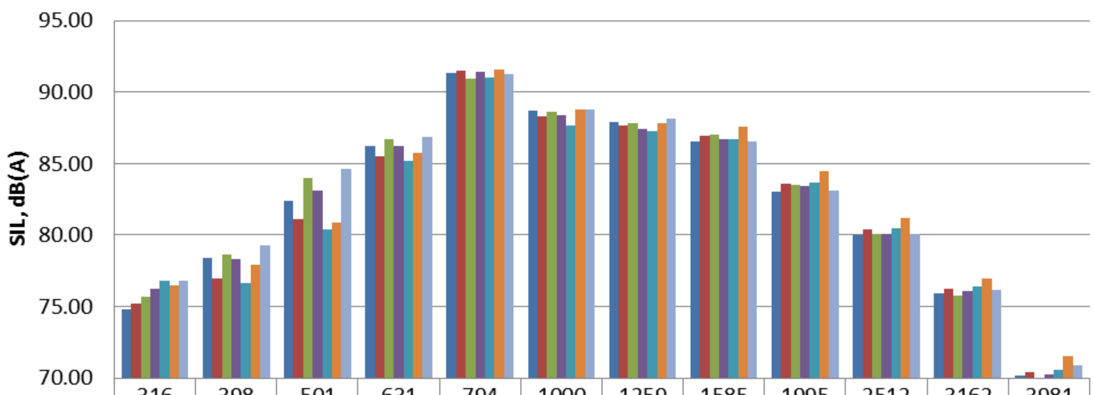
	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
SB B1	78.01	82.40	87.05	89.94	95.16	93.14	91.47	89.94	86.25	83.68	79.34	74.20
SB B2	78.16	81.59	86.25	90.67	94.89	93.12	91.61	88.90	85.65	82.67	78.01	72.86
SB B3	75.30	79.29	82.18	87.57	93.52	92.77	90.72	89.59	86.44	83.39	78.68	73.84
SB B4	78.45	81.26	83.66	88.24	94.10	92.48	90.60	89.05	85.62	83.04	78.39	73.46
SB B5	81.56	82.96	85.50	89.95	95.40	92.84	90.81	88.67	85.53	82.91	78.70	73.76
SB B6	77.89	82.15	85.54	90.30	95.16	93.54	91.62	88.57	85.62	83.28	78.65	73.70
SB B7	83.91	89.07	90.79	93.87	96.56	94.20	90.99	88.09	85.20	82.72	77.92	72.36

Figure 50. Graph. Sound intensity frequency spectra of the southbound bridges before construction.



	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
NB B1	76.64	78.30	82.59	87.08	92.08	88.86	88.00	87.14	83.97	80.60	76.97	71.12
NB B2	76.65	78.64	83.16	86.04	90.79	88.20	87.75	86.11	82.84	79.98	76.39	70.57
NB B3	75.70	78.07	82.39	85.91	91.22	88.77	88.10	87.19	84.06	80.98	77.09	71.36
NB B4	75.94	77.79	81.33	85.23	90.92	88.59	87.89	87.32	84.57	81.07	77.09	71.43
NB B5	77.36	80.34	84.53	87.27	91.44	88.95	87.80	86.42	83.40	80.69	76.80	71.25
NB B6	78.88	79.25	82.39	87.24	91.32	88.82	88.02	86.95	83.71	80.82	76.89	71.36
NB B7	77.08	78.14	81.99	86.07	91.93	89.10	88.43	87.74	84.60	81.43	77.43	71.65

Figure 51. Graph. Sound intensity frequency spectra of the northbound bridges after construction.



	316	398	501	631	794	1000	1259	1585	1995	2512	3162	3981
SB B1	74.77	78.36	82.38	86.19	91.37	88.69	87.89	86.58	83.05	80.00	75.92	70.20
SB B2	75.24	76.96	81.09	85.54	91.51	88.26	87.67	86.97	83.60	80.39	76.23	70.42
SB B3	75.66	78.67	83.99	86.72	90.92	88.65	87.85	87.06	83.55	80.07	75.75	70.00
SB B4	76.28	78.33	83.09	86.22	91.38	88.40	87.39	86.72	83.44	80.06	76.08	70.29
SB B5	76.81	76.64	80.40	85.18	91.05	87.68	87.29	86.67	83.66	80.47	76.42	70.61
SB B6	76.51	77.91	80.84	85.73	91.54	88.78	87.85	87.60	84.48	81.22	76.98	71.53
SB B7	76.83	79.31	84.61	86.86	91.29	88.79	88.14	86.54	83.09	80.10	76.17	70.85

Figure 52. Graph. Sound intensity frequency spectra of the southbound bridges after construction.

Global sound intensity levels were calculated using logarithmic addition of the one-third octave band frequencies across the spectra. The average value of the northbound and southbound bridges dropped 4.0 dB(A) from 100.8 to 96.7 dB(A). While not meeting the HfL goal of 96.0 dB(A), the bridges were quieter than the old bridges. The global sound intensity levels are summarized in Table 13.

Smoothness Measurement

Smoothness testing was done in conjunction with the sound intensity testing utilizing NCAT's Automatic Road Analyzer (ARAN) van, shown in Figure 53. This equipment collects data from both wheelpaths via high-speed inertial profilers, the results of which are reported as IRI values. The average IRI value for the bridges dropped from 294 to 103 inches/mile. This represents a 65 percent reduction in IRI and reflects the increase in both ride and construction quality. The IRI values are summarized in Table 14.

Table 13. Summary of the global sound intensity levels before and after construction.

Direction	Bridge	Preconstruction Sound Intensity, dB(A)	Postconstruction Sound Intensity, dB(A)
Northbound	Valley Street	99.1	97.2
Northbound	Webster Street	101.8	96.4
Northbound	Salem St. Westbound	100.9	96.7
Northbound	Salem St. Eastbound	99.5	96.4
Northbound	Riverside Ave	102.1	97.1
Northbound	Mystic River	101.1	96.5
Northbound	Mystic Valley Pkwy	101.8	97.2
Southbound	Valley Street	100.6	96.6
Southbound	Webster Street	100.4	96.5
Southbound	Salem St. Westbound	99.2	96.8
Southbound	Salem St. Eastbound	99.4	96.6
Southbound	Riverside Ave	100.3	96.1
Southbound	Mystic River	100.4	96.7
Southbound	Mystic Valley Pkwy	102.2	97.0
	Average value	100.8	96.7

Figure 53. Photo. Auburn University ARAN van. (source: NCAT).

Table 14. Summary of IRI levels before and after construction.

Direction	Bridge	Preconstruction IRI, inches/mile	Postconstruction IRI, inches/mile
Northbound	Valley Street	198	103
Northbound	Webster Street	252	146
Northbound	Salem St. Westbound	373	89
Northbound	Salem St. Eastbound	299	104
Northbound	Riverside Ave	427	95
Northbound	Mystic River	431	90
Northbound	Mystic Valley Pkwy	478	98
Southbound	Valley Street	261	89
Southbound	Webster Street	161	94
Southbound	Salem St. Westbound	218	76
Southbound	Salem St. Eastbound	248	99
Southbound	Riverside Ave	171	105
Southbound	Mystic River	157	116
Southbound	Mystic Valley Pkwy	445	139
	Average value	294	103

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

USER SATISFACTION

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

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

NuStats and ARA conducted the survey on the behalf of the HfL program and MassDOT. The questionnaire was developed through a joint effort by MassDOT, FHWA, ARA and NuStats (Zmud and Mallela, 2012). The questionnaire covered respondent perceptions of construction-related impacts on day-to-day living and driving, construction-related communications, and basic demographics. Appendix A presents a copy of the questionnaires used in web-based and print-based surveys.

Instead of surveying users with the HfL questions, MassDOT's questionnaire focused on satisfaction with the innovations used to deliver the project in comparison with conventional methods. MassDOT provided a questionnaire to people on a mailing list developed from the public meetings that included nearby residents and other stakeholders to assess their satisfaction with the project delivery method and the replacement bridges.

Satisfaction with New Facility

The participants of the user satisfaction survey indicated that they were satisfied with the condition of I-93 in Medford now, as compared to its previous condition. On a scale of 1 to 5, with 1 being very satisfied and 5 being very dissatisfied, the average rating was 1.3. Fewer than 7 percent of respondents indicated some level of dissatisfaction, as compared to 78 percent who indicated that they were very satisfied with conditions now. Figure 54 shows a breakdown of the survey responses.

Frequent users of I-93 were the most likely to report high overall satisfaction with the condition of I-93 in Medford now as compared with its previous condition. These were also the only two cohorts in which any respondents reported being very dissatisfied with the condition of I-93 in Medford now, as compared with before the construction. Figure 55 shows a breakdown of satisfaction levels by frequency of I-93 use. Those residing further from the construction tended to report a higher level of satisfaction with the project than those residing closer to the construction. Figure 56 provides a breakdown of responses by respondents' home zip code.

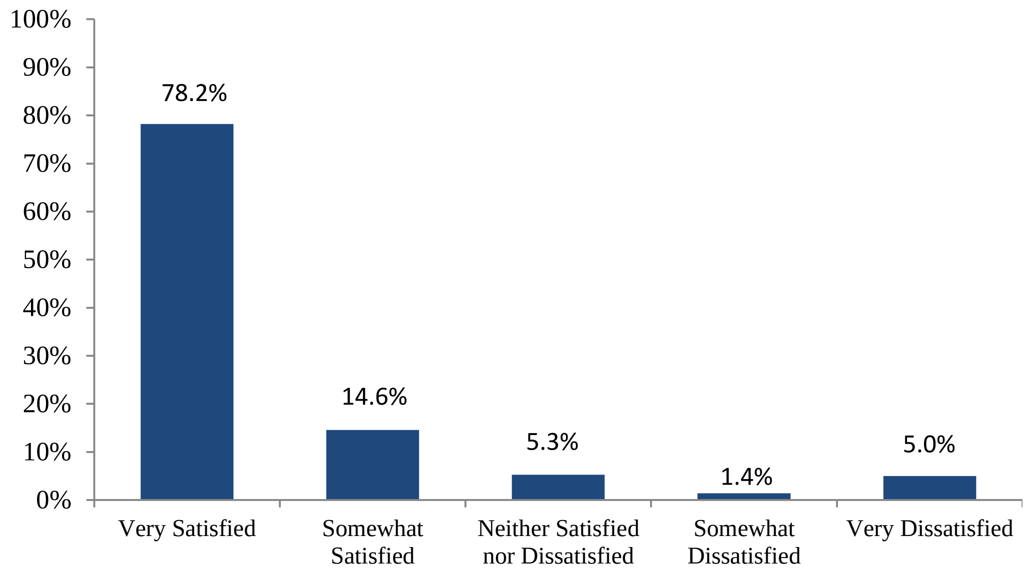


Figure 54. Chart. Overall satisfaction levels (N=418).

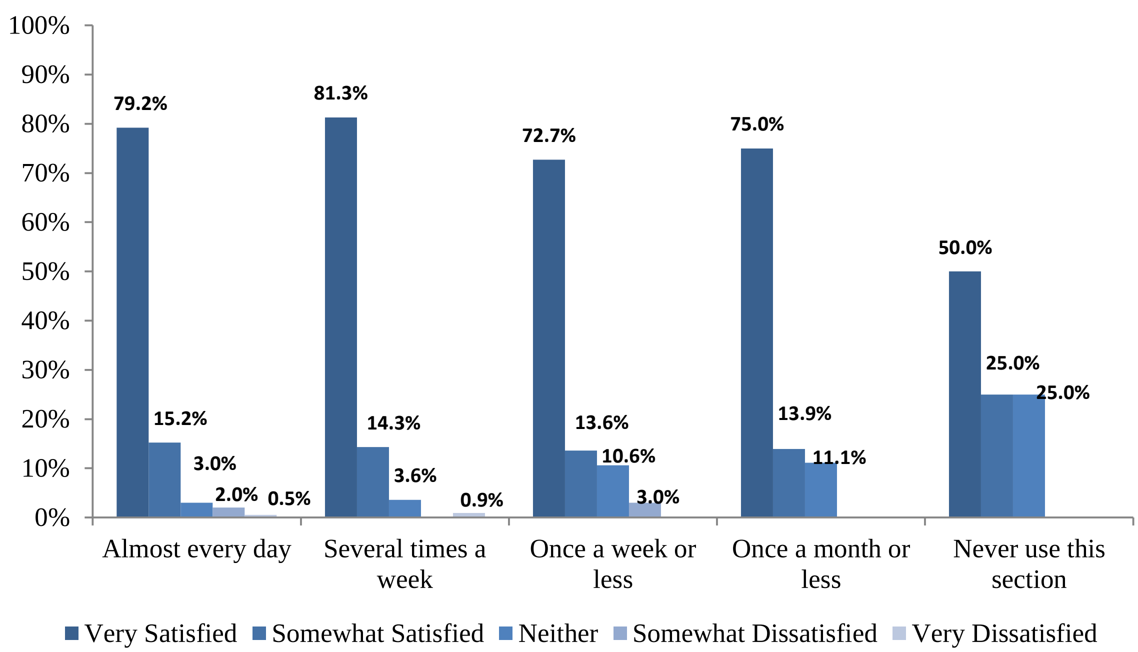


Figure 55. Chart. Satisfaction levels by frequency of I-93 roadway use.

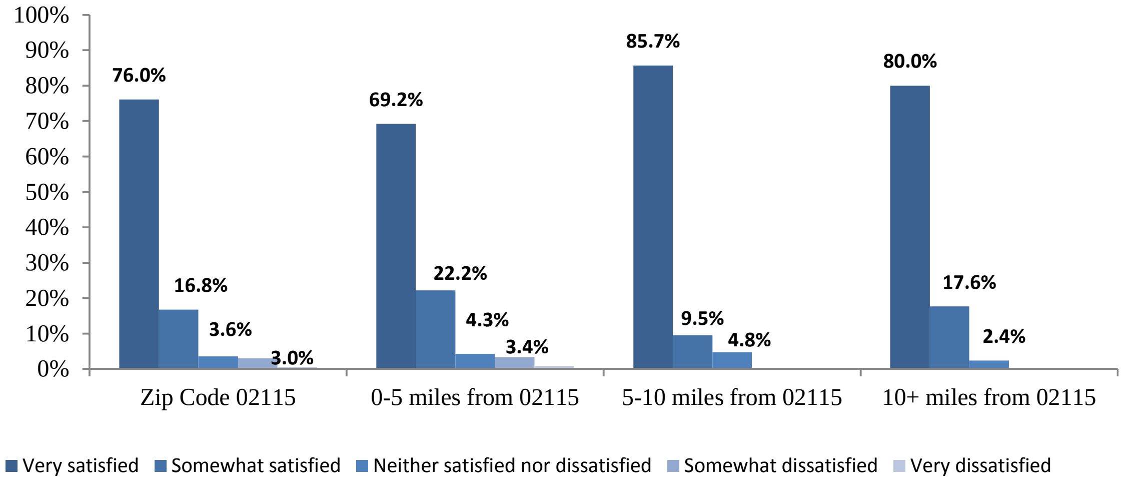


Figure 56. Chart. Satisfaction with the Fast 14 project by residence proximity to construction zone (N=411).

Opinions on Construction Methods

When presented with a brief description of the ABC and conventional construction methods and asked which construction method they would prefer, 83 percent of survey respondents said that they strongly prefer ABC, and only 2 percent said they strongly prefer the conventional construction method (see Figure 57).

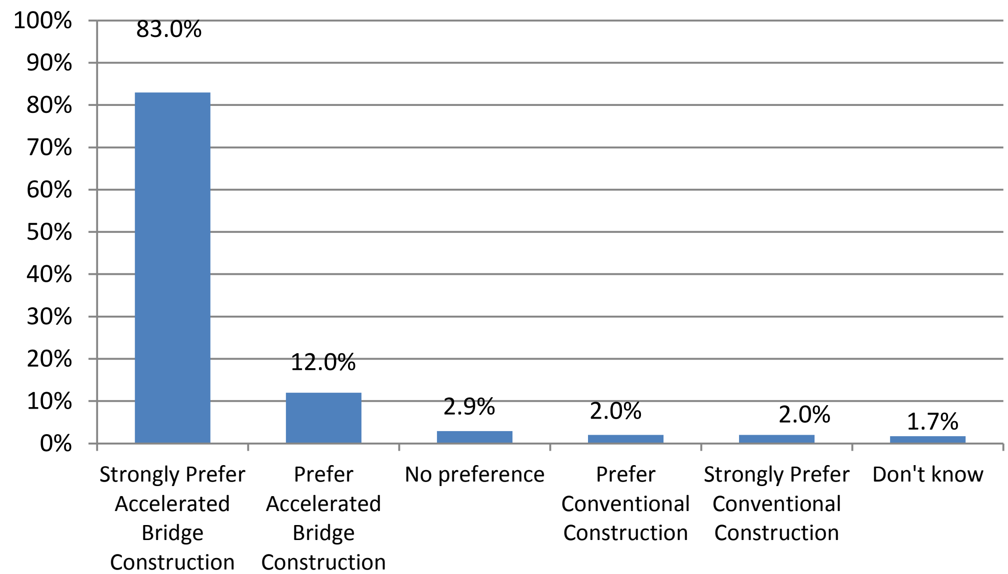


Figure 57. Chart. Construction method preference (N=417).

Those who preferred ABC were asked what they liked about it. As shown in Figure 58, the most common response was that ABC involves a "shorter timeframe," followed closely by "less disruption and/or delays."

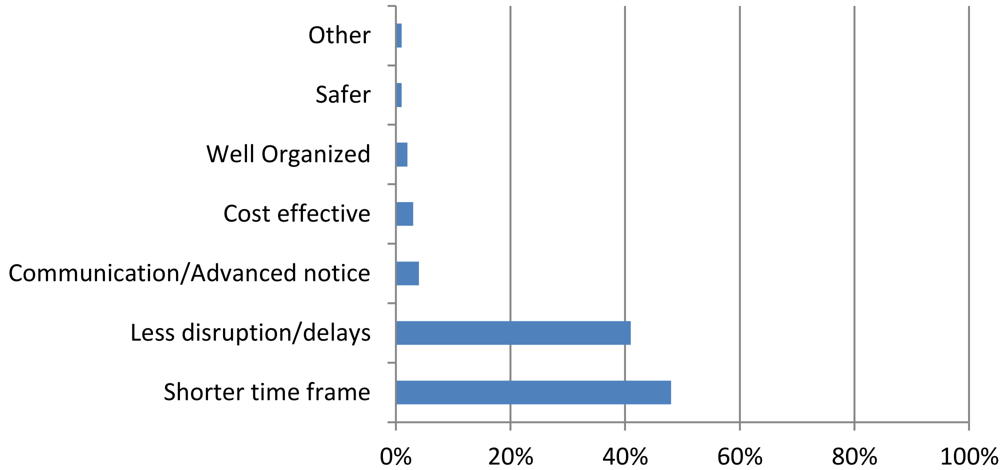


Figure 58. Chart. What do you like about accelerated bridge construction? (N=421)

Impact of I-93 Fast 14 Project on Daily Lives

Survey respondents were asked to rate the impact of the I-93 Fast 14 project on their lives. The reported impact was overwhelmingly positive, with over 77 percent of respondents indicating that the project had either a "very positive" or "somewhat positive" impact on their lives. Figure 59 provides a breakdown of these responses.

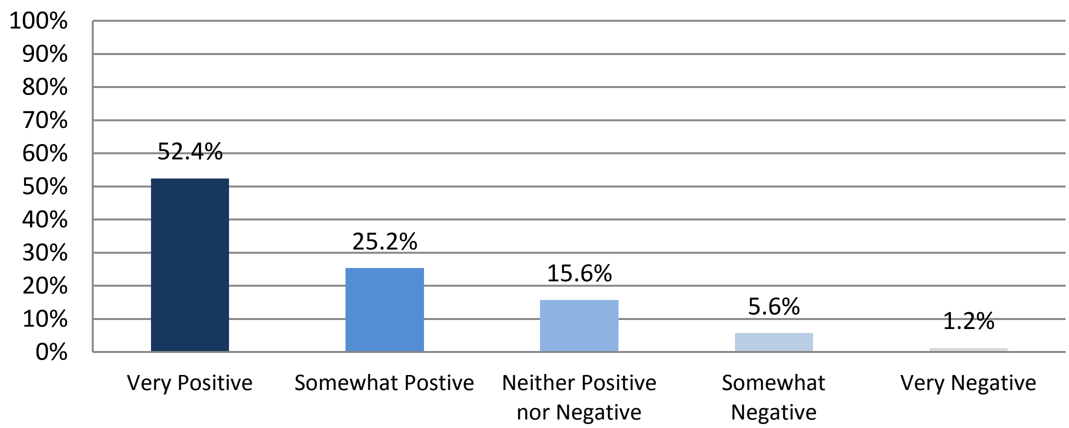


Figure 59. Chart. Impact of the I-93 Fast 14 project (N=416).

Those who indicated that the Fast 14 project has had a positive impact on their lives were asked to indicate the greatest positive impact. As shown in Figure 60, 24 percent thought the road now is less disruptive, 22 percent mentioned that the road is now safer, and 19 percent said that the I-92 corridor in Medford now has a better surface, creating a smooth ride.

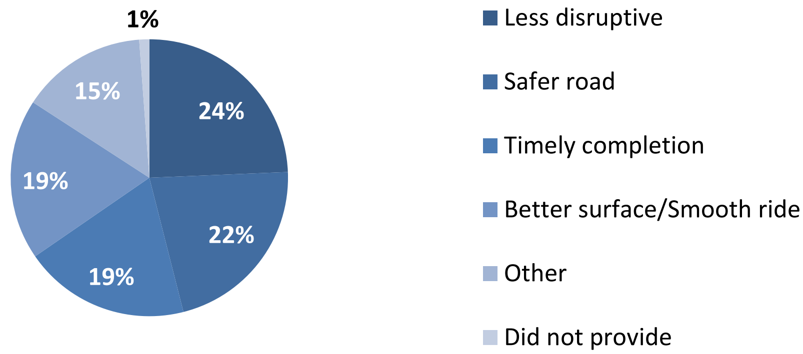


Figure 60. Chart. Distribution of largest positive impact (N=341).

Similarly, those who indicated the Fast 14 project had a negative impact on their lives were asked to describe the greatest negative impact. As shown in Figure 61, traffic jams and delays were the most frequently reported negative impacts (36 percent), followed by having to learn the detour routes (21 percent) and the noise (20 percent).

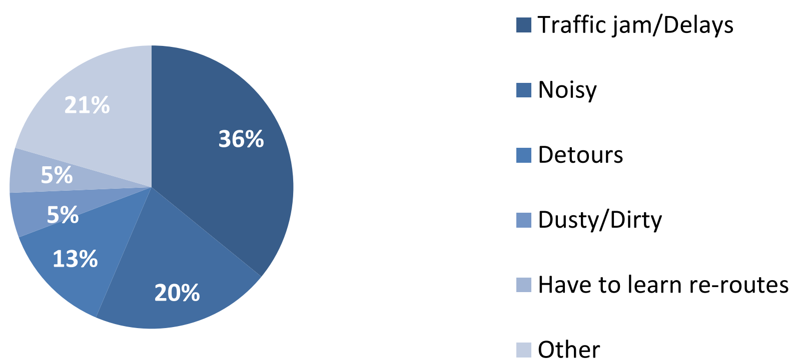


Figure 61. Chart. Distribution of largest negative impact (N=39).

I-93 Fast 14 Project Communications

MassDOT used several methods to get the news out about closings and detours so that local residents, business owners, and road users could be prepared. As shown in Table 15, most of the survey respondents encountered the project website and the electronic signage along the roadway, and about half received the e-mail from 93fast14.info@state.ma.us.

As shown in Figure 62, when asked about the source of information they used to stay informed about construction activities during the construction period (road closures, project schedule, etc.), most survey respondents reported they used the website, the e-mail from MassDOT, or the electronic signage along the roadway.

Table 15. Project-related information sources encountered (multiple response).

Response	Count of Responses	Percent of Respondents
The 93 Fast 14 website	282	70.9
Electronic signage along the roadway	273	68.6

Response	Count of Responses	Percent of Respondents
E-mail from 93fast14.info@state.ma.us	198	49.7
Segments on local television news programs	145	36.4
Items in local newspapers	126	31.7
Traditional signage along the roadway	119	29.9
“Reverse 911” phone calls	110	27.6
Project coverage on the radio	87	21.9
FastLane reminder e-mail	66	16.6
Billboard	48	12.1
MassDOT blog	39	9.8
Public hearing or public information session	33	8.3
Article in newsletter (from any organization)	32	8.0
Flyer	30	7.5
Twitter	29	7.3
Other community meeting or stakeholder briefing	22	5.5
Information on public access television	18	4.5
511 or Sendza	13	3.3
YouTube	9	2.3
Flickr	8	2.0
Sign on bus or at bus stop	6	1.5
Handout at tollbooth	6	1.5
Poster at FastLane office or rest area	5	1.3
Through a place of worship	3	0.8
Other (specify)	15	3.8

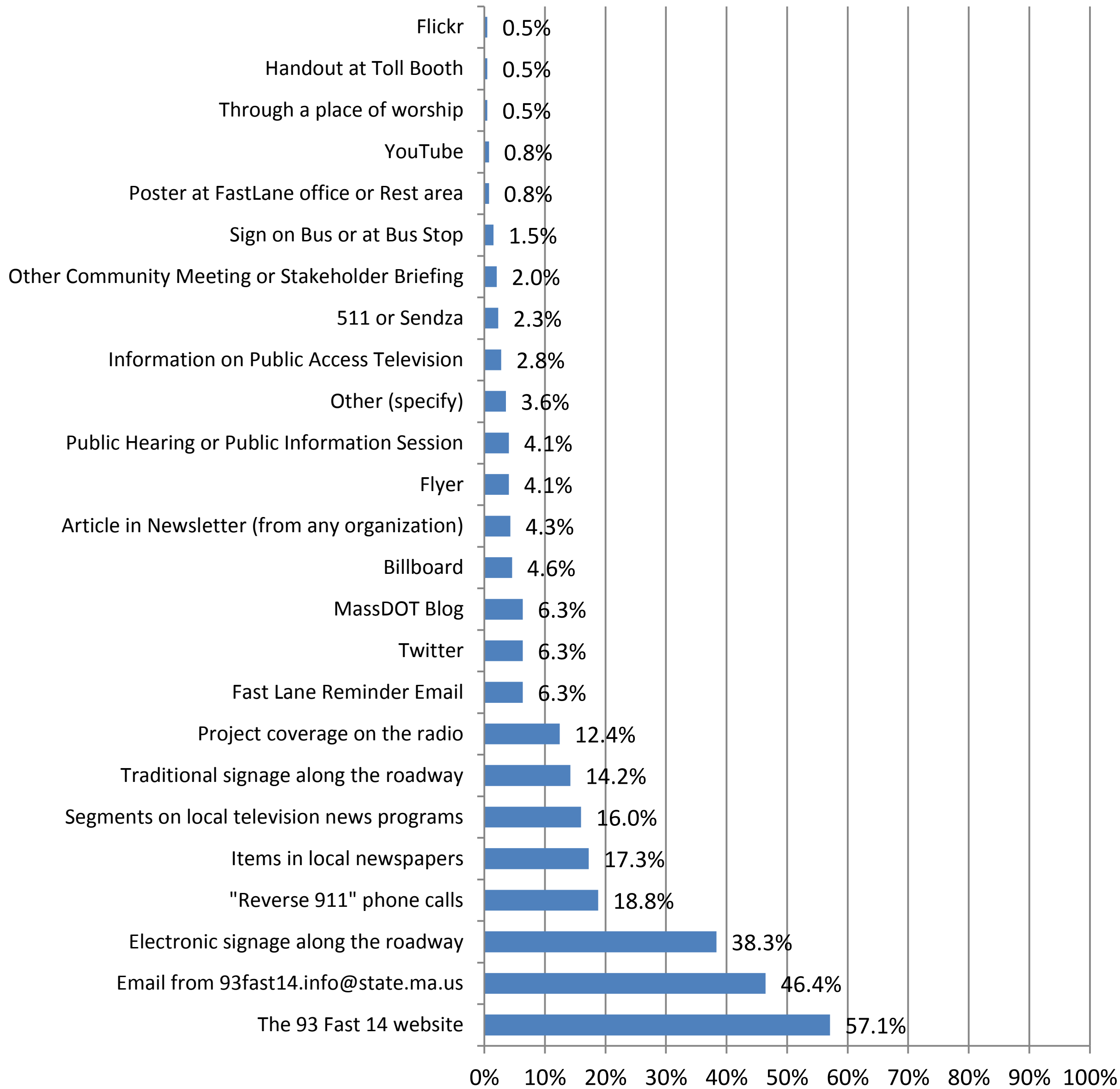


Figure 62. Chart. Information sources used to keep informed (multiple response).

As shown in Figure 63, the greatest number of respondents (38 percent) utilized project information to learn about road closures and traffic detours or to learn about the project schedule (26 percent).

Overall, residents reported being very satisfied with the information they received about the project. Fewer than 1 percent of survey participants indicated that they were very dissatisfied with the project information received. Figure 64 provides a breakdown of these responses.

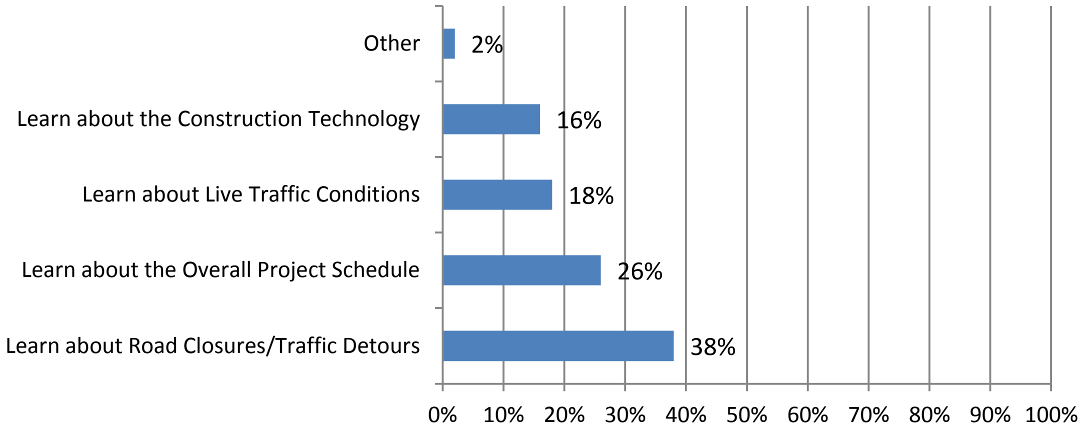


Figure 63. Chart. For what purposes did you utilize project information? (multiple response)

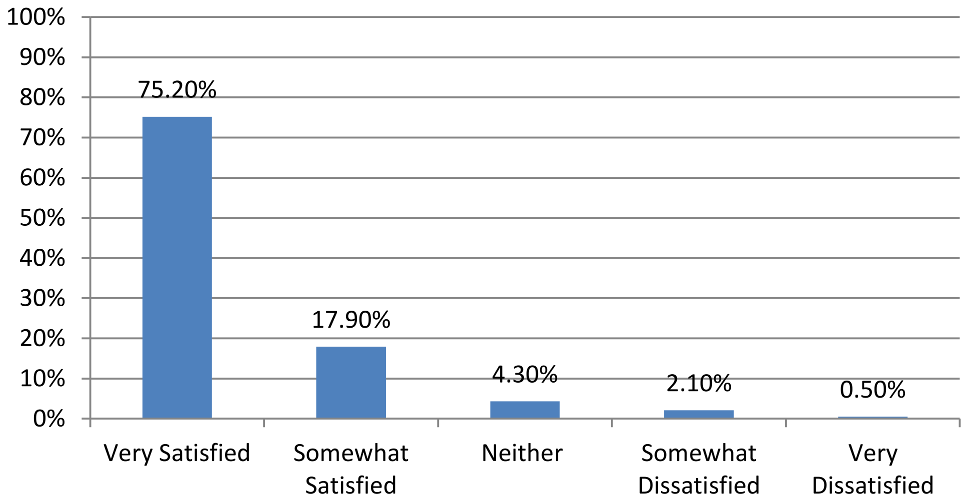


Figure 64. Chart. Satisfaction with project information (N=419).

When asked about the helpfulness of project information in terms of helping to prepare for construction, local road closures, detours, or traffic conditions, respondents indicated overwhelmingly that information was very helpful. As shown in Figure 65, just over 3 percent said that the information could have been more helpful.

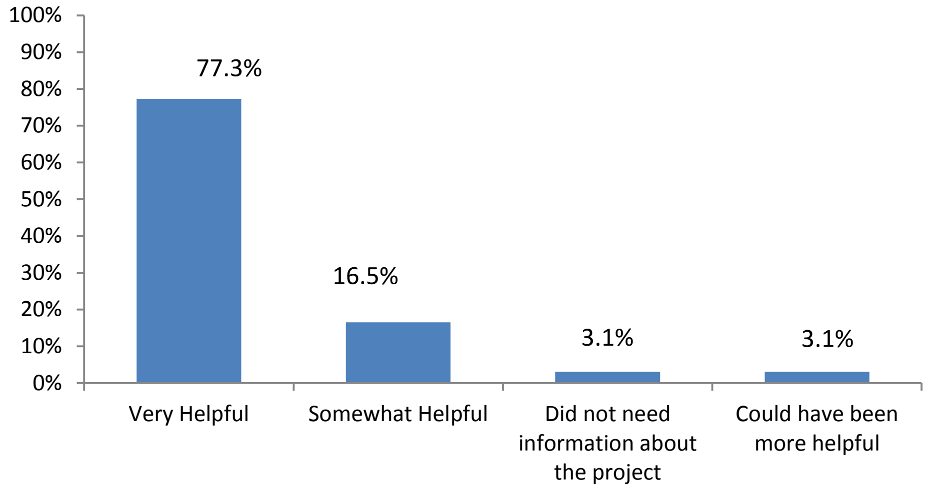


Figure 65. Chart. Helpfulness of project information (N=419).

As shown in Figure 66, participants residing farther from the construction reported that the project information provided was very useful. Four percent of those living within the same zip code, and 4 percent residing up to 5 miles from the construction, reported that the information could have been more helpful.

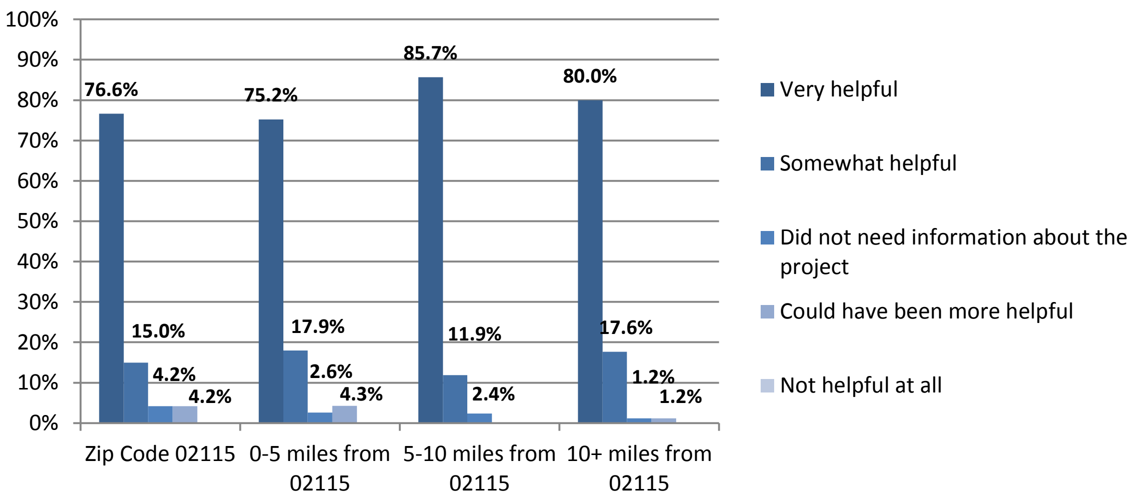


Figure 66. Chart. Perception of project information by residence proximity to construction zone (N=411).

Most of the survey respondents were frequent user of I-93, and of those, most used this portion of I-93 for driving through Medford.

Overall, survey participants reacted positively to the Fast 14 project and the results of the roadway improvements. Seventy-eight percent reported being very satisfied, and only 1 percent indicated they were very dissatisfied with the condition of I-93 in Medford now, compared to its previous condition.

Nearly all participants indicated a strong preference for ABC methods over the conventional construction approach. The only residents who gave any level preference for the conventional construction were residents from within the 02115 zip code, or those residing up to 5 miles from zip code 02115.

MassDOT undertook a comprehensive plan for informing area residents, businesses, and users of I-93 about the construction project, delays, schedule, etc. The survey results showed that 75 percent of respondents were very satisfied with the project-related information they received. The perceived usefulness of this information seemed to correlate with the distance between the respondent's zip code and the construction. Participants residing between 5 and 10 miles from the construction site reported that the project information provided was very useful. In contrast, 4 percent of those living within the same zip code, and 4 percent residing up to 5 miles from the construction, reported that the information could have been more helpful.

The survey showed that the most encountered information outlets were the Fast 14 website, the electronic signage along the roadway, and an e-mail sent from MassDOT. Primarily, respondents used the information provided to learn about road closures and traffic detours.

DURABILITY

The PMSEs are expected to be more durable than traditional cast-in-place construction since the units were fabricated in a factory setting and the concrete was able to cure in an ideal, controlled environment. Each bridge deck was post-tensioned at the piers and connected laterally with closure pours making the deck a continuous span, eliminating the joints that lead to deterioration.

TECHNOLOGY TRANSFER

To promote the innovations used on this project—prefabricated bridge elements, D-B project delivery, and incentive/disincentive clauses—MassDOT, in conjunction with the FHWA, sponsored a 2-day showcase. The showcase was held July 16 and 17, 2011, at the Seaport Hotel in Boston. The event was moderated by Pamela Stephenson, Division Administrator of the FHWA Massachusetts Division, and included featured presentations by representatives of the FHWA, MassDOT, White-Kiewit JV, and ARA. The showcase included a visit to the project site to observe the weekend work on I-93 northbound bridge over Route 16. MassDOT also briefed the participants on successful deployment of innovations in this project. The showcase attracted approximately 150 attendees from Federal and State DOTs, transportation authorities, consultants, contractors, and suppliers. The showcase agenda is presented in appendix B.

Ms. Stephenson welcomed the participants and provided the introductory remarks. She also gave an overview of the FHWA's HfL and Every Day Counts (EDC) goals and initiatives. Highlighting the FHWA Massachusetts Division's efforts on HfL and EDC initiatives, she mentioned about the joint coordination team consisting of 20 representatives from the FHWA Division and MassDOT, as well as the deployment plans they have developed. Ms. Stephenson remarked that the I-93 Fast 14 project was selected as a HfL project because of its commitments to meeting the HfL performance goals.

> "*What we're trying to do nationwide is find a different way to build. These technologies help keep traffic moving, which lets people spend less time in their cars and have more time doing the things they enjoy*."
>
> Mr. Victor Mendez, Administrator, FHWA.

Mr. Victor Mendez, Administrator, FHWA, provided the opening remarks. He said, "This Fast 14 project is a great example of how you can literally take years off the time it takes to replace 14 bridges and do it while tens of thousands of motorists go about their daily routines." He said that the purpose of his visit is to observe the innovations used in this project and implement them all over the country. Mr. Jeffrey Mullan, Secretary and Chief Executive Officer of MassDOT, highlighted the success of the agency's Accelerated Bridge Program, an historic $3 billion investment initiative to repair the Commonwealth's structurally deficient bridges. Under this program, MassDOT has reduced the number of structurally deficient bridges from 543 to 458, a decrease of almost 16 percent.

> "*It is being rebuilt a lot quicker than it was built the first time, so the process is working. Everyone is doing a great job*."
>
> Mr. Michael McGlynn, Mayor, Medford.

Mr. Benjamin Beerman of FHWA provided a national perspective on ABC. He outlined the current EDC initiatives and summarized the benefits of ABC with examples. Highlighting the FHWA's prefabricated bridge elements and systems (PBES) deployment goals, he discussed how FHWA supports the deployment of ABC/PBES through regional peer exchanges, incentive funded programs, web resources webinars, ABC/PBES guides and manuals, and other research efforts.

MassDOT provided an overview on the agency's Accelerated Bridge Program (ABP). The presentation discussed the goals of the ABP, the improvement in bridge condition since its inception, and its contribution to Massachusetts' economic development and job creation. The presentation also highlighted key technologies or innovations used in these projects such as precast arch bridges, precast bridge elements, NEXT beam and bridge in a backpack.

MassDOT also provided an overview of the I-93 Fast 14 project from the perspective of Design-Build project delivery. The overview presentation outlined the mission and goals of the project as well as the reasons for selecting accelerated bridge construction over conventional construction. The presentation also included a brief discussion on the project work plan. Following this presentation, the showcase participants departed for the project site visit. Prior to boarding the bus shuttles, Mr. Ernie Monroe, Resident Engineer of MassDOT, and Mr. Marty Golden, Chief Safety Officer of White-Kiewit JV, briefed the participants on safety guidelines. The participants spent their time at the project site for the rest of the day.

> "*Between last year and right now, we went from identifying the project, developing specifications, putting out to bid, selecting the contractor, designing the contract and getting out here. This is our sixth weekend and never have we turned it around this quick*."
>
> Mr. Michael McGrath, Deputy Chief Engineer for Construction, MassDOT.

Mr. Greg Doyle, Construction Quality Engineer, FHWA, served as the moderator on Day 2. Welcoming the participants, he presented an overview of the proceedings of Day 2. The presentations and discussions on Day 2 focused on how the HfL performance goals were met on this project.

White-Kiewit JV provided an overview of the strategies implemented in this project to ensure worker safety. Mr. Joseph Gill, President, Gill Engineering, presented a discussion on safety features of the new facility including bridge barrier system, guard rail transitions and temporary barriers. Mr. Neil Boudreau, State Traffic Engineer, MassDOT, provided an overview of traffic management strategies to ensure work zone safety. He also presented the statistics indicating the crash history prior to construction. Mr. Boudreau outlines various strategies implemented in this project including movable barriers, crossover considerations, speed limit, access points, and emergency response/incident management.

Mr. Paul Moyer, Quality Control Administrator, White-Kiewit JV, presented an overview of the D-B Quality Control system. This presentation included a discussion of the Quality Management Plan and its development. Mr. Moyer discussed at length the key components of the QMP, including the organizational setup, roles and responsibilities, procedures of design Quality Control and construction Quality Control, and document management. Mr. Jim Cahill, Assistant Project Manager, White-Kiewit JV, presented a discussion on the PMSE fabrication process, transport, and delivery to job sites and pre-installation procedures. His discussion also touched upon various QC activities undertaken during this process.

Mr. Murthy Kolla (District 4 Design-Build Project Manager), Mr. Paul Maloy (District 4 Construction Engineer) and Mr. John Grieco (Director of Research and Materials) gave an overview of MassDOT's process for design and construction Acceptance, including over-the-shoulder review of contractor designs, formal review of design submittals, field inspection, and materials testing and sampling.

During lunch on Day 2, MassDOT gave a presentation on the agency's D-B program. The presentation included various aspects of D-B, including legislative authority, criteria for selecting D-B for project delivery, the procurement process, and related issues. Citing several past D-B projects, MassDOT highlighted the performance benefits of using D-B on these projects (schedule and cost savings). The presentation also included a discussion on the incentive/ disincentive clauses used on the Fast 14 project.

> "*Shortening project delivery is an important initiative throughout the transportation industry. When we implement these innovative ideas at the state level, in partnership with the industry, private sector, federal and state governments, you end up with a safer infrastructure that allows better mobility*."
>
> Mr. Victor Mendez, Administrator, FHWA

After lunch, Dr. Jagannath Mallela, Principal Engineer, ARA, presented the results of ride quality and noise prior to condition and HfL goals associated with them. Mr. Chris Calnan of Tetra Tech, Inc. and Mr. Peter Rapp of White-Kiewit JV presented design details on pavement approaches including pavement design, specifications, and strategies to improve noise and smoothness.

Mr. Boudreau gave an in-depth presentation of MassDOT's traffic management plans and activities undertaken in this project to manage traffic operations and work zone congestion. His presentation provided in-depth details on crossover design, movable barriers, detour routes, RTTM, emergency and incident management, the coordination with State police, MIVIS, and other outreach activities.

Eliza Partington, Accelerated Bridge Program Technical Coordinator, provided a discussion on various measures undertaken for outreach and communication. She highlighted the goals and development of the CCP. She discussed various activities of the project team, including the coordination with key stakeholders and partners. She also outlined various communication measures undertaken through traditional, web, and social media to communicate effectively with the general public.

Mr. Michael Culmo of CME Associates presented the perspectives and lessons learned from the preliminary engineering perspective, including the alternative analysis. Mr. Culmo cited the available timeline for design development, limitations due to the existing deck condition, and traffic management as the key challenges of this project. He cited teamwork between MassDOT and the D-B team as well as the benefits with modular bridge element concepts as primary contributing factors for the success of this project.

Mr. Gill presented the lessons learned from the designer's perspective. According to Mr. Gill, designing the project for the compressed schedule, particularly for the 55-hour closure, was challenging. He stated that the availability of additional time for design would have allowed for more effectiveness and efficiency. He cited the team work coordination between the D-B team and the MassDOT was a positive factor. From the construction perspective, the challenges of this project were the compressed schedule, work coordination, communication, and resource allocation. Mr. Bill Shea of White-Kiewit JV cited the excellent working relationship among the various parties, the union's commitment, and successful materials fabrication and delivery.

In the concluding session of the showcase, MassDOT summarized the following as success factors:

- Trucking all related materials with each panel.
- Deployment of zipper barrier.
- Use of two-way radios.
- Use of SharePoint site for document management.
- Use of State Police Mobile Command.

Ms. Stephenson identified the following factors from the FHWA Massachusetts Division's perspective:

- Good working relationship between the D-B team, MassDOT, and FHWA staff.
- Real-time information sharing among various parties.
- Assigning adequate number of experienced and high-quality staff.
- Weekly progress meetings with over-the-shoulder review breakout sessions between the D-B contractor and MassDOT staff.

ECONOMIC ANALYSIS

A key aspect of HfL demonstration projects is quantifying, as much as possible, the value of the innovations deployed. This involves comparing the benefits and costs associated with the innovative project delivery approach adopted on an HfL project with those from a more traditional delivery approach on a project of similar size and scope. The latter type of project is referred to as a baseline case and is an important component of the economic analysis. For this economic analysis, MassDOT supplied the construction time estimates cost figures for the both cases.

CONSTRUCTION TIME

The Project Controls Unit of the MassDOT Accelerated Bridge Program analyzed possible scenarios of two different delivery methods (D-B and design-bid-build) and two alternative construction sequences to estimates the contract duration if this project had been constructed using a more traditional method. The possible scenarios include the following:

- Scenario 0 – D-B “Fast 14” (i.e., as-built scenario).
- Scenario 1 – design-bid-build 3 distinct construction teams.
- Scenario 2 – D-B 3 distinct construction teams.
- Scenario 3 – design-bid-build 7 distinct construction teams.
- Scenario 4 – D-B 7 distinct construction teams.

The construction sequence “7 distinct construction teams” indicates that each bridge would be constructed using a distinct and separate team. The sequence “3 distinct construction teams” indicates that bridges 1, 2, and 3 would be constructed using one team; bridges 4, 5, and 6 would be constructed using a second distinct team; and, owing to its larger size, bridge 7 would be constructed using a third distinct team.

Tables 16 and 17 present the time estimates for completion of the design and construction phases, respectively, for different scenarios. Figure 67 shows a comparison of project duration from 25 percent design complete to construction completion for five different construction alternatives.

From an assumed date of December 2, 2010, for 25 percent design complete, the selection of D-B for project delivery would have taken 2 months to issue a notice to proceed, while the selection of design-bid-build would have taken 19 months to issue a notice to proceed. Using traditional construction methods with 3 or 7 distinct construction teams would have taken 4 to 5 construction seasons (39 to 48 months) to complete construction from the notice to proceed issue date. Depending on the alternative selected, traditional alternatives would have taken 42 to 67 months, or an additional 31 to 56 months more than the as-built alternative, to complete both design and construction phases.

Based on the alternatives analysis, the Project Controls Unit recommended scenario 1 as the most reasonable and likely alternative, if the I-93 Fast 14 project were constructed using traditional construction alternatives.

Table 16. Time estimates for design completion.

Case	Description	25% Design Complete	Notice to Proceed	Duration (25% Design Complete to NTP)	
				Calendar Days	Months
Scenario 0	D-B "Fast 14"	12/2/2010	2/4/2011	64	2
Scenario 1	design-bid-build 3 distinct teams	12/2/2010	6/29/2012	575	19
Scenario 2	D-B 3 distinct teams	12/2/2010	2/8/2011	68	2
Scenario 3	design-bid-build 7 distinct teams	12/2/2010	6/29/2012	575	19
Scenario 4	D-B 7 distinct teams	12/2/2010	2/8/2011	68	2

Table 17. Time estimates for construction completion.

Case	Description	Notice to Proceed	Construction Completion	Duration (NTP to Completion)		
				Calendar Days	Months	Seasons
Scenario 0	D-B "Fast 14"	2/4/2011	11/15/2011	284	9	1
Scenario 1	design-bid-build 3 distinct teams	6/29/2012	7/6/2016	1468	48	5
Scenario 2	D-B 3 distinct teams	2/8/2011	10/21/2014	1351	44	4
Scenario 3	design-bid-build 7 distinct teams	6/29/2012	9/22/2015	1180	39	4
Scenario 4	D-B 7 distinct teams	2/8/2011	6/16/2014	1224	40	4

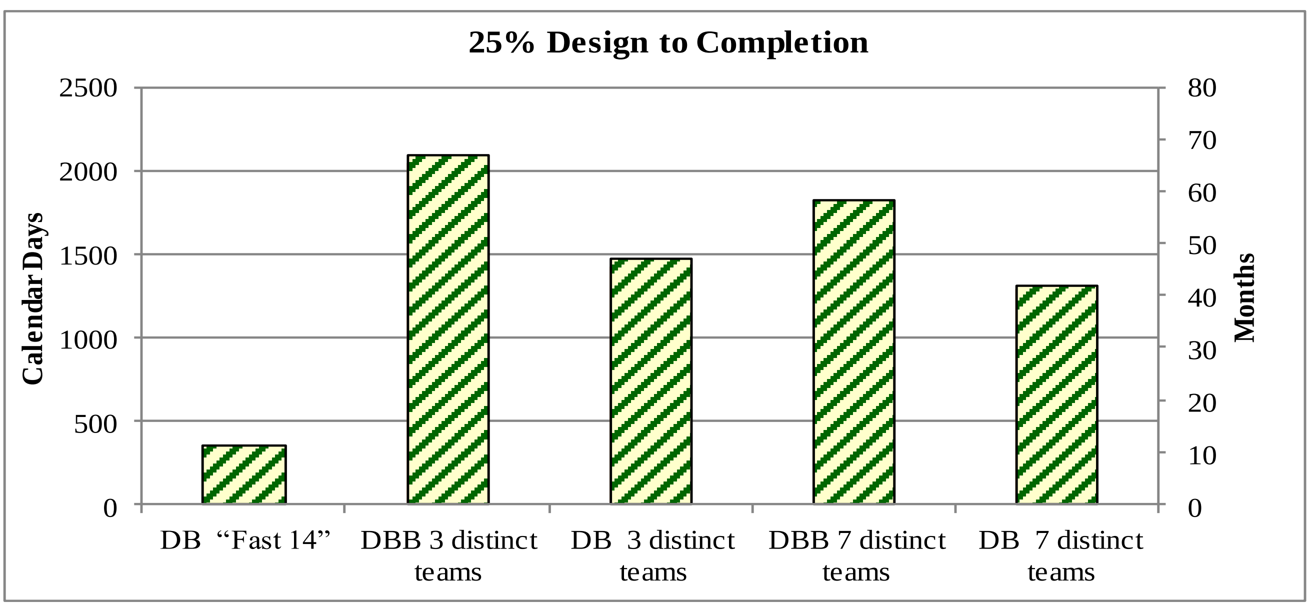


Figure 67. Chart. Comparison of project durations from 25 percent design to construction completion for different alternatives.

This scenario would require a total project duration of 67 months (5 ½ years) to proceed from 25 percent design or 48 months (4 years) from notice to proceed to completion of construction.

The use of innovations, ABC/PMSE, and D-B saved 56 months of total project duration that included 17 and 39 months for design and construction completion, respectively.

In terms of the total impact time on highway users, the as-built scenario required only 550 hours, while the traditional alternative would have taken 48 months. Time savings on this project far exceeded the HfL performance goal of 50 percent reduction in the time highway users are impacted, compared to traditional methods.

CONSTRUCTION COSTS

The Project Controls Unit also provided the cost estimates for both as-built and traditional alternatives; the actual costs specified in the bid award were used for the as-built case, while a bottom-up independent cost estimate was utilized for the traditional alternative.

The bid award included costs for design, fabrication, transport, and installation of PMSE bridge panels and traffic control for each of the 14 bridges constructed over 10 weekends. The cost estimate for the traditional alternative assumed construction of 14 bridges in 5 stages, cast in-place deck construction over bearings and steel beams in regular working hours, and the use of single lane closure for 48 months of construction.

Error! Reference source not found. presents a comparison of assumptions used in the onstruction cost estimates of the two construction methods. Note that the cost estimate for the traditional alternative included an anticipated annual escalation rate of 3.5 percent for 3 additional years of construction. The cost estimate for the traditional alternative assumed that a design-bid-build contract would be issued to a single contractor for constructing all 14 bridges with no special incentive/disincentive clauses applicable for early completion. In addition, MassDOT would incur an estimated 5 percent of construction costs for preliminary engineering, design and construction engineering work.

Error! Reference source not found. presents a comparison of 2011 construction costs of the raditional and the as-built alternatives. The as-built total cost was $1,749,039 or 1.96 percent more than the traditional alternative.

Table 18. Comparison of assumptions used in construction cost estimates.

Construction Method	As-built Alternative	Traditional Alternative
Contract Delivery Method	D-B	Design-bid-build
Construction Duration	3 months	48 months = 208 weeks
Superstructure Design	Similar for all 14 bridges	Similar for all 14 bridges
MassDOT & Engineering Costs	Actual costs	5% of estimate

Construction Method	As-built Alternative	Traditional Alternative
Escalation	included in D-B bid	for 3 years @ 3.5%

Table 19. Capital cost calculation table.

	As-built Alternative	Traditional Alternative
Roadway Items	$12,550,100	$11,798,087
Bridge Items including Design Costs & Fee	$61,200,000	$59,180,157
MassDOT & Engineering costs*	$ 3,783,799	$ 3,940,180
Maximum Incentives [#]	$ 7,000,000	$ 0
Miscellaneous Costs[‡]	$6,500,000	$6,500,000
Escalation[+]	Included in the bid	$ 7,866,435
Total	$91,033,898	$89,284,859
Difference	$1,749,039 or 1.96 percent	

Notes:

[‡] Miscellaneous costs included costs for police, fire services, reinforced concrete excavation, price adjustments, extra work orders, rapid set gypsum concrete, substructure repairs.

[*] The engineering costs were assumed at 5 percent of total cost estimate for the traditional alternative, whereas, for the as-built alternative for the actual costs are presented.

[#] Incentives are not included for traditional alternative.

[+] Escalation costs for the traditional alternative were estimated at 3.5 percent for over a 3-year period, whereas the escalation for the as-built alternative was already built in the D-B bid.

USER COSTS

Generally, the three categories of user costs used in an economic/life cycle cost analysis are vehicle operating costs (VOC), delay costs, and safety-related costs/crash costs. The cost differentials in delay costs and safety costs were considered for comparative analysis of cost differences between the traditional and as-built scenarios. No VOCs were calculated for both scenarios.

User Delay Costs

The user delay cost computation assumed a unit cost of $18.97 per hour per vehicle for travel time delay, as supplied by MassDOT.

As-built Scenario

For the as-built case, the delay time of I-93 traffic over a 55-hour weekend closure was estimated based on the travel time study results presented in Table 12. The computation of user delay costs for the as-built case is presented as follows:

Total delay of I-93 traffic over a weekend = 17,962 vehicle-hours
Total delay of I-93 traffic for the project = 17,962 vehicle-hours/weekend * 10 weekends = 179,620 vehicle-hours
User delay costs for the project = 179, 620 vehicle-hours * $ 18.97/hr = $3,407,391

The estimated user delay costs for the as-built scenario are approximately $3.41 million.

Traditional Scenario

For the traditional scenario, a simple analysis was conducted to estimate user delay costs using the *RealCost* program. The assumptions behind the inputs used in the *RealCost* analysis are as follows:

- Two-way annual average daily traffic (AADT) = 181,000.
- Percent trucks = 3.
- Unit cost for travel delay = $18.97/hr.
- Normal speed limit = 65 mph.
- Normal lane capacity = 2250 (and subsequently adjusted for heavy vehicles).
- Work zone speed limit = 45 mph.
- Traffic control = 3 of 4 lanes open in a single direction and no closure/restrictions in the opposite direction.
- Work zone lane capacity = 1,500.
- Lane closure timing = 9:00 p.m. to 6:00 a.m. (9 hours of closure for standard 8-hr workday).
- Traffic volume during lane closure = 13.2 percent of AADT.
- Work zone length = 4.5 miles.
- Work zone duration = 48 months.

The daily user costs were determined to be $8,235, which represents the cumulative delay costs of affected vehicles for speed reduction and reduced speed. Assuming that the traditional bridge replacement would have taken 48 months, the total road user cost is estimated to be $11,858,105. The total saving in user delay costs between the traditional and as-built cases is as follows:

Savings in user delay cost = $11,858,105 (traditional) - $3,407,391 (as-built) = $8,450,714

MassDOT conducted a separate user cost analysis based on travel delay costs only. Per MassDOT estimates, the potential savings in user delay costs with the use of accelerated techniques is $8.4 million compared to traditional staged, cast in-place construction over 48 months.

Safety Costs

The computation of safety costs involved the following steps:

1. Determine the number of crashes for both as-built and traditional scenarios.

2. Estimate unit crash costs by severity type. Adjust unit costs to current year dollars. Use separate unit crash costs to as-built and traditional scenarios, if necessary.
3. Compute work zone safety costs for both scenarios.

Only the crashes that occurred on the I-93 corridor are considered herein.

Step 1. Determine the Number of Crashes for the Two Scenarios

The actual number of crash incidents for the as-built scenario is presented in Table 8. For the traditional scenario, the expected number of crash incidents was computed by adjusting the annual average number of crashes (based on 2008-2011 crash data) presented in Table 9 for the duration of exposure and elevated risk due to the presence of the work zone.

Ullman et al. (2008) investigated the safety of work zones for various scenarios: (1) crashes during daytime and nighttime work periods when lanes were closed and work was ongoing, (2) crashes when work was ongoing but no closures were required, and (3) crashes when no work was ongoing (the work zone was inactive). They concluded that crashes increased 60 to 66 percent (an average of 63 percent) when a traffic lane was closed day or night.

The expected number of crash incidents by severity type for the traditional scenario is computed as follows:

Number of crashes = Crashes per year prior to construction (from Table 9) * 4 years * 1.63

The number of crash incidents to be used in the safety costs computations is summarized in Table 20 by their severity category for both as-built and traditional scenarios.

Table 20. Number of crashes for safety costs computations.

Crash Severity Category	**Actual Crashes during Construction**	**Average Crashes per Year Prior to Construction**	**Expected Crashes for Traditional Scenario**
Property damage only	24	124.0	808
Non-fatal injury	9	68.3	445
Fatal injury	0	1.7	11

Step 2. Estimate Unit Crash Costs by Severity Type

Since the monetary values of crash incidents were not available, the national average values were used to monetize difference in safety performance between the two scenarios. The unit crash costs as reported in the FHWA report, *Crash Cost Estimates by Maximum Police-Reported Injury Severity within Selected Crash Geometries*, serves as a comprehensive resource for obtaining average human capital and comprehensive costs (Council et al, 2005). The crash cost estimates presented in the FHWA report were in 2001 dollars and were adjusted to current year dollars using the Bureau of Labor Statistics indices: Consumer Price Index (CPI) and Employment Cost Index (ECI).

For the as-built scenario, the work zone was in place between June and August 2011; hence, the CPI and ECI values for this period were used to adjust unit crash costs. **Error! Reference ource not found.** presents the mean human and comprehensive crash costs in 2011 dollars for use in safety costs computation for the as-built scenario.

For the traditional scenario, the expected start date of construction was June-July 2012, and the construction was expected to last for 4 years. Therefore, to update unit crash costs to current year dollars, the average CPI and ECI values for the period between July 2012 and November 2013 were used. Table 22 presents the mean human and comprehensive crash costs in 2012 dollars for use in safety costs computation for the traditional scenario.

Table 21. Mean human and mean comprehensive costs for the as-built scenario.

Crash Cost Category	**Human Costs[a]**		**Comprehensive Costs[b]**	
	2001 dollars	**2011 dollars**	**2001 dollars**	**2011 dollars**
Property damage only	$6,497	$8,277	$7,800	$10,025
Non-fatal injury	$52,569	$66,970	$98,752	$128,924
Fatal injury	$1,277,640	$1,627,653	$4,106,620	$5,422,666

Notes:
[a] human costs of crashes were converted from 2001 to 2011 dollars using a CPI adjustment factor of 1.274
[b] the differential amount between comprehensive and human costs of crashes were converted from 2001 to 2013 dollars using an ECI adjustment factor of 1.341.

Table 22. Mean human and mean comprehensive costs for the traditional scenario.

Crash Cost Category	**Human Costs[c]**		**Comprehensive Costs[d]**	
	2001 dollars	**2012-13 dollars**	**2001 dollars**	**2012-13 dollars**
Property damage only	$6,497	$8,513	$7,800	$10,319
Non-fatal injury	$52,569	$68,882	$98,752	$132,877
Fatal injury	$1,277,640	$1,674,112	$4,106,620	$5,594,200

Notes:
[c] human costs of crashes were converted from 2001 to 2012-13 dollars using a CPI adjustment factor of 1.310
[d] the differential amount between comprehensive and human costs of crashes were converted from 2001 to 2012-13 dollars an ECI adjustment factor of 1.386.

Step 3. Estimate Work Zone Safety Costs

For the as-built scenario, the safety costs are computed by multiplying the actual number of crashes presented in Table 20 by the unit costs presented in Table 21. Similarly, for the traditional scenario, the safety costs are computed by multiplying the actual number of crashes presented in Table 20 with unit costs presented in Table 22. The computed work zone safety costs for both scenarios are presented in Table 23.

As indicated in the table, the estimated safety costs for the as-built scenario are much lower than those of the traditional scenario. The use of innovations in the as-built scenario has resulted in safety cost savings of approximately $127.6 million.

Table 23. Summary of work zone safety costs computations.

Crash Category	**As-built Scenario**			**Traditional Scenario**		
	Number of Incidents	Cost per Incident	Total Costs by Category	Number of Incidents	Cost per Incident	Total Costs by Category
PDO	24	$10,025	$240,596	808	$10,319	$8,337,492
Non-fatal injury	9	$128,924	$1,160,315	445	$132,877	$59,130,400
Fatal injury	0	$5,422,666	$0	11	$5,594,200	$61,536,199
Total	$1,400,910			$129,004,090		
Difference	$127,603,180					

User Costs Summary

As indicated earlier, the user costs are the sum of user delay and safety costs.

Total user costs for the as-built scenario = user delay costs + safety costs
= $3,407,391 + $1,400,910
= $4,808,301

Total user costs for the traditional scenario = user delay costs + safety costs
= $11,858,105 + $129,004,090
= $140,862,195

Savings in user delay cost = $140,862,195 (traditional) - $4,808,301 (as-built) = $136,053,894

In comparison with traditional staged and cast in-place construction, the estimated savings in user costs with the use of accelerated construction techniques are $136 million, or 96.6 percent lower.

COST SUMMARY

From a construction cost standpoint, the ABC delivery approach cost the MassDOT $1.75 million or 1.96 percent more than the traditional alternative but reduced the traffic impact time from 4 years to ten 55-hour weekends. The selection of ABC over traditional staged and cast in-place construction resulted in the user cost savings of approximately $136 million, or 96.6 percent.

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APPENDIX A — USER SATISFACTION SURVEY QUESTIONS

I-93 FAST 14 SURVEY, WEB VERSION

INTRO Thank you for taking the time to complete this short survey about recent bridge reconstruction along I-93 in Medford, MA. The project is known as 93 Fast 14. Your responses are valuable for guiding MassDOT's future construction planning. **This survey should take less than 5 minutes to complete.**

Q01 Now that the construction is complete, overall how satisfied are you with the condition of I-93 in Medford now compared to its previous condition?

1 Very satisfied
2 Somewhat satisfied
3 Neither satisfied nor dissatisfied
4 Somewhat dissatisfied
5 Very dissatisfied

Q02 This project used an innovative construction method called **Accelerated Bridge Construction**. Please read the following and let us know which construction method you prefer.

- **Accelerated Bridge Construction** enabled MassDOT to perform all work on I-93 during off-peak hours. The bridges were demolished and replaced during ten weekends, requiring closure on half the highway in Medford between 8 PM on Fridays and 5 AM on Mondays. All other bridge work, such as paving, was completed in nine months.
- **Conventional Construction**, which was not used, would have taken at least four years, during which traffic would have been continually disrupted—including during rush hours—by shifting lanes, narrowed lanes, ramp closures, and work zones within the highway.

1 Strongly prefer **Accelerated Bridge Construction**→Continue to Q04
2 Prefer **Accelerated Bridge Construction** →Continue to Q04
3 I don't have a preference→Skip to Q05
4 Prefer **Conventional Construction** →Skip to Q03
5 Strongly prefer **Conventional Construction** →Skip to Q03
6 I do not know which I prefer. →Skip to Q05

Q03 What is it that you like about **Conventional Construction** compared to **Accelerated Bridge Construction**?

1 VERBATIM→Skip to Q05

Q04 What is it that you like about **Accelerated Bridge Construction** compared to **Conventional Construction**?

1 VERBATIM→Continue to Q05

Q05 Which best describes how often you use the portion of I-93 that goes through Medford, Massachusetts?

1 Almost every day
2 Several times a week
3 Once a week or less
4 Once a month or less
5 I never use this section of I-93→Skip to Q07

Q06 Which best describes the reason you use the portion of I-93 that goes through Medford, Massachusetts?

1 I use it primarily for local travel within Medford and the surrounding communities
2 I use it regularly for travel through Medford to somewhere else as part of my daily life (such as commuting, going to school, etc.)
3 I use this it irregularly for travel through Medford to somewhere else (recreational travel, visiting family, vacation travel, etc.)
4 I use it as part of my job or for my business. I am a commercial driver or local business owner.
5 I ride a bus that travels on I-93 in Medford
6 I don’t use I-93, but I live near it in Medford
7 I don’t use I-93 or live in Medford

Q07 Which best describes how often you drive on local roads (not I-93) in Medford, excluding construction related detours?

1 Almost every day
2 Several times a week
3 Once a week or less
4 Once a month or less
5 I never use local Medford roads→Skip to Q09

Q08 Which best describes how you use local roads (not I-93) in Medford, excluding construction related detours?

1 I use them primarily for local travel within Medford and the surrounding communities
2 I use them regularly for travel through Medford to somewhere else as part of my daily life (such as commuting, going to school, etc.)
3 I use them irregularly for travel through Medford to somewhere else (recreational travel, visiting family, vacation travel, etc.)
4 I use them as part of my job or for my business. I am a commercial driver or local business owner
5 I ride a bus that uses local roads in Medford
6 I don’t use local roads much, but do live in Medford
7 I don’t use local roads or live in Medford

Q09 How would you rate the impact of the 93 Fast 14 project on your life?

1 Very positive→Continue to Q10
2 Somewhat positive →Continue to Q10
3 Neither positive nor negative →Skip to Q12
4 Somewhat negative→Skip to Q11
5 Very negative→Skip to Q11

Q10 What was the largest positive impact?

1 VERBATIM→Skip to Q12

Q11 What was the largest negative impact?

1 VERBATIM→Continue to Q12

Q12 MassDOT used several methods to get the news out about closings and detours so that local residents, business owners and road users could be prepared. Which of the following sources f project information did you encounter? (Check all that apply)

1 The 93 Fast 14 website
2 Segments on local television news programs
3 Items in local newspapers
4 Project coverage on the radio
5 Electronic signage along the roadway
6 Traditional signage along the roadway
7 Flyer
8 Information on Public Access Television
9 “Reverse 911” phone calls
10 Public Hearing or Public Information Session
11 Other Community Meeting or Stakeholder Briefing
12 Email from 93fast14.info@state.ma.us
13 Billboard
14 Fast Lane Reminder Email
15 Article in Newsletter (from any organization)
16 511 or Sendza
17 Sign on Bus or at Bus Stop
18 Through a place of worship
19 Poster at FastLane office or Rest area
20 Handout at Toll Booth
21 Twitter
22 YouTube
23 Flickr
24 MassDOT Blog
97 Other (specify)

Q13 Which, if any, did you use to keep informed about construction activities (road closures, project schedule, etc.) during the construction period?
CHECK ALL→ONLY OPTIONS SELECTED DURING Q12

Q14 For what purposes did you utilize project information? (check all that apply)

1 Learn about road closures and traffic detours
2 Learn about live traffic conditions
3 Learn about the overall project schedule
4 Learn about the construction technology
97 Other (specify)

Q15 How satisfied are you with the information you received about the project?

1 Very satisfied
2 Somewhat satisfied
3 Neither satisfied nor dissatisfied
4 Somewhat dissatisfied
5 Very dissatisfied

Q16 How helpful was the project information in preparing you for construction, local road closures, detours, or traffic conditions?

1 Very helpful
2 Somewhat helpful
3 Did not need information about the project
4 Could have been more helpful
5 Not helpful at all

Q17 IF Q15>3: What could have been improved about communications to make it more useful for you?

1 VERBATIM

Q18 Please provide a few pieces of basic information for the survey.

AGE Age: PULLDOWN
GENDER Gender: RADIO
HZIP Your home Zip Code VERBATIM

THANK Thank you for your time in taking this survey—your input is valuable and will guide our efforts in the future. If you'd like to participate in future outreach efforts, please provide your name and email below:

EMAIL Email VERBATIM
RESPF First Name VERBATIM
RESPL Last Name VERBATIM
1 SUBMIT SURVEY→Redirect to http://93fast14.dot.state.ma.us/

14. How satisfied are you with the information you received about the project?

- ○ Very satisfied
- ○ Somewhat satisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat dissatisfied
- ○ Very dissatisfied

15. How helpful was the project information in preparing you for construction, local road closures, detours, or traffic conditions?

- ○ Very helpful
- ○ Somewhat helpful
- ○ Did not need information about the project
- ○ Could have been more helpful
- ○ Not helpful at all

16. How could the project information have been improved?

17. What is your age?

- ○ Younger than 18
- ○ 18–24
- ○ 25–34
- ○ 35–44
- ○ 45–54
- ○ 55–64
- ○ 65+ years

18. What is your gender?

- ○ Female
- ○ Male

19. What is your home zip code?

Thank you for your time! Your input is valuable and will guide our efforts in the future. If you'd like to participate in future outreach efforts, please provide your name and email:

First Name: ____________________

Last Name: ____________________

Email: ____________________

BUSINESS REPLY MAIL

FIRST-CLASS MAIL PERMIT NO. 5478 AUSTIN, TX

POSTAGE WILL BE PAID BY ADDRESSEE

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massDOT | 93 FAST 14 I-93 Rapid Bridge Replacement Project

Please complete this short survey about the **93 Fast 14** bridge reconstruction project along I-93 in Medford, MA.

Your responses are valuable for guiding MassDOT's future construction planning.

The survey should only take about 5 minutes.

Proper Mark: ○ ● ○

1. Now that the construction is complete, overall, how satisfied are you with the condition of I-93 in Medford now compared to its previous condition?

- ○ Very satisfied
- ○ Somewhat satisfied
- ○ Neither satisfied nor dissatisfied
- ○ Somewhat dissatisfied
- ○ Very dissatisfied

2. The 93 Fast 14 project used an innovative construction method called Accelerated Bridge Construction. Please read the following and let us know <u>which construction method you prefer</u>.

- **Accelerated Bridge Construction** enabled MassDOT to perform all work on I-93 during off-peak hours. The bridges were demolished and replaced during ten weekends, requiring closure on half the highway in Medford between 8 PM on Fridays and 5 AM on Mondays. All other bridge work, such as paving, was completed in nine months.
- **Conventional Construction**, which was not used, would have taken at least four years. Traffic would have been continually disrupted—including during rush hours—by shifting lanes, narrowed lanes, ramp closures, and work zones on the highway.

- ○ I strongly prefer **Accelerated Bridge Construction** → **Go to Q4**
- ○ I prefer **Accelerated Bridge Construction** → **Go to Q4**
- ○ I don't have a preference → **Go to Q5**
- ○ I prefer **Conventional Construction** → **Go to Q3**
- ○ I strongly prefer **Conventional Construction** → **Go to Q3**
- ○ I don't know → **Go to Q5**

Continue Inside →

Figure 68. I-93 Fast 14 survey – page 1 of print version.

3. Why do you prefer Conventional Construction?

➔ **Go to Q5**

4. Why do you prefer Accelerated Bridge Construction?

5. How often do you use the portion of I-93 that goes through Medford, MA?

- ○ Almost every day
- ○ Several times a week
- ○ Once a week or less
- ○ Once a month or less
- ○ I never use this section of I-93 ➔ **Go to Q7**

6. Why do you use the portion of I-93 that goes through Medford, MA?

- ○ I use it primarily for local travel within Medford and the surrounding communities.
- ○ I use it regularly for travel through Medford to somewhere else as part of my daily life (such as commuting, going to school, etc.).
- ○ I use it irregularly for travel through Medford to somewhere else (recreational travel, visiting family, vacation travel, etc.).
- ○ I use it as part of my job or for my business. I am a commercial driver or local business owner.
- ○ I ride a bus that travels on I-93 in Medford.
- ○ I don't use I-93, but I live near it in Medford.
- ○ I don't use I-93 or live in Medford.

7. How often do you drive on local roads *(not I-93)* in Medford, excluding construction related detours?

- ○ Almost every day
- ○ Several times a week
- ○ Once a week or less
- ○ Once a month or less
- ○ I never use local Medford roads ➔ **Go to Q9**

8. How do you use local roads *(not I-93)* in Medford, excluding construction related detours?

- ○ I use them primarily for local travel within Medford and the surrounding communities.
- ○ I use them regularly for travel through Medford to somewhere else as part of my daily life (such as commuting, going to school, etc.).
- ○ I use them irregularly for travel through Medford to somewhere else (recreational travel, visiting family, vacation travel, etc.).
- ○ I use them as part of my job or for my business. I am a commercial driver or local business owner.
- ○ I ride a bus that travels on local roads in Medford.
- ○ I don't use local roads much, but do live in Medford.
- ○ I don't use local roads or live in Medford.

9. How would you rate the impact of the 93 Fast 14 project on your life? Was it...

- ○ Very positive ➔ **Go to Q10**
- ○ Somewhat positive ➔ **Go to Q10**
- ○ Neither positive nor negative ➔ **Go to Q12**
- ○ Somewhat negative ➔ **Go to Q11**
- ○ Very negative ➔ **Go to Q11**

10. What was the largest positive impact?

➔ **Go to Q12**

11. What was the largest negative impact?

12. MassDOT used several methods to inform residents, business owners, and road users about closings and detours. Which of the following sources of project information did you: A. Encounter and B. Use to keep updated / informed about the construction activities? *(Mark all that apply)*

		A. Encounter	B. Use for updates
a.	The 93 Fast 14 website	○	○
b.	Segments on local TV news programs	○	○
c.	Items in local newspapers	○	○
d.	Project coverage on the radio	○	○
e.	Electronic signage along the roadway	○	○
f.	Traditional signage along the roadway	○	○
g.	Flyer	○	○
h.	Information on public access television	○	○
i.	"Reverse 911" phone calls	○	○
j.	Public hearing / Public information session	○	○
k.	Other community meeting / Stakeholder briefing	○	○
l.	Email from 93fast14.info@state.ma.us	○	○
m.	Billboard	○	○
n.	Fast Lane reminder email	○	○
o.	Article in newsletter (from any organization)	○	○
p.	511 or Sendza	○	○
q.	Sign on bus or at bus stop	○	○
r.	Through a place of worship	○	○
s.	Poster at Fast Lane office or rest area	○	○
t.	Handout at toll booth	○	○
u.	Twitter	○	○
v.	YouTube	○	○
w.	Flickr	○	○
x.	MassDOT blog	○	○
y.	Other *(specify)*:	○	○

13. How did you use the sources of project information in Question 12? To learn about... *(Mark all that apply)*

- ○ Road closures and traffic detours
- ○ Live traffic conditions
- ○ Overall project schedule
- ○ Construction technology
- ○ Other (specify): ______________________

Continue on the back ➔

Figure 69. I-93 Fast 14 survey – page 2 of print version.

APPENDIX B — SHOWCASE AGENDA

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

I-93 FAST 14 Project Showcase
July 16 - 17, 2011
AGENDA

Day 1

Saturday, July 16, 2011

Moderator: Pamela Stephenson, Division Administrator – FHWA Massachusetts Division

7:30am - 10:00am	**Registration and Sign In**
8:00am - 9:30am	**Optional Tour of MassDOT Highways Operations Center**
10:00am - 10:10am	**Moderator Welcome/Showcase Overview** Pamela Stephenson, Division Administrator – FHWA Massachusetts Division
10:10am - 10:50am	**Opening Remarks** Victor Mendez, Administrator – Federal Highway Administration Jeffrey Mullan, Secretary and CEO – MassDOT
10:50am - 11:15am	**Every Day Counts (EDC) and Highways for LIFE (HfL) Overview** Pamela Stephenson, Division Administrator – FHWA Massachusetts Division
11:15am - 11:45am	**National Perspective on Accelerated Bridge Construction** Benjamin Beerman, Senior Structural Engineer – Federal Highway Administration
11:45am - 12:45pm	**Lunch *(provided)*** **MassDOT Accelerated Bridge Program Overview** Shoukry Elnahal, Deputy Chief Engineer for Bridges and Tunnels – MassDOT
12:45pm - 1:15pm	**I-93 FAST 14 Project Overview** Christine Mizioch, Manager of Design-Build Programs – MassDOT
1:15pm - 1:45pm	**Preview of Project Site Visit and Safety Briefing** Ernie Monroe, Resident Engineer – MassDOT Marty Golden, Chief Safety Officer – White-Kiewit JV (J.F. White, Inc.)
1:45pm	**Load Buses**
2:00pm	**Buses Depart for Project Site Visit**
2:15pm - 5:00pm	**I-93 FAST 14 Project Site Visit – Salem Street** Early shuttle will leave at approx. 4:00pm
5:00pm	**Buses Depart for Hotel**
	Dinner *(on your own)*

Day 2

Sunday, July 17, 2011

Moderator: Greg Doyle, Construction Quality Engineer – Federal Highway Administration

8:00am - 9:00am	**Registration and Sign In**
9:00am - 9:10am	**Moderator Welcome/Workshop Overview** Greg Doyle, Construction Quality Engineer – Federal Highway Administration
9:10am - 10:10am	**HfL Goal – Safety** ***Part 1 – Worker Safety*** Jack Harney, Principal in Charge – White-Kiewit JV (J.F. White, Inc.) ***Part 2 – Workzone Crash Data*** Neil Boudreau, State Traffic Engineer – MassDOT ***Part 3 – Upgraded Bridge and Median Barriers*** Joe Gill, Bridge Engineering Lead – White-Kiewit JV (GEA, Inc.)
10:10am - 10:35am	**HfL Goal – Quality** ***Part 1 – Design-Builder Quality Control System*** Paul Moyer, Quality Control Administrator – White-Kiewit JV (GEA, Inc.)
10:35am - 10:50am	**Break**
10:50am - 11:45am	**HfL Goal – Quality *(cont'd)*** ***Part 2 – MassDOT Acceptance System*** Murthy Kolla, District 4 Design-Build Project Manager – MassDOT Paul Maloy, District 4 Construction Engineer – MassDOT John Grieco, Director of Research and Materials – MassDOT ***Part 3 – Prefabricated Modular Structural Elements*** Jim Cahill, Assistant Project Manager – White-Kiewit JV (J.F. White, Inc.)
11:45am - 12:45pm	**Lunch *(provided)*** **Accelerated Project Delivery – Alternative Contracting** ***(Design-Build, CM/GC and Incentive/Disincentive Clauses)*** Christine Mizioch, Manager of Design-Build Programs – MassDOT
12:45pm - 1:15pm	**HfL Goal – Quality *(cont'd)*** ***Part 4 – Pavement Smoothness and Noise*** Jag Mallela, Principal Engineer – Applied Research Associates, Inc. Chris Calnan, Design Manager – White-Kiewit JV (Tetra Tech) Peter Rapp, Project Manager – White-Kiewit JV (J.F. White, Inc.)
1:15pm - 2:00pm	**HfL Goal – Construction Congestion** ***Part 1 – Overview of Traffic Management*** Neil Boudreau, State Traffic Engineer – MassDOT ***Part 2 – Operational Outreach and Contingency Planning*** Neil Boudreau, State Traffic Engineer – MassDOT
2:00pm - 2:30pm	**HfL Goal – User Satisfaction / Public Outreach Effort** Eliza Partington, ABP Technical Coordinator – MassDOT

2:30pm - 2:45pm	**Break**
2:45pm - 3:45pm	**I-93 FAST 14 Project Issues and Lessons Learned** Preliminary Designer Perspective: Mike Culmo – CME Associates, Inc. D-B Final Designer Perspective: Joe Gill – White-Kiewit JV (GEA, Inc.) D-B Constructor Perspective: Peter Rapp – White-Kiewit JV (J.F. White, Inc.) State DOT Perspective: Christine Mizioch – MassDOT State DOT Perspective: Alexander Bardow – MassDOT FHWA Perspective: Rick Marquis – Federal Highway Administration
3:45pm - 4:30pm	**Open Question and Answer Session** Tom Broderick, Acting Chief Engineer – MassDOT Rick Marquis, Assistant Division Administrator – FHWA Massachusetts Division Mike Culmo, VP of Transportation and Structures – CME Associates, Inc. Jack Harney, Principal in Charge – White-Kiewit JV (J.F. White, Inc.) Abbie Goodman, Executive Director – ACEC of MA John Pourbaix, Executive Director – Construction Industries of Massachusetts
4:30pm	**Adjourn**

Special Thanks to:

U.S. Department of Transportation
Federal Highway Administration

Every Day Counts
innovation ingenuity imagination invention

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

massDOT
Massachusetts Department of Transportation

93 FAST 14
I-93 Rapid Bridge Replacement Project

WHITE | Kiewit
A JOINT VENTURE

Figure 70. I-93 Fast 14 project showcase agenda.

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