Integrated Delivery of SHRP 2 Renewal Research Projects

DETAILS

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SHRP 2 Renewal Project R31

Integrated Delivery of SHRP 2 Renewal Research Projects

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EXECUTIVE SUMMARY

Introduction

Although there have been signs in recent years that pavement and bridge conditions in the United States have begun to stabilize or even slightly improve (e.g., the percentage of pavements in good or acceptable condition has increased, the number of structurally deficient bridges has decreased) (FHWA 2010), spending on the infrastructure continues to lag. According to the American Society of Civil Engineers (ASCE) 2013 Infrastructure Report Card, the Federal Highway Administration (FHWA) has estimated that $170 billion in capital investment is needed on an annual basis to bring the physical conditions of the roads into a state of good repair by 2028. A similar estimate for bridges indicates that $20.5 billion in annual investment is needed to eliminate the nation's backlog of deficient bridges by 2028.

Given that even maintaining current funding levels is uncertain, questions arise as to what else can be done by the transportation community to help maintain a highly aged transportation infrastructure. Recent work by Luhr et al. (2011) strongly suggests that even in the face of declining funding, implementation of transportation infrastructure technology can be a major factor in maintaining system performance. One approach is to maximize the resources available through better transportation infrastructure design, construction, and operation, which is an overarching goal of the second Strategic Highway Research Program (SHRP 2) program and its four research focus areas: Capacity, Reliability, Renewal, and Safety.

The SHRP 2 Renewal focus area addresses the need to develop a consistent, systematic approach to completing highway projects quickly, with minimal disruption to the community, while producing long-lasting facilities. It includes over 30 research projects developed around five product areas: nondestructive testing (NDT), bridges, pavements, utilities/railroads, and project management/delivery. The products are intended to help state highway agencies (SHAs) achieve rapid renewal on highways through enhanced planning, design, construction, maintenance, and preservation.

Although implementation of the Renewal products can take place on an individual basis (i.e., a single product/technology put into use on a particular highway project to satisfy a single need), the large number of products available and their diverse applications create the opportunity for combined implementation. In other words, two or more of the products could be used together to address multiple needs identified by users involved in the different phases of the highway life cycle. SHRP 2 Project R31 was established to transform the idea of integrated application of Renewal products into a framework and useable tool for leveraging the improvement capabilities of the various Renewal products. The guiding principle of the study was to maximize the potential for product implementation through quick accessibility to the products, an organized and detailed knowledge base for the products, and an intuitive system for identifying and assembling multiple products that can help address a complementary set of user needs.

Findings

Renewal Project Reviews

A comprehensive review of the 29 Renewal projects listed in Table ES.1 was performed in the R31 study, leading to the development of 3- to 5-page expanded summaries for each project.

Table ES.1. Renewal Projects Reviewed

Project Number	Project Title
NDT	
R06	A Plan for Developing High-Speed, Nondestructive Testing Procedures for both Design Evaluation and Construction Inspection
R06A	Nondestructive Testing to Identify Concrete Bridge Deck Deterioration
R06B	Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials
R06C	Using Both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers
R06D	Nondestructive Testing to Identify Delamination between HMA Layers
R06E	Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction
R06F	Development of Continuous Deflection Device
R06G	High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings
Bridges	
R04	Innovative Bridge Designs for Rapid Renewal
R19A	Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems and Components
R19B	Bridges for Service Life Beyond 100 Years: Service Limit State Design
Pavements	
R02	Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Working Platform
R05	Modular Pavement Technology
R21	Composite Pavement Systems
R23	Using Existing Pavement in Place and Achieving Long Life
R26	Preservation Approaches for High-Traffic-Volume Roadways
Utilities and Railroads	
R01	Encouraging Innovation in Locating and Characterizing Underground Utilities
R01A	Technologies to Support the Storage, Retrieval, and Utilization of 3-D Utility Location Data
R01B	Utility Locating Technology Development Utilizing Multi-Sensor Platforms
R01C	Innovation in Location of Deep Utility Pipes and Tunnels
R15	Strategies for Utility and Transportation Agency Priorities in Highway Renewal Projects
R15B	Identification of Utility Conflicts and Solutions
R16	Railroad-DOT Institutional Mitigation Strategies
R16A	Communicating Railroad–DOT Mitigation Strategies
Project Management/Delivery	
R03	Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments
R07	Performance Specifications for Rapid Renewal
R09	Guide for the Process of Managing Risk on Rapid Renewal Projects
R10	Project Management Strategies for Complex Projects
R11	Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process

Some of the key aspects of the projects gleaned from the review and included in the expanded summaries were as follows:

- Project status and time frame (contract start and end dates).
- Project objectives and findings.
- SHRP 2 Renewal product category/area (e.g., NDT, Bridges, Pavements).
- Highway asset area/type (e.g., bridges, pavements, utilities).
- Impact on a highway agency's ability to consistently apply rapid renewal (i.e., types of benefits).
- Product developed (or being developed): name and description.
- Product status: current availability of product and where/how to access it.
- Target audience: expected end users at the functional/technical level and/or administrative/program level.
- Pertinent applications: phases in the highway life cycle (e.g., planning, final design, construction) impacted by the product.
- Pertinent technical areas: specific work functions, such as designing a pavement, evaluating the condition of a bridge deck, or maintaining a utilities database system.
- Implementation activities: product testing done as part of the Renewal project or actual implementation of the product outside of the Renewal project.
- Functional/technical-level implementation paths: ways that a mid-level manager can implement or further test the product(s) as part of an actual highway project.
- Administrative/program-level implementation paths: ways that an upper-level manager can implement the product(s) into agency practice (e.g., training, policy development meetings, procedural manual updates).
- Barriers/challenges and ways to overcome them.

The in-depth reviews of the Renewal projects provided valuable insight into different ways in which the projects and products could be logically grouped for implementation at the functional/technical level and/or administrative/program level. Nearly all of the aspects/features of the Renewal projects identified as a basis for grouping the products were included in the expanded summaries document, and that information was used to develop a preliminary integration/packaging matrix and a corresponding framework/process for the integration tool.

Integration of Renewal Projects

Because highway agencies use different approaches to implement research products and because individuals within an agency have unique perspectives and interests regarding implementation, outreach with SHA representatives and other stakeholders was performed to identify typical implementation processes and to assess the feasibility of an integrated approach to Renewal product implementation. This outreach included (a) several teleconference interviews with a broad collection of members of the American Association of State Highway and Transportation

(AASHTO) and (b) a half-day workshop targeted to mid- and upper-level engineers and managers within various highway agencies.

Based on the results of the outreach activities, it was determined that each Renewal project should be carefully evaluated to identify target audiences for the tool and to develop a specific set of user needs for which the Renewal products would have direct application and could be of significant benefit. Expected end users were grouped into the following two audiences:

- Middle-level management and technical staff: front-line managers, supervisors, engineers, and other technical professionals within an agency who are responsible for carrying out the various functional aspects of highway renewal at the project, corridor, or network level.
- Executives and upper-level management: high-level administrators and decision makers within an agency who are responsible for setting policies and defining the practices and standards for achieving highway renewal.

For each audience, a specific set of user needs (e.g., for strategy selection, suitability of precast concrete pavement [PCP] or modular pavement as a preservation/rehabilitation treatment for an existing concrete pavement) were developed for which the Renewal products have direct application and could be beneficial. The user needs were grouped into the following user needs categories, corresponding to the two target audiences:

Functional/Technical Level (mid-level management and technical staff)

- Project scoping
- Strategy selection
- Preliminary design
- Final design
- Specifications
- Construction
- Evaluation/testing

Administrative/Program Level (executives and upper-level management)

- Project scoping practices
- Strategy selection practices
- Design practices
- Specifications development
- Construction practices
- Maintenance practices
- Evaluation/testing practices
- Education/training
- Research/development/implementation

The established user needs and user needs categories were incorporated into a detailed integration/packaging matrix that can provide an effective and practical mechanism for product integration. Table ES.2 shows an example cut-out of the integration/packaging matrix developed for the functional/technical-level application. It lists the Renewal project and user need combinations that would be pertinent to pavement assets covering users throughout the entire highway life cycle. The number codes listed in the table represent the Renewal project number and a specific user need number developed for the Renewal project (e.g., 2-1 equals Renewal Project R02 and user need number 1 defined for Project R02).

Conceptualized Integration Tool

The detailed packaging/integration matrix provided the basis for developing a highly conceptualized and visualized model for the proposed integration tool, named Project Builder Application (PBA). In developing the framework for the tool, the primary focus was on getting users connected to the relevant product information from the Renewal research program. The model requires that the tool analyze user needs and interests and determine what subset of products could assist with those needs.

As illustrated in Figure ES.1, defining the user audience helps the PBA tool focus on the strategic objectives that are most important to that group. Based on these objectives, the tool can interact with the user to determine his or her specific requirements. To facilitate this, the PBA tool framework incorporates a number of user requirements into its design, which should cover many of the potential use cases for the Renewal research program results. The interaction allows the tool to narrow down the user requirements and translate them into functional requirements for the application. Implementing the functional requirements takes the user to a customized set of results covering specifically those research products most relevant to the user's needs.

Table ES.2. Example Cut-Out of Revised Functional/Technical-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Pavements Asset Type

Asset Item	User Needs Category	Project Delivery (project/corridor-level application)											
		Project Development–Preliminary Design and Final Design									Contracting and Construction		
		Project Managers	Roadway Designers	Traffic and Safety Engineers	Bridge/ Structure Designers	Pavement Designers	ROW & Utilities Engineers and Railroad Liaisons	Environmental Engineers	Geotech Engineers	Specification Engineers	Contract/ Construction Managers	Construction Engineers	Materials Engineers
Pavement/ Shoulder Structures	Project Scoping/Cost Estimating	3-1, 9-1, 10-1, 11-1	3-1, 9-1, 10-1, 11-1	11-1		2-1			2-1		3-1, 9-1, 10-1, 11-1		
	Preliminary Design	3-2, 10-2, 11-2	3-2, 10-2, 11-2	11-2		2-2, 23-1			2-2		3-2, 10-2, 11-2		
	Strategy Evaluation/Selection (Construction, Rehab, Preservation)	7-1, 9-2, 11-3	7-1, 9-2, 11-3	7-1, 11-3		2-3, 5-1, 5-2, 7-1, 21-1, 23-2, 26-1, 26-2			2-3, 7-1		9-2, 7-1, 11-3		
	Final Design	3-3	3-3			2-4, 5-3, 5-4, 21-2			2-4		3-3		
	Specifications (Materials/Systems, Design, Construction)	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	7-8		2-5, 5-5, 5-6, 6C-3, 6C-4, 6E-2, 7-2, 7-3, 7-4, 7-5, 21-3, 23-3			2-5, 7-6	2-5, 5-5, 5-6, 5-7, 5-8, 6C-3, 6C-4, 6E-2, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	2-5, 5-5, 5-6, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3	2-5, 5-5, 5-6, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3
	Construction Procedures	3-4, 11-4	3-4, 11-4	11-4		2-6, 5-7, 5-8, 21-4			2-6	2-6, 5-7, 5-8, 21-4	3-4, 11-4	2-6, 5-7, 5-8, 11-4, 21-4	2-6, 5-7, 5-8, 21-4
	Strategy Evaluation/Selection (Testing Tools)					6C-1				6C-1		6C-1	6C-1
	Evaluation/Testing Procedures (New Infrastructure)											6B-1, 6C-2, 6E-1	6B-1, 6C-2, 6E-1
	Evaluation/Testing Procedures (Existing Infrastructure)					6F-1							

(continued on next page)

Table ES.2. Example Cut-Out of Revised Functional/Technical-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Pavements Asset Type *(continued)*

Asset Item	User Needs Category	Program and System Management (network-level application)							
		Program and System Support		Asset Preservation				Program Development	
		Research/Materials Engineers	IT Professionals	Maintenance/ Preservation Engineers	Bridge/Structure Managers	Pavement Managers	Utilities Managers	Planners	Programmers
Pavement/ Shoulder Structures	Project Scoping/Cost Estimating	2-1	2-1					2-1, 3-1, 11-1	
	Preliminary Design	2-2, 23-1				23-1		3-2, 11-2	
	Strategy Evaluation/Selection (Construction, Rehab, Preservation)	2-3, 5-1, 5-2, 7-1, 21-1, 23-2, 26-1, 26-2	21-1, 23-1, 23-2	5-1, 26-1, 26-2		5-1, 5-2, 21-1, 23-2, 26-1, 26-2		5-1, 11-3, 21-1	5-1
	Final Design	2-4, 5-3, 5-4, 21-2							
	Specifications (Materials/Systems, Design, Construction)	2-5, 5-5, 5-6, 5-7, 5-8, 7-2, 7-3, 7-4, 7-5, 7-6, 21-3, 23-3		7-5		7-5			
	Construction Procedures	21-4							
	Strategy Evaluation/Selection (Testing Tools)	6C-1							
	Evaluation/Testing Procedures (New Infrastructure)	6B-1, 6C-2, 6E-1							
	Evaluation/Testing Procedures (Existing Infrastructure)	6F-1		6F-1		6F-1			

Note: Numbers listed in table cells are a combination of the Renewal project number and a specifically defined user need for that project.

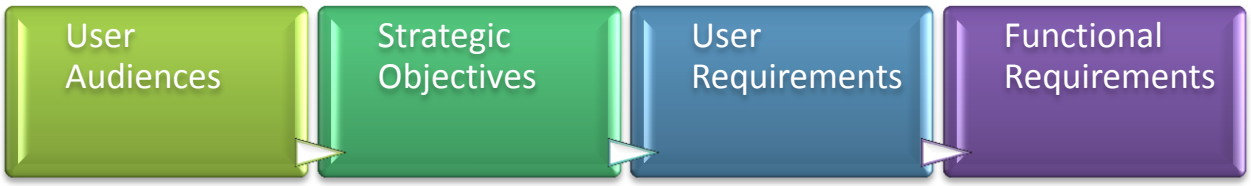

Figure ES.1. Outline of the PBA tool framework.

Using the outline of the PBA framework, the features and functionality of the PBA tool were described in detail for 20 different user audiences, covering both the functional/technical and administrative/program levels. Table ES.3 provides an example illustration for the utility engineer user audience.

Table ES.3. Strategic Objectives and Tool Requirements for Utilities Engineers

User Requirements	Functional Requirements
Strategic Objective 1— Locate and track utility installations located within a rapid renewal project.	
• Identification of utility-locating/characterizing technology for use in a roadway project. • Procedures for tracking and evaluating utility installation data for a roadway project. • Procedures for providing notification of changes in utility information or status within the right-of-way.	• Collect input regarding availability of utility location information and recommend decision support tool to select utility-locating methods from SHRP 2 R01. • Collect information on existing utility tracking practices and recommend utility database model based on SHRP 2 R01A.
Strategic Objective 2— Manage and resolve utility conflicts as part of project activities.	
• Tools for management of utility conflicts and relocation. • Procedures for tracking utility conflict resolution and milestones. • Communication and coordination of utility conflict information with stakeholders (utility owners, one-call providers).	• Collect input on agency practices for utility conflict management. Recommend appropriate tools and best practices such as a utility conflict matrix based on SHRP 2 R15B.

To illustrate how the PBA tool would operate, high-level visualized examples of the application input screens were created (Figures ES.2 through ES.5). These examples indicate how a user might interact with the tool through a sequence of steps. At each step, the tool would gather information according to the PBA framework that helps the user identify which research products to implement or investigate further.

1. The PBA tool would request general information to identify which audience role(s) to assign the user (Figure ES.2). From this starting point, the tool would determine whether the user is likely to focus on project-level information or prefer a broader program-oriented approach.
2. The tool looks to narrow down which aspects of infrastructure assets are most relevant to the user (Figure ES.3).

3. The initial input from the user suggests what user requirements may be appropriate. At this point, the tool asks for further input to validate those requirements as it displays for review the assumptions that took it there (Figure ES.4).
4. After analyzing and validating the user input, the tool generates a customized recommendation (Figure ES.5). This may include specific products to consider for implementation as well as resources for further investigation.

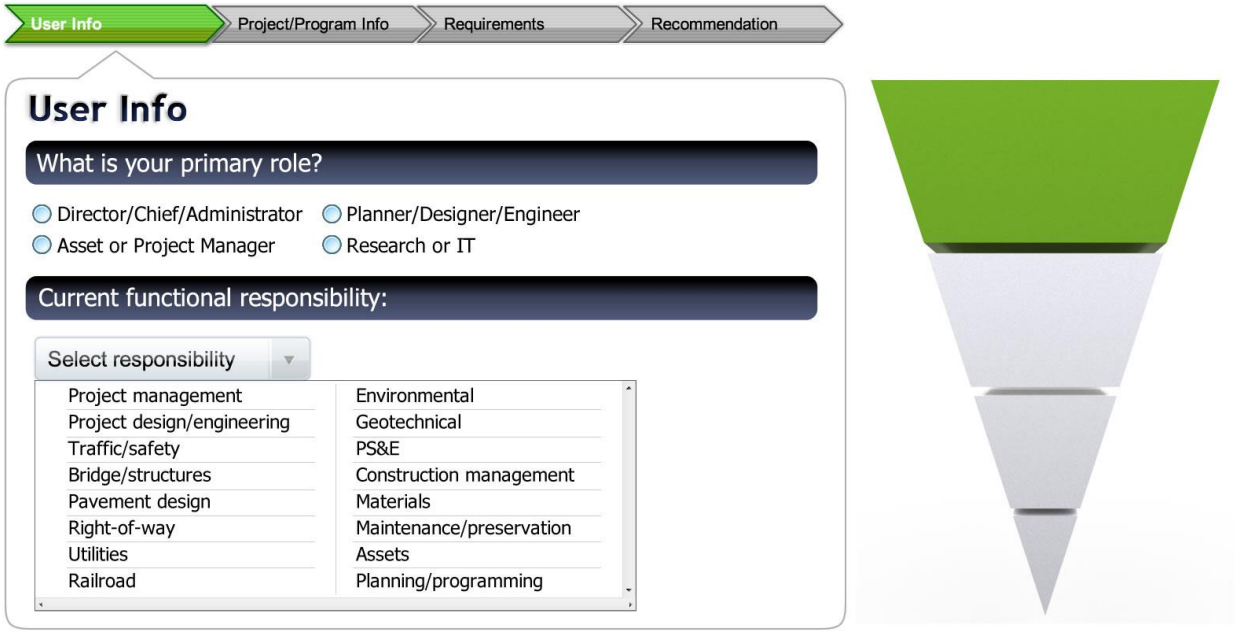

Figure ES.2. Sample PBA tool interface for identifying the user audience role.

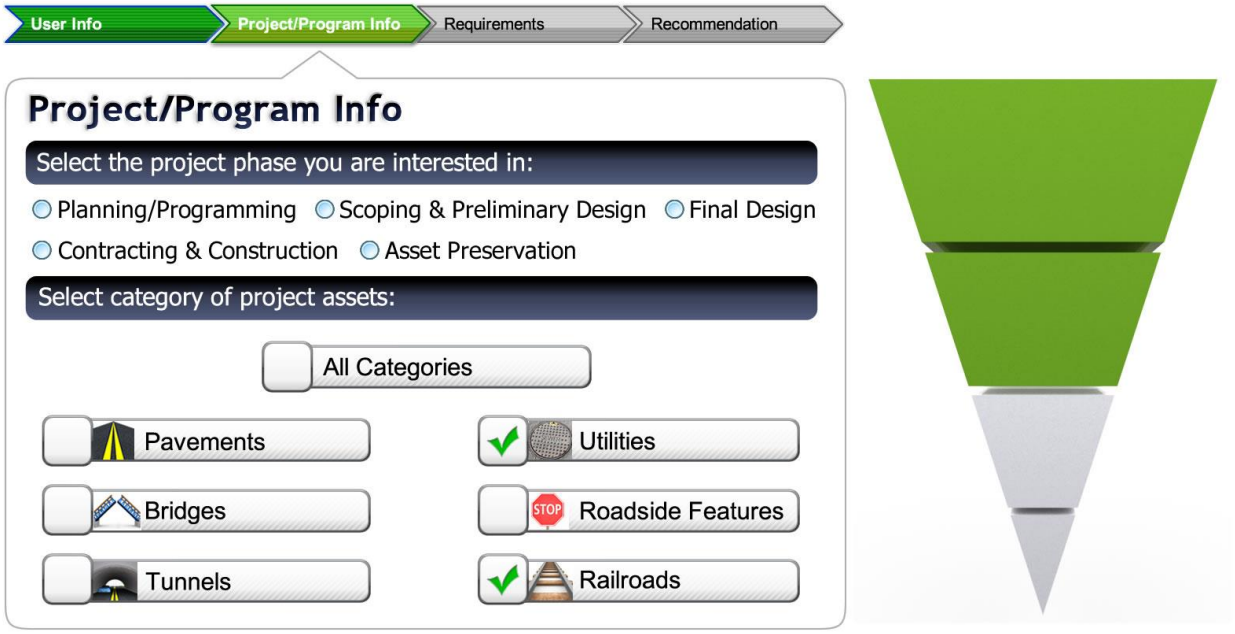

Figure ES.3. Sample interface showing user interaction with PBA tool.

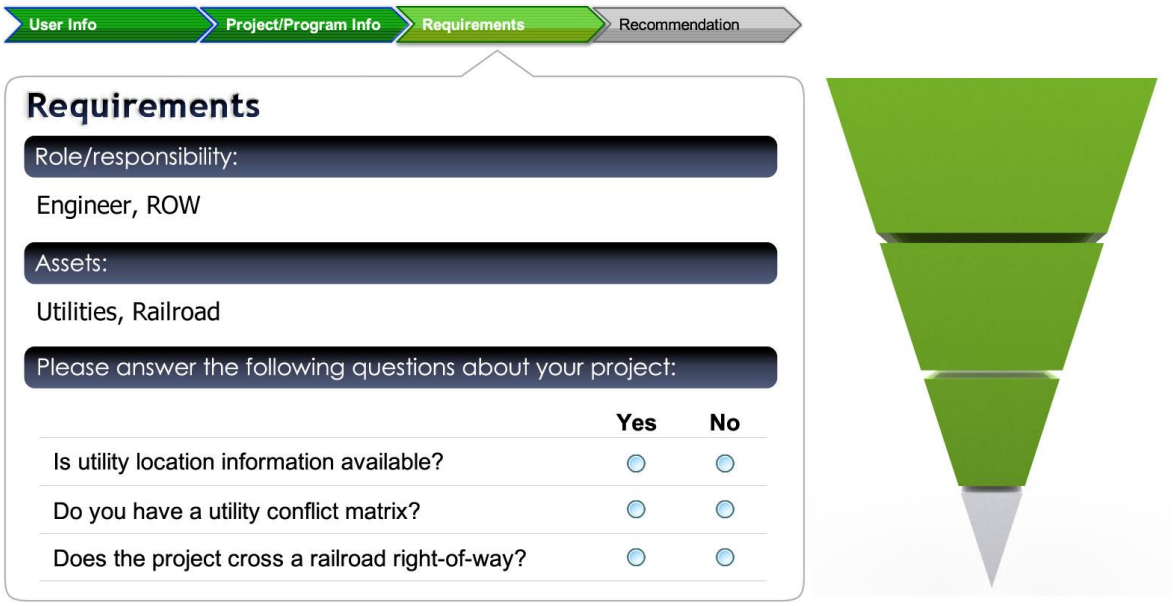

Figure ES.4. Sample PBA tool interface for identifying user requirements.

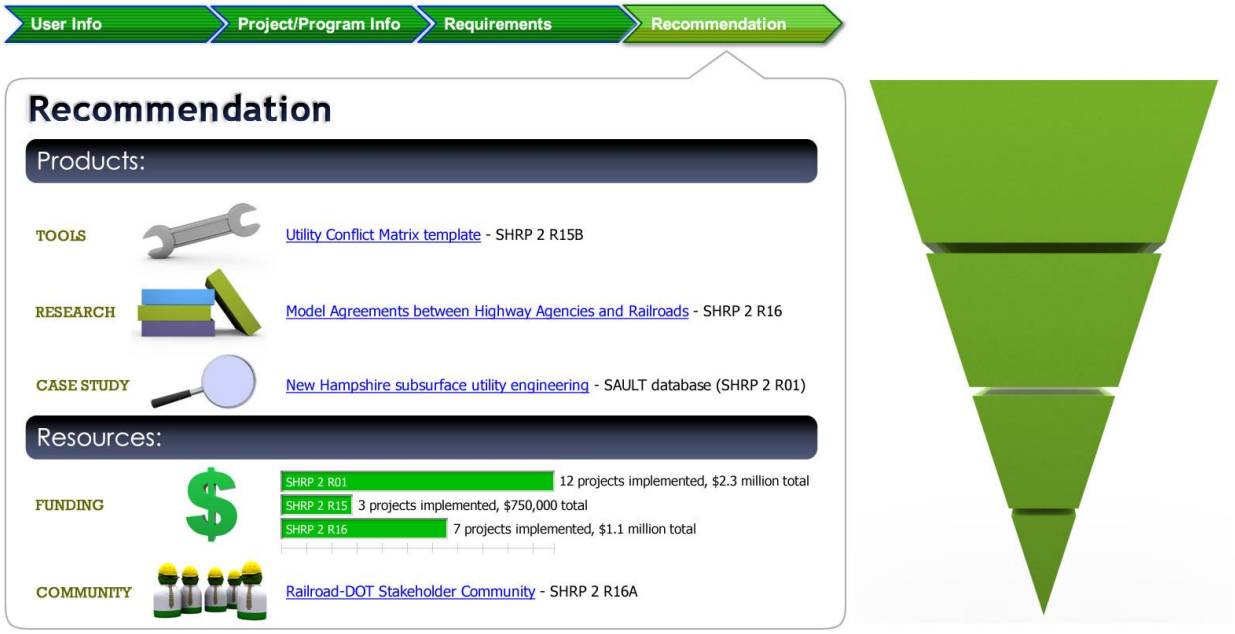

Figure ES.5. Sample PBA tool interface showing recommendation based on user requirements.

The PBA tool provides a number of potential benefits to agencies and individual users. It is designed to offer a simple, streamlined process through which users can identify the products that are relevant to their specific needs and interests. The tool does not assume that the user will need to bring significant prior knowledge related to the research, gather information not readily available, perform complex calculations, or engage in other preparations in advance. Instead, the framework builds off the user's existing knowledge to provide results that should make sense intuitively to the user.

By integrating all of the Renewal research program results under a single framework, the PBA facilitates packaging multiple products together. It helps users discover relationships between products and identify ways in which they might complement each other to the benefit of the agency. The integration and packaging is further supported by maintaining the simplicity of the framework; by filtering out superfluous results, the tool focuses attention on those products that are most likely to address user needs.

The PBA tool also maintains the integrity of the products by including support materials and resources in the recommendation provided to the user. This ensures that implementation does not happen without the education necessary for success. It can also provide the agency with knowledge of delivery strategies and demonstration projects that may be needed to make the case for implementation.

Implementation of the PBA tool can be expected to face certain barriers and challenges during the development process. The most significant of these are as follows:

- *User Adoption*: The impact of the tool depends on growing a significant user population. This requires that the tool have the attention-grabbing capability to stimulate interest initially, while also providing a user-friendly experience to convert that interest into ongoing engagement.
- *Tool Relevance*: If the tool is released but not properly maintained, its usefulness is likely to have a short shelf life. Key features should include dynamic updating capabilities and real-time access, so that users have all of the latest information available to them.
- *Providing Value*: The tool needs to demonstrate that it provides a valuable resource by integrating the Renewal research program results. It will not succeed if it lacks products that can really address users' needs.
- *Institutional Support*: Successful development of the PBA tool will require additional resources dedicated to the project. The integration tool cannot move forward without a committed owner or host agency.

Conclusions

Several major conclusions were developed in this study. The most notable conclusions are the following:

- The SHRP 2 Renewal focus area has included many substantive research projects that have developed (or will soon develop) products intended to help highway agencies achieve rapid highway renewal. The products are targeted to users at the functional/technical level and the administrative/program level, are applicable to a variety of highway assets, and can be used to address different needs throughout the highway life cycle.
- Product/technology implementation can take place in several ways and at different levels within an agency. Interviews with AASHTO subcommittee members indicated that single-product implementation is usually led by the appropriate technical area, whereas integrated implementation is most likely to occur at the upper-management level but

could happen at lower levels if there is high collaboration among the divisions/offices involved.

- The concept of integrated implementation of Renewal products and the development of a software tool for identifying products for complementary use is viewed as very appealing, but very challenging. Major recommendations for such a tool included that it be (a) dynamic and updatable, (b) centered around problem/constraint identification and needs, (c) informative about product benefits and costs, (d) sharing or forum-oriented, and (e) attention grabbing. Additional recommendations cited the need for a simple tool with hard facts, bottom-line expected benefits, and sound information about the risks of implementation and ways to mitigate the risks.
- The Renewal products address potential needs and concerns across a variety of agency activities. This means that taken collectively, the size of the potential audience increases substantially over that of any one project individually. In order to conceptualize a tool that can serve this audience effectively, it is necessary to begin by approaching the broadest possible group and identifying suitable filters (audience roles, project characteristics, agency priorities, etc.) that can help guide users through the results. This process will channel the audience into more narrowly defined groups and match them up with products that satisfy their specific requirements.

Recommendations

Listed below are key recommendations for enabling increased application of the Renewal research program products.

- Create an integration tool that will help agencies identify Renewal research program products that fit their needs.
- Help agencies discover research products easily by maintaining a simple approach that does not demand significant advance knowledge or preparation from the user.
- Focus on offering solutions to existing agency problems where research can be implemented.
- Promote integration of products where appropriate by identifying potential relationships and packaging multiple products together.
- Provide guidance and additional resources for users who need to learn more about a specific product prior to deployment.

All of these elements can be achieved within the framework proposed for the PBA tool. Since the tool framework incorporates all of the research results together, agencies can use it to create customized recommendations based on their specific needs and address their biggest challenges. The design of the tool enables a streamlined process for integrating research products while also making available the detailed information backing the recommendations. Because of the extensive needs for renewal of existing highway infrastructure, agencies are likely to benefit significantly from such a tool to accelerate and improve the quality of their decision making.

CHAPTER 1
Introduction

SHRP 2 Renewal Overview and Background

The U.S. highway system is an extensive network of roads that facilitates the movement of people and goods and supports the growth of the national economy by providing access to national and international markets (FHWA 2010). The highway system includes over 4 million miles of roads and over 600,000 bridges (longer than 20 ft) that are owned and operated by agencies at the federal, state, and local levels (3.2 percent, 19.3 percent, and 77.4 percent of the total system, respectively). The system infrastructure is subjected to approximately 3 trillion vehicle miles of travel (VMT) annually, consisting of various forms of household-based travel (work commuting, visits and recreation, shopping and errands) and commerce-related travel (FHWA 2013).

Although there have been signs in recent years that pavement and bridge conditions in the United States have begun to stabilize or even slightly improve (e.g., the percentage of pavements in good or acceptable condition has increased, the number of structurally deficient bridges has decreased) (FHWA 2010), spending on the infrastructure continues to lag. According to the American Society of Civil Engineers (ASCE) 2013 Infrastructure Report Card, the Federal Highway Administration (FHWA) has estimated that $170 billion in capital investment is needed on an annual basis to bring the physical conditions of the roads into a state of good repair by 2028. A similar estimate for bridges indicates that $20.5 billion in annual investment is needed to eliminate the nation's bridge deficient backlog by 2028.

Given that even maintaining current funding levels is uncertain, questions arise as to what else can be done by the transportation community to help maintain a highly aged transportation infrastructure. Recent work by Luhr et al. (2011) strongly suggests that even in the face of declining funding, implementation of transportation infrastructure technology can be a major factor in maintaining system performance. One approach is to maximize the resources available through better transportation infrastructure design, construction, and operation. This is an overarching goal of the second Strategic Highway Research Program (SHRP 2), which was authorized by Congress in 2005 to sponsor high-payoff research in four focus areas:

- Capacity
- Reliability
- Renewal
- Safety

The SHRP 2 Renewal focus area is an applied research program that addresses the need to develop a consistent, systematic approach to completing highway projects quickly, with minimal disruption to the community, while producing long-lasting facilities. The Renewal program includes over 30 research projects developed around five product areas: nondestructive

testing (NDT), bridges, pavements, utilities/railroads, and project management/delivery. Each of the products resulting from the Renewal research program makes a contribution to achieving the above objectives.

Renewal is defined as the reconstruction or substantial rehabilitation of deteriorating highway infrastructure to new standards of service. Rapid renewal implies accelerated construction, but it also includes planning, project development, and maintenance and operations features that minimize the total project duration, produce long-lasting facilities, and minimize motorist delay. To date, rapid renewal has typically been achieved only under special, high-profile circumstances, because very real barriers exist to consistent application of these tactics. For instance, to build facilities more quickly it is necessary to perform in situ work faster, do as much as possible away from the site, monitor and inspect construction rapidly, and provide a contracting environment that allows this to happen. Similarly, limits on sensing technology inhibit rapid inspection and construction acceptance.

R31 Project Background

The Renewal research program was initiated in early 2007 and is expected to be completed by 2015. Most of the Renewal projects have been completed or are nearing completion with draft deliverables currently under review by SHRP 2. Further discussion of the various Renewal projects is provided in Chapter 2. Detailed descriptions of the projects, their current status, and the products developed (or under development) are provided in Appendix A.

The Renewal research products are expected to enhance the planning, design, construction, maintenance, and preservation of the nation's transportation infrastructure. They are targeted for a variety of highway practitioners and stakeholders, including representatives of state highway agencies, local governments, toll road authorities, utility and railroad companies, and their supporting consultants and contractors. The products have applications throughout the highway life cycle (e.g., planning, preliminary design, final design, construction, and maintenance) and may be of interest/use to individuals at different levels within a highway agency (e.g., junior and senior technical staff, low- to mid-level managers, high-level managers and executives).

Although implementation of the Renewal products can take place on an individual basis (i.e., a single product/technology put into use on a particular highway project to satisfy a single need), the large number of products available and their diverse applications create the opportunity for combined implementation. In other words, two or more of the products could be used together to address multiple needs identified by users involved in the different phases of the highway life cycle. For example, an improved project scoping process, better project management strategies, more accurate design methodologies, and the use of performance-related specifications during construction could all be instituted on a highway project to reduce costs and time and to improve safety. Such a project might only involve one particular type of asset (e.g., a bridge, a stretch of roadway pavement) or multiple asset types together (e.g., a roadway corridor with bridges, pavement, and utilities).

SHRP 2 Project R31 was established to transform the idea of integrated application of Renewal products into a framework and useable tool for leveraging the improvement capabilities of the various Renewal products. The guiding principle of the study is to maximize the potential

for product implementation through quick accessibility to the products, an organized and detailed knowledge base for the products, and an intuitive system for identifying and assembling multiple products that can help address a complementary set of user needs. The envisioned tool would effectively equip highway agency professionals and other stakeholders with relevant and actionable information when needed for applying rapid renewal.

Project Objectives

The objective of this project is to develop a tool or tools to promote and support systematic and integrated application of the products developed in the Renewal research program. These tools are expected to enhance a transportation agency's ability to consistently apply rapid renewal in the development and execution of the planning, design, construction, maintenance, and preservation of their infrastructure.

The tools are intended to provide insight into questions such as the following:

- How can the products from the NDT, bridges, pavements, utility/railroads, and project management/delivery product areas be used to enhance an agency's ability to develop and execute the planning, design, construction, and maintenance of their infrastructure?
- How do the products or combinations of products enhance transportation agencies' ability to rapidly renew their infrastructure?

Project Scope and Approach

To accomplish the project objectives, the study was divided into two phases of work consisting of the following tasks:

Phase 1

1. Conduct an extensive review of the SHRP 2 Renewal products and describe how each product individually improves a transportation agency's ability to consistently apply rapid renewal.
2. Document and analyze the relationships between the SHRP 2 Renewal products and how they could be integrated and/or applied in complementary ways to enhance a transportation agency's ability to consistently achieve rapid renewal in the development and execution of the planning, design, construction, maintenance, and preservation of their infrastructure.
3. Describe how the various product combinations considered in Task 2 can enhance a transportation agency's ability to consistently achieve rapid renewal in the development and execution of the planning, design, construction, maintenance, and preservation of their infrastructure.
4. Identify challenges/barriers (both technical and nontechnical) to the integration and/or complementary use of the Renewal products and recommend ways to overcome them.
5. Develop and submit a Phase 1 interim report detailing the findings of the preceding tasks and provide a work plan for Phase 2.

Phase 2

6. Develop a tool or tools that clearly communicate and demonstrate how the SHRP 2 Renewal products can be systematically applied to enhance a transportation agency's ability to consistently apply rapid renewal in the development and execution of the planning, design, construction, maintenance, and preservation of infrastructure.
7. Work with key stakeholders (transportation professionals from state transportation agencies, AASHTO, FHWA, consultants, and contractors) to demonstrate and validate the usefulness of the tool(s) under real project scenarios.
8. Refine the tool(s) based on feedback from key stakeholders.
9. Submit draft final deliverables, including the final report and final tool(s) and supporting documentation.
10. Revise all draft deliverables in response to review comments and submit final deliverables.

Key components of Phase 1 included detailed reviews of each of 29 completed or ongoing Renewal projects, outreach to highway agencies and other stakeholders to obtain insights on the proposed integration tool, and the development of an integration/packaging matrix and a corresponding tool framework/model. The Renewal project reviews were accompanied by the development of expanded summaries that capture the many relevant aspects of the projects, such as the performance time frame, project objectives, major findings, key products, availability and access of the products, targeted audience/users of the products, and the implementation paths for the products.

The Phase I outreach consisted of interviews with selected members of several AASHTO subcommittees (e.g., Design, Utilities and Right-of-Way [ROW], Materials) and a half-day workshop with a variety of professionals from throughout the highway industry. The information and inputs gathered in these outreach efforts provided a better understanding of how implementation occurs within different agencies and within different groups of an agency. They also provided ideas for and guidance in grouping Renewal products for inclusion in the new tool.

Following the outreach activities, SHRP 2 decided not to support the Phase II work involving the development of the tool(s). A revised work plan for completing Phase I was developed, which focused on the development of an integration/packaging matrix for the Renewal products, development of a highly conceptualized and visualized integration tool, and the preparation of this report.

CHAPTER 2
SHRP 2 Renewal Projects

Introduction

This chapter provides an overview of the SHRP 2 Renewal projects. The projects are presented and discussed in five sections that correspond with the five product areas that comprise the Renewal research program: NDT, bridges, pavements, utilities and railroads, and project delivery. For each product area, a briefing on the status of the projects is provided and a summary is given of the product types that were developed (or are currently under development) in each project. The primary benefits of the products and the expected users of the products are presented, followed by a short description of the major barriers/challenges expected in implementing the products.

Also included in the product area sections is information on the product development activities undertaken in each Renewal project, as well as information on product implementation activities that have occurred (or are expected to occur) following completion of a project. The development activities were intended to demonstrate, showcase, test/vet, and refine the products. They range from hands-on project-level applications (e.g., technology demonstrations, pilot implementations, field validations) to broader, outreach applications at the program level (e.g., workshops, training courses, and webinars). . The implementation activities reflect highway agency efforts to put Renewal products to use in a routine way.

Renewal Project Reviews

To fully understand the scope of each Renewal project and the outcomes of the work performed in terms of findings, recommendations, and products, a comprehensive review of each project was performed. This review began with the collection of all available plans, reports, and product documents from the SHRP 2 website and the National Academy of Sciences (NAS) information portal. Key information was gleaned from the gathered materials and compiled into an expanded summaries document capturing the following relevant aspects of the projects:

- SHRP 2 Program Officer responsible for overseeing the project.
- Contractor and principal investigator (PI) charged with conducting the study.
- Project status and time frame (contract start and end dates).
- SHRP 2 Renewal product category/area (e.g., NDT, bridges, pavements).
- Highway asset area/type (e.g., bridges, pavements, utilities).
- Impact on a highway agency’s ability to consistently apply rapid renewal (i.e., types of benefits).
- Project objectives.
- Project findings.
- Product name and description (e.g., a manual, a specification, a software tool).
- Product status: current availability of product and where/how to access it.

- Target audience: expected end users at the functional/technical level and/or administrative/program level.
- Pertinent applications: phases in the highway life cycle (e.g., planning, final design, construction) impacted by the product (see Figure 2.1).
- Pertinent technical areas: specific work functions, such as designing a pavement, evaluating the condition of a bridge deck, or maintaining a utilities database system. Implementation activities: product testing done as part of the Renewal project or actual implementation of the product outside of the Renewal project.
- Project-level implementation paths: ways that a mid-level manager (or possibly upper-level manager) can implement or further test the product(s) as part of an actual highway project.
- Program-level implementation paths: ways that an upper-level manager (or possibly mid-level manager) can implement the product(s) into agency practice (e.g., training, policy development meetings, procedural manual updates).
- Barriers/challenges and ways to overcome them.
- Project key words.

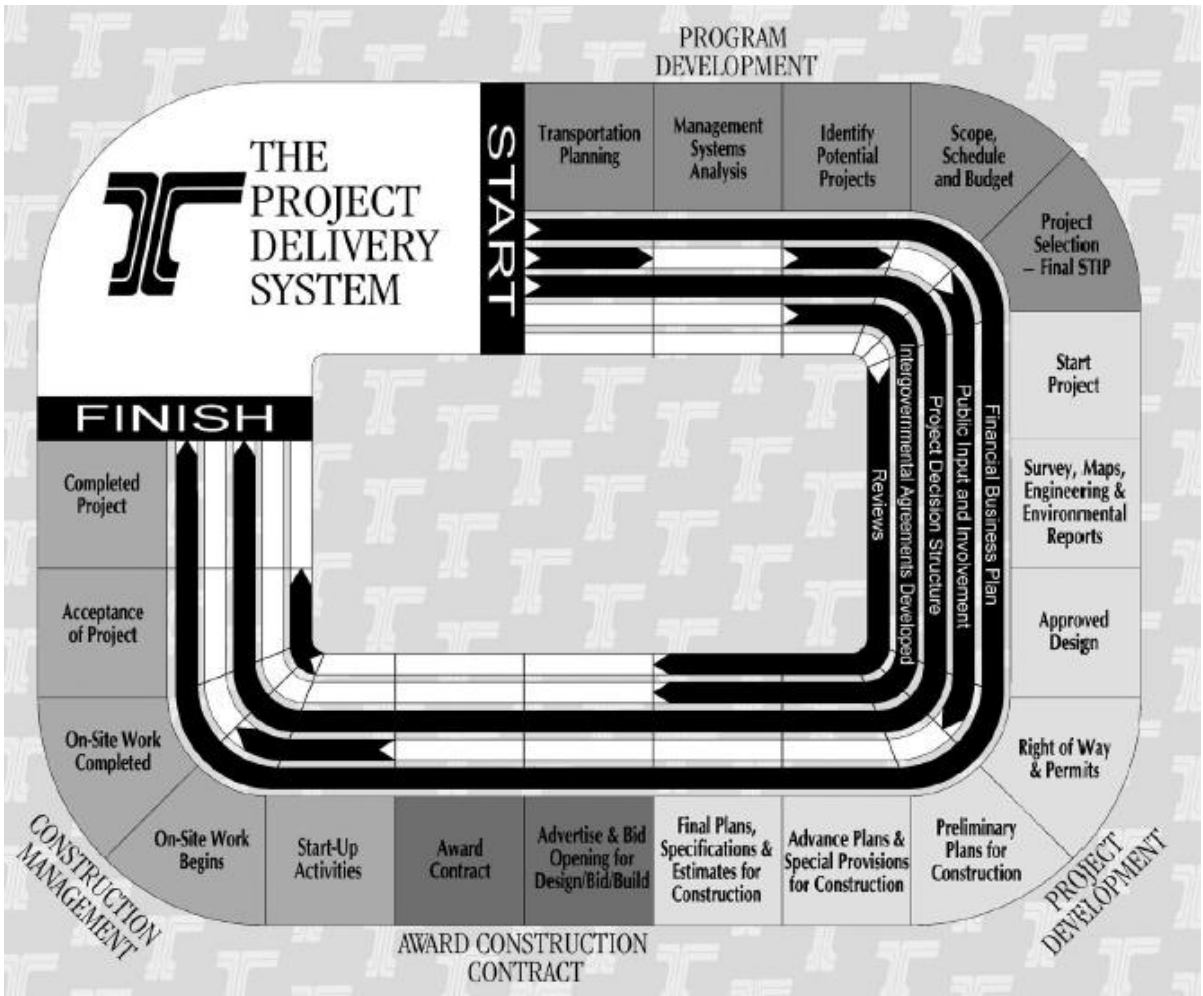

Figure 2.1. Example of highway life-cycle phases and steps (Oregon DOT, 2010).

The information for each Renewal project was kept to a maximum of 5 pages. Reviews of the initial drafts of each expanded summary were requested of SHRP 2 staff and the Renewal project PIs. The comments and suggested edits received from the reviewers were incorporated, as appropriate. A final updating of the Renewal project summaries was performed during the development of this final report.

The information presented in these summaries and throughout this chapter represent a snapshot in time. As more of the Renewal projects reach their conclusion, some of the information provided will undoubtedly change. Appendix A contains the final version of the Expanded Summaries document.

Nondestructive Testing

The NDT product area includes the following eight research projects:

- R06. A Plan for Developing High-Speed, Nondestructive Testing Procedures for both Design Evaluation and Construction Inspection
- R06A. Nondestructive Testing to Identify Concrete Bridge Deck Deterioration
- R06B. Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials
- R06C. Using both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New Hot-Mix Asphalt (HMA) Layers
- R06D. Nondestructive Testing to Identify Delamination between HMA Layers
- R06E. Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction
- R06F. Development of Continuous Deflection Device
- R06G. High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings

These projects have applications to various highway assets, including bridges (R06, R06A), pavements (R06, R06C, R06D, R06E, and R06F), tunnels (R06, R06G), earthworks and retaining walls (R06), and certain roadway features like traffic markings (R06B).

The NDT research was initiated in March 2007 with project R06, which identified 29 areas of study (i.e., specific NDT technologies and applications for highway renewal) that needed to be addressed with subsequent research and that provided detailed recommendations (and corresponding research problem statements) to address the top six research needs. Based on those recommendations, seven follow-on studies were funded and initiated in spring 2009 (projects R06A through R06F) and fall 2009 (project R06G). Three of these projects are completed (R06E, R06F, and R06G), with the remaining four expected to be completed sometime in 2014.

The products developed (or currently under development) in the NDT area focus on the evaluation of highway assets, including pavements, bridges, tunnels, and roadway traffic markings. They are intended to ensure the quality of construction of new assets, identify and quantify deficiencies in existing assets, minimize road closure times and disruptions to traffic,

reduce life-cycle costs and user costs, and/or improve highway worker and user safety. The products are geared toward a variety of technical-level practitioners (e.g., construction engineers, materials engineers, maintenance engineers, pavement and bridge inspectors, and pavement and bridge/structure management engineers), as well as mid- to upper-level managers responsible for establishing and carrying out asset policies/practices, overseeing highway programs, and monitoring/managing the highway network.

The main barriers/challenges to implementation of the NDT-related products are believed to include the following:

- Perceived risks and high costs of some of the testing devices/equipment.
- Lack of knowledge in the operation of the devices/equipment and/or the analysis of data and interpretation of results.
- Resistance from agency field personnel and/or contractor personnel due to lack of resources/manpower and/or perception of the devices/equipment as being a low priority.
- Limited capabilities of several of the testing devices/equipment. Some devices are good at detecting/characterizing some distresses, but are not good at doing the same for other distresses.

The products developed (or currently under development) in the NDT area are listed in Table 2.1, grouped according to various product categories. As can be seen, the primary non-informational product types include manual/guide documents, draft/proposed/recommended specifications and/or testing procedures, sample standard plans and/or detail sheets, case histories, example/hypothetical applications, training/workshop materials, videos, and stand-alone spreadsheet tools.

Table 2.2 shows the product development and implementation activities for the Renewal projects in the NDT area. As can be seen, there have been several field evaluation/validation tests and technology demonstrations of the different NDT technologies, as well as a workshop on one of the technologies (continuous deflection equipment). As for post-project implementations, several states have drafted, or are considering drafting, specifications that incorporate the infrared (IR) imaging technology.

Bridges

The Bridges product area includes the following three research projects:

- R04. Innovative Bridge Designs for Rapid Renewal
- R19A. Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems and Components
- R19B. Bridges for Service Life Beyond 100 Years: Service Limit State Design

In addition, two of the NDT research projects—R06 and R06A—and project R07 have direct applications to bridges.

The R04 and R19A projects were initiated in fall 2007. Project R19B was begun in fall 2008 and was intended to use the results of R19A in carrying out its objectives. All three projects have anticipated completion dates in the last quarter of 2013.

The products developed (or currently under development) in the bridges area focus on the rapid replacement (and/or expansion) of existing bridges and the design and construction of long-life bridges and are primarily intended to minimize road closure times and disruptions to traffic, reduce user costs, increase bridge performance/life, reduce bridge life-cycle costs, increase sustainability, and/or improve highway worker and user safety. The products are geared toward a variety of technical-level practitioners (e.g., bridge designers, project managers, plans specifications and estimates [PS&E] engineers, bridge construction engineers, materials engineers, bridge maintenance, and bridge inspectors), as well as mid- to upper-level managers responsible for setting bridge policies/practices, overseeing bridge programs, and monitoring/managing the bridge network.

Table 2.1. Products Developed under the NDT Product Area

Product Category	Product Type	Renewal Project							
		R06	**R06A**	**R06B**	**R06C**	**R06D**	**R06E**	**R06F**	**R06G**
Guide Material Products	Technical Best Practices Manuals/Guides			✓ (FR)		✓ (planned)	✓ (FR)		✓ (planned)
	Policy Manuals/Guides								
	Model Concepts/Frameworks, Model Analysis Methods/Procedures, and/or Decision/Selection Processes								
	Guide/Model Specifications and/or Testing Procedures						✓ (FR)		
	Draft/Proposed/Recommended Specifications and/or Testing Procedures			✓ (FR)	✓ (FR)				
	Sample Standard Plans and/or Detail Sheets								
	Case Histories[1]								
	Case Studies[2]								
	Example/Hypothetical Applications							✓ (FR)	
Training/ Demonstration Products	Training/Workshop Materials (instructor/participant manuals, slide presentations/notes, problem exercises)								
	Video Demonstrations		✓		✓				
Software Products	Stand-Alone Software Programs								✓ (planned)
	Stand-Alone Spreadsheet Tools								
	Data Models and/or Database Files/Systems								
	Computational Design, Performance, and/or Cost Models								
	Information Clearinghouses and/or Internet Portals								
	Web-Based Programs/Tools		✓						
	Online Library/Knowledge Systems		✓ (WBP)	✓ (planned)					

Equipment/ Hardware Products	Field/Lab Testing Devices/Equipment		✓*	✓*	✓*	✓*	✓*	✓*	✓*
	Computer Hardware								
Technical Support Products	Technical Assistance Services								
	Software Technical Support								
	Expert Task Groups/Communities of Interest								
Informational Products	Final Reports	✓	✓	✓	✓	✓	✓	✓	✓
	Interim/Phase and/or Construction Reports								
	Product Development Reports					✓			
	Technical Briefs/Fact Sheets								
	Implementation Plans/ Recommendations/Guidelines							✓ (FR)	
	Research Needs Statements	✓ (FR)						✓ (FR)	
	Catalogues/Reference Documents		✓ (FR)			✓ (FR)		✓ (FR)	
	Outreach Materials (product briefs, brochures, newsletters)				✓				

Note: WBP = Product delivered as part of web-based program; M/G = Product delivered as part of manual/guide document; FR = Product delivered as part of final report; DR = Product delivered as part of development report;
PR = Product delivered as part of phase report.
* Evaluation/refinement of existing devices/equipment.
[1] A case history documents who, where, why, and how transportation agencies and/or other stakeholders have used a particular technology/product in the past, either as a routine highway project or as a formal research experiment/study. It demonstrates the successful application of the technology/product and highlights its benefits.
[2] A case study entails a detailed investigation/review of an actual project (either pre-existing or new) and/or a detailed evaluation/analysis of data obtained from that project. It describes the subject project, discusses the investigation/review and/or data evaluation/analysis carried out, and identifies key findings, conclusions, and ideas that would support the larger research being performed.

Table 2.2. Summary of Development and Implementation Activities for Renewal Projects in the NDT Product Area

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R06 A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	None.	None.	None.	None.
R06A Nondestructive Testing to Identify Concrete Bridge Deck Deterioration	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Field validation testing of 10 NDT technologies on Rt. 15 bridge over I-66 in Haymarket, VA.	None.	None.	None.
R06B Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Field validation testing of different NDT technology applications (material/method combinations) at 8 different locations in Connecticut.	None.	None.	None.

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R06C Using Both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers	Technology Demonstrations and/or Showcase Expositions • 4 Field Demonstrations of ground-penetrating radar (GPR) and IR technologies conducted in AASHTO Region 1 (Maine), Region 2 (Florida), Region 3 (Minnesota), and Region 4 (Texas) as part of HMA Overlay Projects. • Model specifications pilot testing in Vermont. • 2 additional Field Demonstrations planned for Spring 2013 in Virginia and Pennsylvania.	None.	Implementations • Several states are considering drafting or have already drafted specifications that incorporate the IR technology.	None.
R06D Nondestructive Testing to Identify Delamination Between HMA Layers	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • 2 Uncontrolled Field Evaluations of improved versions of GPR and impact echo/spectral analysis of surface wave (IE/SASW) NDT equipment for detecting HMA layer delaminations (FL I-75 and KS US 400).	None.	None.	None.
R06E Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • 1 Field Evaluation of GOMACO GSI and Ames real-time transit protocol (RTP) on I-75 in Adel, GA. Technology Demonstrations and/or Showcase Expositions • 4 Field Demonstrations of GOMACO GSI and Ames RTP on Vilonia Bypass near Vilonia, AR, I-94 in Jackson County, MI, I-90 Thruway near Weedsport, NY, and SH 114/SH 121 near Dallas/Ft. Worth, TX.	None.	None.	None.
R06F Development of Continuous Deflection Device	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Field Testing/Verification of one candidate NDT device; TSD in the United Kingdom.	Training Courses/Workshops/ Working Group Meetings • Mini-workshop on continuous deflection equipment conducted at Pavement Evaluation 2010 Conference.	None.	None.
R06G High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects Field validation testing at Chesapeake Bay Channel Tunnel (Norfolk, VA); Hakamaentie and Vuosaari Tunnels in Helsinki, Finland; Eisenhower Memorial Tunnel (Dillon, CO); Hanging Lake Tunnel (Glenwood Springs, CO); No Name Tunnel (Garfield County, CO); and Washburn Tunnel (Houston, TX).	None.	None.	None.

The main barriers/challenges to implementation of the bridge-related products are believed to include the following:

- Perceived risks and high initial cost of accelerated bridge construction (ABC) technology.
- Modifying standard practices to accommodate ABC technology.
- Availability of contractors that can bid and implement ABC techniques on bridge renewal projects.
- Establishing realistic expectations for ABC techniques among owners, contractors, and traveling public.
- Ability to change the focus of bridge component initial costs to life-cycle costs.
- Ability to change from the conventional bridge funding approach of "worst-first" rehabilitation/replacement to bridge preservation approach.

The products developed (or currently under development) in the bridges area are listed in Table 2.3, grouped according to various product categories. As can be seen, the primary non-informational product types include manual/guide documents, draft/proposed/recommended specifications and/or testing procedures, sample standard plans and/or detail sheets, case histories, example/hypothetical applications, training/workshop materials, videos, and stand-alone spreadsheet tools.

Table 2.4 shows the product development and implementation activities for the Renewal projects in the Bridges area. As can be seen, there have been two ABC bridge demonstration projects to date and more are planned. A workshop accompanied one of the ABC bridge demonstration projects, and videos of the demonstration were developed and made available online. An ABC webinar and a Bridges for Service Life webinar have also been conducted. As for post-project implementations, several ABC bridge projects are being planned as part of the AASHTO/FHWA/SHRP 2 Implementation Assistance Program.

Pavements

The pavements product area includes the following five research projects:

- R02. Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Working Platform
- R05. Modular Pavement Technology
- R21. Composite Pavement Systems
- R23. Using Existing Pavement in Place and Achieving Long Life
- R26. Preservation Approaches for High-Traffic-Volume Roadways

In addition, five of the NDT research projects—R06, R06C, R06D, R06E, and R06F—and project R07 have direct applications to pavements.

The five pavements area projects were initiated independently between fall 2007 and spring 2008. Two of the projects—R02 and R23—are still ongoing, with an anticipated completion date of December 2014.

Table 2.3. Products Developed under the Bridges Product Area

Product Category	Product Type	Renewal Project		
		R04	R19A	R19B
Guide Material Products	Technical Best Practices Manuals/Guides	✓	✓	✓ (planned)
	Policy Manuals/Guides			
	Model Concepts/Frameworks, Model Analysis Methods/Procedures, and/or Decision/Selection Processes		✓ (M/G)	✓ (planned)
	Guide/Model Specifications and/or Testing Procedures			
	Draft/Proposed/Recommended Specifications and/or Testing Procedures	✓ (M/G) (FR)		✓ (planned)
	Sample Standard Plans and/or Detail Sheets	✓ (M/G) (FR)		
	Case Histories[1]	✓ (FR)		
	Case Studies[2]			
	Example/Hypothetical Applications	✓ (M/G)	✓ (M/G)	✓ (planned)
Training/ Demonstration Products	Training/Workshop Materials (instructor/participant manuals, slide presentations/notes, problem exercises)	✓ (planned)		
	Video Demonstrations	✓		
Software Products	Stand-Alone Software Programs			
	Stand-Alone Spreadsheet Tools			✓ (planned)
	Data Models and/or Database Files/Systems			
	Computational Design, Performance, and/or Cost Models	✓ (Mathcad and CADD files)		
	Information Clearinghouses and/or Internet Portals			
	Web-Based Programs/Tools			
	Online Library/Knowledge Systems			
Equipment/ Hardware Products	Field/Lab Testing Devices/Equipment			
	Computer Hardware			
Technical Support Products	Technical Assistance Services			
	Software Technical Support			
	Expert Task Groups/Communities of Interest			
Informational Products	Final Reports	✓ (pre-pub draft)	✓ (planned)	✓ (planned)
	Interim/Phase and/or Construction Reports			
	Product Development Reports			
	Technical Briefs/Fact Sheets	✓		
	Implementation Plans/Recommendations/Guidelines			
	Research Needs Statements			
	Catalogues/Reference Documents			
	Outreach Materials (product briefs, brochures, newsletters)			

Note: WBP = Product delivered as part of web-based program; M/G = Product delivered as part of manual/guide document; FR = Product delivered as part of final report; DR = Product delivered as part of development report; PR = Product delivered as part of phase report.

[1] A case history documents who, where, why, and how transportation agencies and/or other stakeholders have used a particular technology/product in the past, either as a routine highway project or as a formal research experiment/study. It demonstrates the successful application of the technology/product and highlights its benefits.
[2] A case study entails a detailed investigation/review of an actual project (either pre-existing or new) and/or a detailed evaluation/analysis of data obtained from that project. It describes the subject project, discusses the investigation/review and/or data evaluation/analysis carried out, and identifies key findings, conclusions, and ideas that would support the larger research being performed.

Table 2.4. Summary of Development and Implementation Activities for Renewal Projects in the Bridges Product Area

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R04 Innovative Bridge Designs for Rapid Renewal	Technology Demonstrations and/or Showcase Expositions • Field Demonstration of ABC Bridge Replacement Project in fall 2011 (Keg Creek Bridge near Council Bluffs, IA). • Field Demonstration of ABC Bridge Project in fall 2013 (I-84 bridge over Dingle Ridge Road in New York). • Field Demonstration of ABC Bridge Projects planned in 2014 (Vermont).	Training Courses/Workshops/Working Group Meetings • Highways for Life ABC Workshop accompanied the Keg Creek Bridge Field Demonstration. Webinars • ABC Toolkit Webinar conducted January 2012.	AASHTO/FHWA/ SHRP 2 Implementation Assistance Program • 9 agencies approved for assistance (Arizona, California, Kentucky, Maine, Michigan, Missouri, Nebraska, Rhode Island, and Wisconsin).	None.
R19A Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems and Components	None.	Webinars • Bridges for Service Life Webinar scheduled for October 2013.	None.	None.
R19B Bridges for Service Life Beyond 100 Years: Service Limit State Design	None.	None.	None.	None.

The products developed (or currently under development) in the pavements area are primarily intended to extend pavement performance/life, reduce pavement life-cycle costs, minimize disruptions to traffic, reduce user costs, increase sustainability, and/or improve highway worker and user safety. The products are geared toward a variety of project-level practitioners (e.g., pavement designers, materials engineers, construction engineers, and maintenance/preservation engineers), as well as mid- to upper-level managers responsible for setting policies/practices, overseeing programs, and monitoring/managing the pavement network.

The primary barriers/challenges to implementation of the pavement-related products are believed to include the following:

- Avoiding the inappropriate use of the product by inexperienced or untrained technical individuals, leading to potential problems down the road.
- Potential for products becoming quickly outdated due to the dynamics of technology development.

- Resistance to change within the agency (concern over the resources available and the level of effort required to accommodate the change) and by industry groups (concern over market/competition effects).
- Perception of greater risk (in terms of costs, performance, and possibly safety) associated with implementing and using the products.
- Initial cost of a particular pavement technology is too high for it to be realistically considered and used.

The products developed (or currently under development) in the pavements area are listed in Table 2.5, grouped according to various product categories. As can be seen, the primary non-informational product types include manual/guide documents, model procedures and/or decision/selection processes, and guide/model specifications and/or testing procedures.

Table 2.5. Products Developed under the Pavements Product Area

Product Category	Product Type	Renewal Project				
		R02	R05	R21	R23	R26
Guide Material Products	Technical Best Practices Manuals/Guides	✓ (WBP)	✓ (FR)	✓ (FR)	✓	✓
	Policy Manuals/Guides					
	Model Concepts/Frameworks, Model Analysis Methods/Procedures, and/or Decision/Selection Processes	✓ (WBP)	✓ (FR)	✓ (FR)	✓ (FR/WBP)	✓ (M/G)
	Guide/Model Specifications and/or Testing Procedures	✓ (WBP)	✓	✓ (FR)	✓	
	Draft/Proposed Specifications and/or Testing Procedures					
	Sample Standard Plans and/or Detail Sheets					
	Case Histories[1]	✓ (FR)				
	Case Studies[2]			✓ (PR, FR)		
	Example/Hypothetical Applications			✓ (FR)		✓ (M/G)
Training/ Demonstration Products	Training/Workshop Materials (instructor/participant manuals, slide presentations/notes, problem exercises)			✓		
	Video Demonstrations			✓		
Software Products	Stand-Alone Software Programs			✓		
	Stand-Alone Spreadsheet Tools					
	Data Models and/or Database Files/Systems			✓		
	Computational Design, Performance, and/or Cost Models			✓		
	Information Clearinghouses and/or Internet Portals					
	Web-Based Programs/Tools	✓			✓	
	Online Library/Knowledge Systems	✓ (WBP)			✓ (WPB)	
Equipment/ Hardware Products	Field/Lab Testing Devices/Equipment					
	Computer Hardware					
Technical	Technical Assistance Services					

Support Products	Software Technical Support					
	Expert Task Groups/Communities of Interest					
Informational Products	Final Reports		✓	✓	✓ (pre-pub draft)	✓
	Interim/Phase and/or Construction Reports	✓ (pre-pub draft)		✓		
	Product Development Reports	✓				
	Technical Briefs/Fact Sheets	✓ (WBP)				✓
	Implementation Plans/Recommendations/Guidelines	✓ (PR)	✓ (FR)			
	Research Needs Statements					
	Catalogues/Reference Documents	✓ (WBP)			✓ (FR)	
	Outreach Materials (product briefs, brochures, newsletters)					

Note: WBP = Product delivered as part of web-based program; M/G = Product delivered as part of manual/guide document; FR = Product delivered as part of final report; DR = Product delivered as part of development report; PR = Product delivered as part of phase report.

[1] A case history documents who, where, why, and how transportation agencies and/or other stakeholders have used a particular technology/product in the past, either as a routine highway project or as a formal research experiment/study. It demonstrates the successful application of the technology/product and highlights its benefits.

[2] A case study entails a detailed investigation/review of an actual project (either pre-existing or new) and/or a detailed evaluation/analysis of data obtained from that project. It describes the subject project, discusses the investigation/review and/or data evaluation/analysis carried out, and identifies key findings, conclusions, and ideas that would support the larger research being performed.

Table 2.6 shows the product development and implementation activities for the Renewal projects in the pavements area. As can be seen, there were many field trials conducted as part of the five projects, along with various workshops and/or webinars with participating highway agencies and other stakeholders. As for post-project implementations, the Illinois Tollway has been using R05 and R21 products, and several implementations of the R23 and R26 products are being planned as part of the AASHTO/FHWA/SHRP 2 Implementation Assistance Program.

Table 2.6. Summary of Development and Implementation Activities for Renewal Projects in the Pavements Product Area

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R02 Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Working Platform	Pilot Implementations, Experimental/ Test Sections, Development Projects, and/or Field Validations Projects • 9 development projects in Iowa, Kansas, Oklahoma, and Texas completed to help fill gaps for specific geoconstruction technologies.	Training Courses/Workshops/ Working Group Meetings • Previews, demonstrations, and reviews of the Web-Based GeoTechTools program at TRB and in meetings at Louisiana Department of Transportation and Development, Iowa State University, and Virginia Tech University	None.	None.
R05 Modular Pavement Technology	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Field testing of 14 previously installed/in-service PCP projects in California, Delaware, Illinois, Michigan, Minnesota, Missouri, New Jersey, New York, Texas, and Virginia. Technology Demonstrations and/or Showcase Expositions • PCP demonstration project on IL I-90/Beverly Road ramp.	Training Courses/Workshops/ Working Group Meetings • Workshop in Apr 2013. Webinars • Webinar in Sep 2013.	Implementations • IL I-294 Tri-State Tollway in 2012 • 2013 plans for IL I-55/I-294 ramp, IL I-294/I-80 ramp, IL I-88 at Highland Ave, and IL I-88 at Spring Road	None.
R21 Composite Pavement Systems	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Test sections built/monitored in three locations ➢ MnROAD (3 sections). ➢ UCPRC HVS Facility (12 sections). ➢ IL I-94 Tollway (2 sections). • Field surveys of 64 HMA/PCC and PCC/PCC sections in U.S., Canada, and Europe.	Training Courses/Workshops/ Working Group Meetings • ?	Implementations • Illinois Tollway projects in 2012, including I-88 reconstruction/ widening with 2-lift PCC/PCC and I-90/Rt. 47 interchange ramp construction using HMA/PCC.	Presentation on design of composite pavements at the Illinois Tollway Open House on Sustainable Concrete Paving Practices (Aug 20–21, 2013)
R23 Using Existing Pavement in Place and Achieving Long Life	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Design verification via 6 actual projects Michigan, Minnesota, Missouri, Texas, Virginia, and Washington State.	Training Courses/Workshops/ Working Group Meetings • Pilot workshop in Washington State • Regional workshop in Virginia • Regional workshop in Missouri	AASHTO/FHWA/ SHRP 2 Implementation Assistance Program Planning under way	None.
R26 Preservation Approaches for High-Traffic-Volume Roadways	None.	Webinars • Webinar conducted Sep 2010 describing HTV preservation guidelines.	AASHTO/FHWA/ SHRP 2 Implementation Assistance Program 14 agencies approved for assistance (Arizona, Delaware, Georgia, Kentucky, Massachusetts, Maine, Minnesota, Missouri, Pennsylvania, Rhode Island, Tennessee, Washington State, Wisconsin, and Washington, DC)	None.

Utilities and Railroads

The utilities and railroads product area includes the following eight research projects:

- R01. Encouraging Innovation in Locating and Characterizing Underground Utilities
- R01A. Technologies to Support the Storage, Retrieval, and Utilization of 3-D Utility Location Data
- R01B. Utility Locating Technology Development Utilizing Multi-Sensor Platforms
- R01C. Innovation in Location of Deep Utility Pipes and Tunnels
- R15. Strategies for Utility and Transportation Agency Priorities in Highway Renewal Projects
- R15B. Identification of Utility Conflicts and Solutions
- R16. Railroad-DOT Institutional Mitigation Strategies
- R16A. Communicating Railroad–DOT Mitigation Strategies

The R01 project was the parent project for three utilities location technology research projects. It was initiated in January 2007 and completed in January 2010. Project R01A was initiated in fall 2008, while projects R01B and R01C were begun in fall 2009. All three of these offshoot projects have anticipated completion dates in the last quarter of 2013.

The R15 project, initiated in July 2007 and completed in December 2009, provided the impetus for project R15B. The R15B project, conducted between March 2009 and July 2011, looked at one of the best practices (the utility conflict matrix [UCM]) featured in the R15 report.

The R16 project was initiated in January 2008 and completed in October 2009. It provided the basis for project R16A, which was begun in November 2011 and is expected to be completed by the end of 2013 (Note: A second R16-series project, R16B, began after the start of project R31 and is scheduled for completion in 2015. Because R16B is still in the early stages, it has not been included in the R31 integration efforts).

The products developed (or currently under development) in the utilities and railroads area focus on improved ways of locating and managing utility infrastructure items and coordinating the activities of highway agencies and other stakeholders (utility companies and railroads). The products are primarily intended to expedite construction activities (or at least prevent delays in those activities), minimize road closure times and disruptions to traffic, reduce project costs and user costs, and/or improve highway worker and user safety. The products are geared toward a variety of project-level practitioners (e.g., utility engineers and coordinators, ROW engineers, railroad liaisons, roadway designers, construction engineers), as well as mid- to upper-level managers responsible for establishing utility and railroad policies/practices, overseeing construction programs, and managing utilities at the network level.

The main barriers/challenges to implementation of the utilities- and railroads-related products are believed to include the following:

- Some of the utility-locating technologies are not currently cost-effective to implement (R01B) or are not effective (R01C).

- Agency resistance to taking on more responsibility for utilities within the ROW, as far as identifying their location and character and managing and updating their status.
- Agency resistance to change in the process of coordinating with utility companies (coordination has a tendency to take place in the latter stages of a project).
- Agency reliance on using one-call utility-locating services as design tools, rather than developing, maintaining, and using a utility location database system.
- Lack of training for utility engineers and coordinators in utility location and management technologies.
- Lack of recognized standards and common baselines of performance as it relates to communication/coordination between highway agencies and railroads.
- Increased railroad traffic volumes will make railroads less tolerant of delays or encroachments.
- Lack of understanding between agencies and railroads of each other's objectives and how to reach mutually acceptable agreements.

The products developed (or currently under development) in the utilities and railroads area are listed in Table 2.7, grouped according to various product categories. As can be seen, the primary non-informational product types include manual/guide documents, draft/proposed/recommended specifications and/or testing procedures, sample standard plans and/or detail sheets, case histories, example/hypothetical applications, training/workshop materials, videos, and stand-alone spreadsheet tools.

Table 2.8 shows the product development and implementation activities for the Renewal projects in the utilities and railroads area. In addition to several webinars covering several of the utilities-related Renewal projects, field tests have been conducted for the prototype utility locator devices and some testing of the utility conflict matrix (UCM) prototype. Additional testing or trial implementation of these technologies is underway outside of the Renewal program. Opportunities for assistance in the implementation of the railroad-DOT mitigation strategies developed under project R16 are being planned as part of the AASHTO/FHWA/SHRP 2 Implementation Assistance Program.

Project Management/Delivery

The project management/delivery product area includes the following five research projects:

- R03. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments
- R07. Performance Specifications for Rapid Renewal
- R09. Guide for the Process of Managing Risk on Rapid Renewal Projects
- R10. Project Management Strategies for Complex Projects
- R11. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process

These five projects were initiated independently between fall 2007 and fall 2009. Three projects (R03, R07, and R10) have anticipated completion dates during the last quarter of 2013.

The products developed (or currently under development) in the project management/delivery area are primarily intended to improve risk management planning, improve project delivery by managing time and schedule, accelerate decision making, minimize lane closures and disruptions to traffic, improve asset performance by improving quality and durability of construction, reducing project costs, and/or reducing user costs. The products are geared toward a variety of project-level practitioners (e.g., planners, design engineers, geotechnical engineers, project managers, plans, specifications, and estimates (PS&E) engineers, and construction engineers), as well as mid- to upper-level managers responsible for establishing policies/practices and overseeing programs related to project management and delivery.

Table 2.7. Products Developed under the Utilities and Railroads Product Area

Product Category	Product Type	Renewal Project							
		R01	R01A	R01B	R01C	R15	R15B	R16	R16A
Guide Material Products	Technical Best Practices Manuals/Guides		✓ (planned)						
	Policy Manuals/Guides								
	Model Concepts/Frameworks, Model Analysis Methods/Procedures, and/or Decision/Selection Processes		✓ (planned)					✓ (FR)	
	Guide/Model Specifications and/or Testing Procedures								
	Draft/Proposed Specifications and/or Testing Procedures								
	Sample Standard Plans and/or Detail Sheets								
	Case Histories[1]	✓							
	Case Studies[2]								
	Example/Hypothetical Applications								
Training/ Demonstration Products	Training/Workshop Materials (instructor/participant manuals, slide presentations/notes, problem exercises)		✓ (planned)				✓		
	Video Demonstrations								
Software Products	Stand-Alone Software Programs								
	Stand-Alone Spreadsheet Tools						✓		
	Data Models and/or Database Files/Systems		✓ (planned)				✓		
	Computational Design, Performance, and/or Cost Models								
	Information Clearinghouses and/or Internet Portals								
	Web-Based Programs/Tools	✓							
	Online Library/Knowledge Systems	✓ (WBP)							
Equipment/ Hardware Products	Field/Lab Testing Devices/Equipment			✓* (planned)	✓* (planned)				
	Computer Hardware								

Technical Support Products	Technical Assistance Services								
	Software Technical Support								
	Expert Task Groups/Communities of Interest								✓
Informational Products	Final Reports	✓	✓ (planned)	✓ (planned)	✓ (planned)	✓	✓	✓	✓ (planned)
	Interim/Phase and/or Construction Reports								
	Product Development Reports								
	Technical Briefs/Fact Sheets								
	Implementation Plans/ Recommendations/Guidelines								
	Research Needs Statements								
	Catalogues/Reference Documents	✓							
	Outreach Materials (product briefs, brochures, newsletters)								

Note: WBP = Product delivered as part of web-based program; M/G = Product delivered as part of manual/guide document; FR = Product delivered as part of final report; DR = Product delivered as part of development report; PR = Product delivered as part of phase report.

* Evaluation/refinement of existing devices/equipment.

[1] A case history documents who, where, why, and how transportation agencies and/or other stakeholders have used a particular technology/product in the past, either as a routine highway project or as a formal research experiment/study. It demonstrates the successful application of the technology/product and highlights its benefits.

[2] A case study entails a detailed investigation/review of an actual project (either pre-existing or new) and/or a detailed evaluation/analysis of data obtained from that project. It describes the subject project, discusses the investigation/review and/or data evaluation/analysis carried out, and identifies key findings, conclusions, and ideas that would support the larger research being performed.

Table 2.8. Summary of Development and Implementation Activities for Renewal Projects in the Utilities and Railroads Product Area

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R01 Encouraging Innovation in Locating and Characterizing Underground Utilities	None.	Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research).	None.	None.
R01A Technologies to Support the Storage, Retrieval, and Utilization of 3-D Utility Location Data	None.	Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research). • Webinar conducted Feb 2012 ("New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis").	None.	None.
R01B Utility Locating Technology Development Utilizing Multi-Sensor Platforms	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Proof-of-concept testing of GPR and TEMS prototype tools in actual underground utility projects in two states (Virginia and Georgia).	Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research).	Implementations • Additional testing of prototype tools in two FL projects.	None.

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	Program-Level	Project-Level	Program-Level
R01C Innovation in Location of Deep Utility Pipes and Tunnels	None.	Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research).	None.	None.
R15 Strategies for Utility and Transportation Agency Priorities in Highway Renewal Projects	None.	Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research).	None.	None.
R15B Identification of Utility Conflicts and Solutions	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • Testing of UCM Prototypes 1 and 2 in three states (California, Georgia, and Texas).	Training Courses/Workshops/ Working Group Meetings • 2 Pilot training courses held in AR and SD in Jan 2011. Webinars • Webinar conducted Aug 2011 (joint webinar on SHRP 2 utility research). • Webinar conducted Feb 2012 ("New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis").	Implementations • Trial implementation of UCM spreadsheet matrix in MD (being done under SHRP 2 R15C).	None.
R16 Railroad-DOT Institutional Mitigation Strategies	None.	Webinars • Webinar conducted Aug 2011.	AASHTO/FHWA/SHRP 2 Implementation Assistance Program R16 implementation assistance announced in Jul 2013. Recipients to be announced in fall 2013.	None.
R16A Communicating Railroad–DOT Mitigation Strategies	None.	None.	None.	None.

The main barriers to implementation of the project management/delivery-related products are believed to include the following:

- Fatigue risk management programs may be over-sophisticated for the contracting industry, and the resources for implementing a fatigue risk management system may be inadequate.
- Agency organizational structure and interaction may be counter to the cooperative and collaborative approach needed in developing comprehensive performance specifications.
- A wide variance in project management and delivery practices exists among agencies, making it challenging to apply standardized solutions.
- Project paradigms that limit the number of perspectives from which a problem can be approached.
- Difficulty mastering the complexity of factors that affect project management, particularly in the accelerated environment of rapid renewal projects.
- Resistance to change and concerns about trying innovative methods that deviate from traditional practices.

The products developed (or currently under development) in the project management/delivery area are listed in Table 2.9, grouped according to various product categories. As can be seen, the primary non-informational product types include manual/guide documents, model frameworks and analysis methods, guide/model specifications and testing procedures, case studies, example applications, training/workshop materials, and stand-alone software programs or spreadsheet tools.

Table 2.10 shows the product development and implementation activities for the Renewal projects in the project management/delivery area. As can be seen, there were many field trials conducted as part of the five projects, along with various workshops and/or webinars with participating highway agencies and other stakeholders. As for post-project implementations, proof-of-concept evaluations and lead adopter implementations are underway as part of the AASHTO/FHWA/SHRP 2 Implementation Assistance Program for two of the projects (R09 and R10), and additional implementations as part of that program are forthcoming under project R07.

Renewal Project Tactics

The SHRP 2 Renewal program was designed to develop products capable of achieving three strategic objectives for highway renewal (SHRP 2 2007):

- Can be performed rapidly.
- Can cause minimum disruption.
- Can produce long-lived facilities.

Eight specific tactics were identified for overcoming a variety of barriers to these strategic objectives. These tactics are as follows (SHRP 2 2007):

Rapid Approaches

- Perform faster in situ construction.
- Minimize field fabrication effort.
- Perform faster construction inspection and monitoring.
- Facilitate innovative and equitable contracting environment.

Minimize Disruption

- Plan improvements to mitigate disruption.
- Improve customer relationships.

Table 2.9. Products Developed Under the Project Management/Delivery Product Area

Product Category	Product Type	Renewal Project				
		R03	R07	R09	R10	R11
Guide Material Products	Technical Best Practices Manuals/Guides	✓ (pre-pub draft)		✓	✓ (pre-pub draft)	✓ (pre-pub draft)
	Policy Manuals/Guides					
	Model Concepts/Frameworks, Model Analysis Methods/Procedures, and/or Decision/Selection Processes	✓ (M/G)		✓ (M/G)	✓ (M/G)	✓ (M/G, FR)
	Guide/Model Specifications and/or Testing Procedures		✓ (pre-pub draft)			
	Draft/Proposed Specifications and/or Testing Procedures					
	Sample Standard Plans and/or Detail Sheets					
	Case Histories[1]					
	Case Studies[2]				✓ (M/G, FR)	
	Example/Hypothetical Applications	✓ (FR)		✓ (M/G)		
Training/ Demonstration Products	Training/Workshop Materials (instructor/participant manuals, slide presentations/notes, problem exercises)	✓ (M/G)		✓ (M/G)	✓ (planned)	✓
	Video Demonstrations					
Software Products	Stand-Alone Software Programs					✓
	Stand-Alone Spreadsheet Tools			✓		
	Data Models and/or Database Files/Systems					✓
	Computational Design, Performance, and/or Cost Models					
	Information Clearinghouses and/or Internet Portals					
	Web-Based Programs/Tools					
	Online Library/Knowledge Systems					
Equipment/ Hardware Products	Field/Lab Testing Devices/Equipment					
	Computer Hardware					
Technical Support Products	Technical Assistance Services					
	Software Technical Support					
	Expert Task Groups/Communities of Interest					
Informational Products	Final Reports	✓ (pre-pub draft)	✓ (pre-pub draft)	✓ (planned)	✓ (pre-pub draft)	✓ (pre-pub draft)
	Interim/Phase and/or Construction Reports					
	Product Development Reports					
	Technical Briefs/Fact Sheets					
	Implementation Plans/Recommendations/Guidelines		✓ (pre-pub draft)			
	Research Needs Statements					
	Catalogues/Reference Documents					

	Outreach Materials (product briefs, brochures, newsletters)					

Note: WBP = Product delivered as part of web-based program; M/G = Product delivered as part of manual/guide document; FR = Product delivered as part of final report; DR = Product delivered as part of development report; PR = Product delivered as part of phase report.

[1] A case history documents who, where, why, and how transportation agencies and/or other stakeholders have used a particular technology/product in the past, either as a routine highway project or as a formal research experiment/study. It demonstrates the successful application of the technology/product and highlights its benefits.

[2] A case study entails a detailed investigation/review of an actual project (either pre-existing or new) and/or a detailed evaluation/analysis of data obtained from that project. It describes the subject project, discusses the investigation/review and/or data evaluation/analysis carried out, and identifies key findings, conclusions, and ideas that would support the larger research being performed.

Table 2.10. Summary of Development and Implementation Activities for Renewal Projects in the Project Management/Delivery Product Area

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	**Program-Level**	**Project-Level**	**Program-Level**
R03 Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments	None.	None.	None.	None.
R07 Performance Specifications for Rapid Renewal	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • 3 Field Demonstration projects conducted to showcase the performance specifications (Rt. 141 Chesterfield, MO; Rt. 208 Lake Anna Bridge in VA; US 90 Frontage Road in Ibernia Parish, LA).	Webinars • Webinar conducted Jun 2013.	AASHTO/FHWA/SHRP 2 Implementation Assistance Program • R07 implementation assistance announced in Jul 2013. Recipients to be announced in fall 2013.	None.
R09 Guide for the Process of Managing Risk on Rapid Renewal Projects	None.	None.	AASHTO/FHWA/SHRP 2 Implementation Assistance Program 2 agencies approved for assistance in Round 1 (Florida, Georgia) and 8 agencies applying for assistance in Round 2 (Colorado, Florida, Georgia, Minnesota, Oregon, Pennsylvania, Utah, and Vermont).	None.

Renewal Project	Renewal Project Development Activities		Post-Project Implementation Activities	
	Project-Level	**Program-Level**	**Project-Level**	**Program-Level**
R10 Project Management Strategies for Complex Projects	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • 15 US Case Study projects (Virginia, Michigan, California, Oklahoma, Florida, Connecticut, Maryland, Washington State, Kentucky, Missouri-Illinois, North Carolina, Texas, Colorado) and 3 International Case Study projects (Canada, United Kingdom, New Zealand) used to identify project management tools/strategies. • 2 Validation studies (I-15 Las Vegas, NM; I-74 Corridor IA).	Training Courses/Workshops/Working Group Meetings • 2 Pilot Workshops (Missouri and Utah) and 6 Formal Workshops (New York, Ohio, Iowa, California, Texas, Florida) in fall 2011 conducted during development of best practice strategies. • 2 Training Courses (Colorado and Minnesota) conducted in spring/fall 2011 covering the 5DPM concepts and strategies. Webinars • Webinar conducted May 2013 explored 5DPM approach • 13 webinars currently being developed for future deployment.	AASHTO/FHWA/SHRP 2 Implementation Assistance Program • 5 agencies approved for assistance (Georgia, Massachusetts, Michigan, New Mexico, and Federal Lands Highways)	None.
R11 Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process	Pilot Implementations, Experimental/Test Sections, Development Projects, and/or Field Validations Projects • 2 Selected Sites for WISE Verification and Pilot Application—Phoenix Regional Freeway System expansion/renewal, Des Moines I-235 Corridor renewal. • 2 Proposed Sites for additional WISE Verification and Pilot Application—New York Metro Area, Orlando Metro Area.	Training Courses/Workshops/Working Group Meetings • 2 Workshops completed in Nov 2011 (Baton Rouge, LA—dry run to evaluate WISE planning module) and Dec 2011 (Fairfax, VA—review WISE planning module). • 2nd set of workshops held in Feb 2012 (Houston, TX—review WISE improvements).	None.	None.

Produce Long-Lived Facilities

- Design and construct low-maintenance facilities.
- Preserve facility life.

Using the Renewal project information presented earlier in this chapter combined with these strategic objectives and tactics, the summary table shown in Table 2.11 is presented, in which it can be seen that some Renewal projects touch upon multiple product areas and in some cases one or more projects can be used to achieve more than one tactic. This table represents a preliminary matrix showing the cross-cutting capabilities of the Renewal projects. A more detailed matrix is presented and described in the next chapter.

Table 2.11. Renewal Projects by Product Areas and Tactics

Strategic Objective	Tactic	Product Area	
		NDT	Bridges
Rapid Approaches	Perform Faster In Situ Construction		**R02**. Geoconstruction technologies, GEOTECHTOOLS web-based tool *R03. Fatigue Management Procedures*
	Minimize Field Fabrication Effort		**R04**. Accelerated bridge construction (ABC) design and construction technologies and specifications
	Perform Faster Construction Inspection and Monitoring	**R06**. High-speed NDT equipment/procedures for design evaluation and construction testing **R06A**. NDToolbox web tool for bridge deck evaluation **R06B**. Spectroscopic NDT devices for fingerprinting construction materials **R06C**. NDT technologies and specifications for measuring new HMA pavement uniformity **R06D**. NDT technologies for detecting HMA pavement delamination **R06E**. NDT technologies and specifications for real-time smoothness measurement of new PCC pavement **R06F**. NDT technologies for continuous measurement of pavement deflections **R06G**. NDT technologies for identifying/locating defects in tunnel linings	***R06***. *High-speed NDT equipment/procedures for design evaluation and construction testing* ***R06A***. *NDToolbox web-based tool for bridge deck evaluation*
	Facilitate Innovative and Equitable Contracting Environment		***R07***. *Performance specifications and implementation guidelines for rapid renewal projects*
Minimize Disruption (for users on and adjacent to project)	Plan Improvements to Mitigate Disruption		***R04***. Accelerated bridge construction (ABC) design and construction technologies and specifications ***R11***. *Strategic approaches for minimizing traffic disruption on renewal projects, WISE software tool*
	Improve Customer Relationships		
Produce Long-Lived Facilities	Design and Construct Low-Maintenance Facilities		**R19A**. Design guidelines for long-life (>100 years) bridges **R19B**. Technologies for service limit state design of long-life bridges
	Preserve Facility Life		

Note: Italicized projects are those with products in secondary product areas.

Table 2.11. Renewal Projects by Product Areas and Tactics (*continued*)

Strategic Objective	Tactic	Product Area		
		Pavements	**Utilities and Railroads**	**Project Management/ Delivery**
Rapid Approaches	Perform Faster In Situ Construction	**R02**. Geoconstruction technologies, GEOTECHTOOLS web-based tool ***R03***. *Fatigue Management Procedures*	**R01**. Utilities location/characterization state-of-practice, Selection Assistant for Utility Locating Technologies (SAULT) web-based tool **R01A**. Best practices for 3-D utilities data **R01B**. Multi-sensor devices for utilities mapping **R01C**. Prototype detection systems/tools for deep utilities	**R03**. Fatigue Management Procedures
	Minimize Field Fabrication Effort	**R05**. Design and construction technologies and specifications for modular concrete pavement		
	Perform Faster Construction Inspection and Monitoring	***R06***. *High-speed NDT equipment/procedures for design evaluation and construction testing* ***R06C***. *NDT technologies and specifications for measuring new HMA pavement uniformity* ***R06D***. *NDT technologies for detecting HMA pavement delamination* ***R06E***. *NDT technologies and specifications for real-time smoothness measurement of new portland cement concrete (PCC) pavement* ***R06F***. *NDT technologies for continuous measurement of pavement deflections*		
	Facilitate Innovative and Equitable Contracting Environment	***R07***. *Performance specifications and implementation guidelines for rapid renewal projects*		**R07**. Performance specifications and implementation guidelines for rapid renewal projects **R09**. Risk management guidelines for rapid renewal projects **R10**. Five-dimensional project management (5DPM) strategies for complex projects
Minimize Disruption (for users on and adjacent to project)	Plan Improvements to Mitigate Disruption	***R11***. *Strategic approaches for minimizing traffic disruption on renewal projects, WISE software tool* ***R26***. *Guidelines for pavement preservation on high-traffic-volume roads*		**R11**. Strategic approaches for minimizing traffic disruption on renewal projects, WISE software tool
	Improve Customer Relationships		**R15**. Strategies for integrating the priorities of transportation agencies and utility companies **R15B**. Utility tracking and analysis tools (utility conflict matrix and utility conflict data model/database) **R16**. Railroad-DOT mitigation strategies, railroad and DOT model agreements **R16A**. Community of interest for communicating railroad-DOT mitigation strategies	
Produce Long-Lived Facilities	Design and Construct Low-Maintenance Facilities	**R21**. Design and construction technologies and specifications for composite pavement, MEPDG composite pavement design software **R23**. Guidelines and practices for long-life pavement renewal, web-based scoping tool		
	Preserve Facility Life	**R05**. Design and construction technologies and specifications for modular concrete pavement **R26**. Guidelines for pavement preservation on high-traffic-volume roads		

Note: Italicized projects are those with products in secondary product areas.

CHAPTER 3
Integration of Renewal Projects

Overview of Approach

The in-depth reviews of the renewal projects provided valuable insight into different ways in which the projects and products could be logically grouped for implementation at the functional/technical level and/or administrative/program level. Nearly all of the aspects/features of the renewal projects identified as a basis for grouping the products were included in the expanded summaries document, and that information was used to develop a preliminary integration/packaging matrix and a corresponding framework/process for the integration tool.

Because highway agencies use different approaches to implement research products and because individuals within an agency have unique perspectives and interests regarding implementation, outreach with SHA representatives and other stakeholders was performed to identify typical implementation processes and to assess the feasibility of an integrated approach to renewal product implementation. This outreach included several teleconference interviews with a broad collection of AASHTO members and a half-day workshop targeted to mid- and upper-level engineers and managers within various highway agencies.

Based on the results of the outreach activities, it was determined that each renewal project should be further evaluated to identify target audiences for the tool and to develop a specific set of user needs for which the renewal products would have direct application and could be of benefit. This evaluation led to the development of a revised packaging/integration matrix, which in turn provided the basis for a highly conceptualized and visualized model for the tool.

This chapter describes the activities undertaken to integrate the renewal projects and products for complementary use in rapid renewal projects. It also presents case studies that describe actual highway projects in which renewal products were tested and/or implemented and that demonstrate how other renewal products could have been used on those highway projects. Lastly, it presents and discusses the various benefits associated with integrated implementation of renewal products, as well as some of the major barriers/challenges involved.

Preliminary Integration/Packaging Matrix and Tool Framework/ Process

Early development of the integration/packaging matrix focused on four aspects/features of the renewal projects. These included (a) the highway life-cycle phase in which a product is suitable for use (simplified to the five phases shown in Figure 3.1), (b) the type of highway asset on which a product is applied or used, (c) the specific end user(s) who would benefit from the product (see Figure 3.1), and (d) the type of benefit sought or expected from the end user. Placing items (a) and (c) across the top rows of a table and items (b) and (d) along the first two columns of the table, a basic integration/packaging matrix was developed. The matrix was then populated by listing the renewal projects in each cell having products applicable to the scenario of the cell.

Tables 3.1 and 3.2 show example cut-outs of the preliminary matrix that was developed for functional/technical-level application. Table 3.1 shows the renewal projects that would be pertinent to pavement assets covering users throughout the entire highway life cycle, while Table 3.2 shows the renewal projects that would be pertinent to the final design phase covering all five asset item areas. The numbers listed in the cells of these tables represent the renewal project numbers.

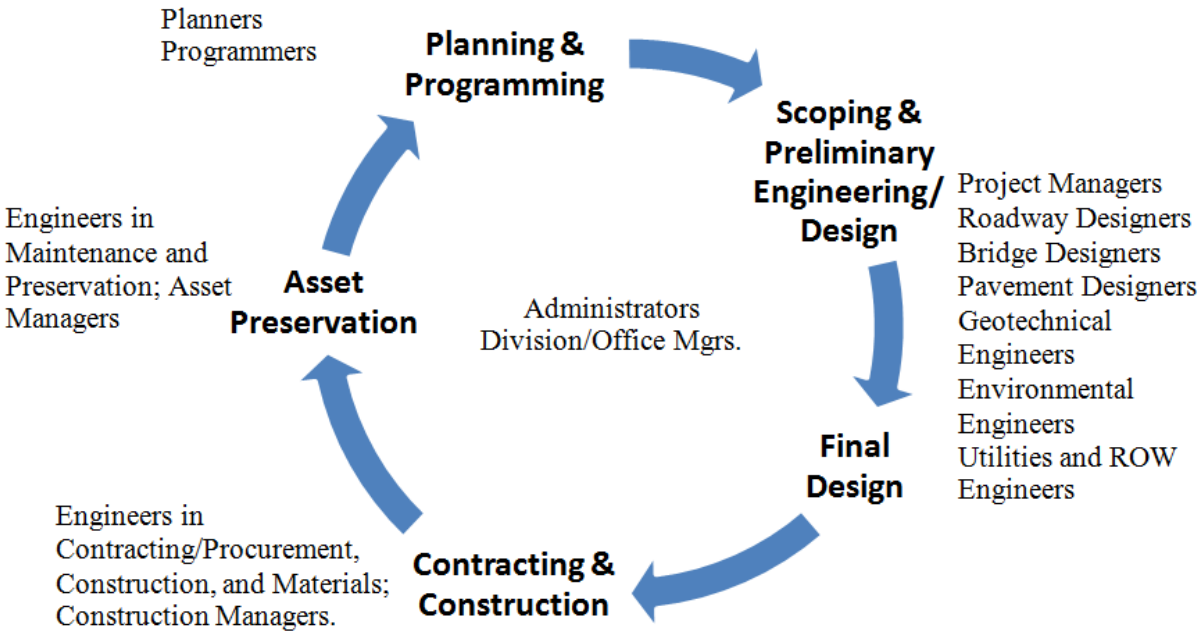

Figure 3.1. Five basic phases in the highway life cycle and targeted end users.

Using this preliminary integration/packaging matrix, a basic framework/process for the integration tool was developed. As illustrated in Figure 3.2, the process filters through the entire set of Renewal projects and identifies those that are relevant to the scenario defined by the user. The sequence in defining the scenario would be at the discretion of the user, and, as more information about the scenario is provided by the user, a more concise list of Renewal projects is developed via the integration/packaging matrix. After the relevant Renewal projects are identified for the user's scenario, the user would then be able to view the specific types of products (e.g., manuals, specifications, software programs, webinars) available for each project and select the products to be implemented.

Outreach to Stakeholders and Targeted Users

Two types of outreach were planned and performed in the study. The first type of outreach involved teleconference interviews with selected members of various AASHTO subcommittees, including Construction, Design, Maintenance and Asset Management (combined), Right-of-Way/Utilities, Bridges/Structures, and Materials. The second type of outreach was a workshop conducted as part of the TRB Annual Meeting. Details of each outreach activity, including important ideas and suggestions made by participants, are presented in the sections below.

Teleconferencing with AASHTO Subcommittee Members

The teleconference interviews were scheduled and conducted between December 21, 2012 and January 7, 2013. The primary objectives of the interviews were to (a) develop a better understanding of how highway agencies go about putting national-level research products into practice and determine to what extent an integrated approach to product implementation is used, and (b) determine the appropriateness of the preliminary integration framework/process in terms of the needs and interests of highway agency representatives and identify improvements to the framework/process.

Table 3.1. Example Cut-out of Preliminary Integration/Packaging Matrix: Renewal Projects Pertinent to the Pavements Asset Type.

Asset Item	Product Benefit/ Highway Needs	Highway Life-Cycle Phase													
		Planning & Programming	Project Development—Scoping & Prelim. Design						Project Development—Final Design						
		Planners/ Programmers	Project Mgrs	Designers	ROW Engineers	Utilities Engineers	Railroad Liaisons	Env Engineers	Project Mgrs	Designers	ROW Engineers	Utilities Engineers	Railroad Liaisons	Env Engineers	Geotech Engineers	PS&E Engineers
Pavement/ Shoulder Structures	Improved Asset Mgt & Planning/ Programming	23, 26		6F, 23, 26						6F, 23, 26						23, 26
	Improved Hwy Operational Efficiency/LOS	5, 9, 11, 23, 26	9, 11	5, 6F, 9, 11, 21, 23, 26					9, 11	5, 6, 6F, 9, 11, 21, 23, 26						5, 6E, 9, 11, 21, 23, 26
	Increased Safety	26	3	6F, 26					3	6F, 26						3, 6E, 26
	Accelerated Proj Development & Cost Schedule	5, 9, 23	3, 9	5, 7, 9, 10, 23					3, 9	5, 6, 7, 9, 10, 23						3, 5, 7, 9, 10, 23
	Improved Project/Asset Performance	5, 9, 23, 26	2, 3, 9	2, 5, 7, 9, 21, 23, 26					2, 3, 9	2, 5, 7, 9, 21, 23, 26					2	3, 5, 6E, 7, 9, 21, 23, 26
	Reduced Project/Asset Life-Cycle Cost	5, 9, 26	3, 9	5, 9, 21, 26					3, 9	5, 9, 21, 26						3, 5, 6E, 9, 21, 26
	Increased Hwy Sustainability	21		21						21						21

Asset Item	Product Benefit/ Highway Needs	Highway Life-Cycle Phase				
		Contracting & Construction			Asset Preservation	
		Contract/Construction Mgrs	Construction Engineers	Materials Engineers	Maintenance/Preservation Engineers	Asset Mgrs
Pavement/ Shoulder Structures	Improved Asset Mgt & Planning/Programming	23	23		6F, 23, 26	6F, 23, 26
	Improved Hwy Operational Efficiency/LOS	5, 9, 11, 21, 23	5,6, 6B, 6C, 6E, 9, 11, 21, 23	6, 6, 6B, 6C, 6E, 21	5, 6B, 6C, 6F, 23, 26	5, 6, 6B, 6C, 6E, 6F, 23, 26
	Increased Safety	3	3, 6C, 6D, 6E	6C, 6D, 6E	6C, 6D, 6F, 26	6C, 6D, 6E, 6F, 26
	Accelerated Proj Development & Cost Schedule	3, 5, 7, 9, 10, 23	3, 5, 6, 6B, 7, 9, 10, 23	5, 6, 6B, 7	5, 6B, 23	5, 6, 6B, 23
	Improved Project/Asset Performance	3, 5, 7, 9, 21, 23	2, 3, 5, 6B, 6C, 6D, 6E, 7, 9, 21, 23	5, 6B, 6C, 6D, 6E, 7, 21	5, 6B, 6C, 6D, 23, 26	2, 5, 6B, 6C, 6D, 6E, 23, 26
	Reduced Project/Asset Life-Cycle Cost	3, 5, 9, 21	3, 5, 6B, 6C, 6D, 6E, 9, 21	5, 6B, 6C, 6D, 6E, 21	5, 6B, 6C, 6D, 26	5, 6B, 6C, 6D, 6E, 26
	Increased Hwy Sustainability		21	21		21

Note: Numbers listed in the table cells are the Renewal project numbers (e.g., 9 equals project R09).

Table 3.2. Example Cut-out of Preliminary Integration/packaging Matrix: Renewal Projects Pertinent to the Final Design Phase in the Highway Life Cycle

Asset Item	Product Benefit/Highway Needs	Staged Adoption/Use (Project-Level) Project Development—Final Design							
		Project Managers	Designers	ROW Engineers	Utilities Engineers	Railroad Liaisons	Environmental Engineers	Geotech Engineers	PS&E Engineers (Const/Mtls Engineers)
Pavement/ Shoulder Structures	Improved Asset Mgt & Plann/Program		6F, 23, 26						23, 26
	Improved Hwy Operational Efficiency/LOS	9, 11	5, 6, 6F, 9, 11, 21, 23, 26						5, 6E, 9, 11, 21, 23, 26
	Increased Safety	3	6F, 26						3, 6E, 26
	Accelerated Proj Development & Const Schedule	3, 9	5, 6, 7, 9, 10, 23						3, 5, 7, 9, 10, 23
	Improved Project/Asset Performance	2, 3, 9	2, 5, 7, 9, 21, 23, 26					2	3, 5, 6E, 7, 9, 21, 23, 26
	Reduced Project/Asset Life-Cycle Cost	3, 9	5, 9, 21, 26						3, 5, 6E, 9, 21, 26
	Increased Highway Sustainability		21						21
Bridge/ Culvert Structures	Improved Asset Mgt & Plann/Program		6A						6A
	Improved Hwy Operational Efficiency/LOS	9, 11	6, 9, 11						9, 11
	Increased Safety	3, 4	4, 19A, 19B						3, 19A, 19B
	Accelerated Proj Development & Const Schedule	3, 9	6, 7, 9, 10						3, 7, 9, 10
	Improved Project/Asset Performance	2, 3, 4, 9	2, 4, 6A, 7, 9, 19A, 19B					2	3, 6A, 7, 9, 19A, 19B
	Reduced Project/Asset Life-Cycle Cost	3, 4, 9	4, 6A, 9						3, 6A, 9
	Increased Highway Sustainability	4	4						
Tunnel Structures	Improved Asset Mgt & Plann/Program								
	Improved Hwy Operational Efficiency/LOS		6						
	Increased Safety	3							3
	Accelerated Proj Development & Const Schedule	3	6						3
	Improved Project/Asset Performance	3							3
	Reduced Project/Asset Life-Cycle Cost	3							3
	Increased Highway Sustainability								

Utilities & ROW	Improved Asset Mgt & Plann/Program								
	Improved Hwy Operational Efficiency/LOS			1C	1C				
	Increased Safety	3	1	1	1				3
	Accelerated Proj Development & Const Schedule	3, 15B	1, 1A, 15B	1, 1A, 1B, 1C, 15B	1, 1A, 1B, 1C, 15B		1B	1B	3, 15B
	Improved Project/Asset Performance	3							3
	Reduced Project/Asset Life-Cycle Cost	3, 15, 15B	15, 15B	15, 15B	15, 15B				3, 15, 15B
	Increased Highway Sustainability								
Roadside & Traffic Features	Improved Asset Mgt & Plann/Program								
	Improved Hwy Operational Efficiency/LOS								
	Increased Safety	3							3
	Accelerated Proj Development & Const Schedule	3							3
	Improved Project/Asset Performance	3							3
	Reduced Project/Asset Life-Cycle Cost	3							3
	Increased Highway Sustainability								
Railroads	Improved Asset Mgt & Plann/Program								
	Improved Hwy Operational Efficiency/LOS								
	Increased Safety	3							3
	Accelerated Proj Development & Const Schedule	3, 16, 16A	16, 16A	16, 16A	16, 16A	16, 16A			3, 16, 16A
	Improved Project/Asset Performance	3							3
	Reduced Project/Asset Life-Cycle Cost	3							3
	Increased Highway Sustainability								

Note: Numbers listed in the table cells are the Renewal project numbers (e.g., 9 equals project R09).

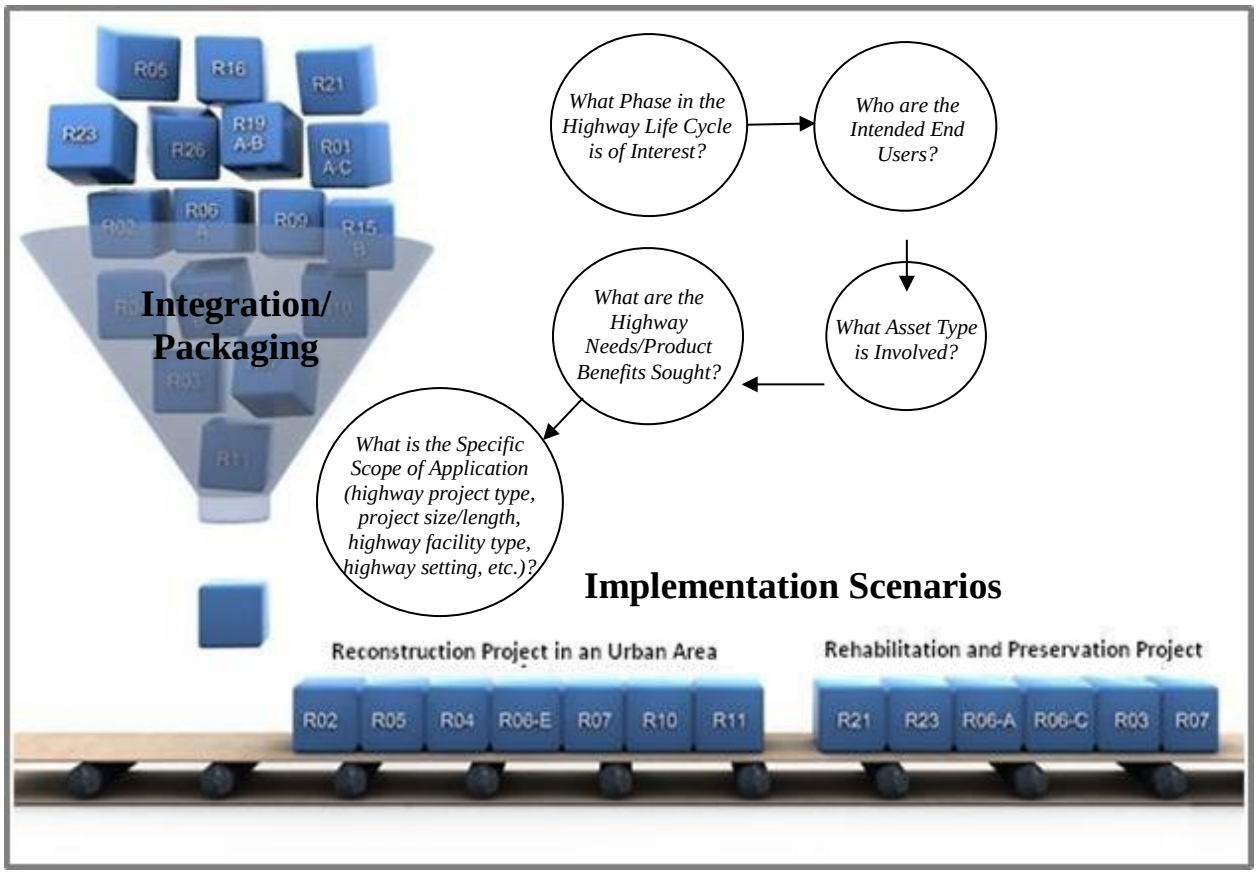

Figure 3.2. Example illustration of the preliminary integration framework/process.

A total of six interviews were performed—one for each subcommittee, except the maintenance and asset management subcommittees, which were combined into one—with each interview lasting approximately 1 hour. Although eight to ten members from each subcommittee were chosen and requested to participate in the interviews (primarily on the basis of geographical representation and coverage of the many specific areas of technical expertise), the actual number of participants ranged from three to five. Each interview was facilitated and documented by key members of the APTech team (including consultants with specific subject matter expertise).

Listed below are key points gleaned from the teleconference interviews.

- Generally, implementation of a new technology or research result within an agency is led by the appropriate technical area. A research office may lead this effort, but more often their responsibility is to provide assistance to the technical areas. Occasionally, initiatives are issued as directives from administrators (upper management), but the technical area is responsible for implementation.
- Integrated implementation of renewal products is generally going to happen at the upper-management level. At the functional/technical level, implementation usually occurs one technology at a time so that the effects can be clearly observed. Agencies that have high collaboration among divisions may have greater potential for integrated implementation.

- Agencies like the idea of coordinated implementations, such as pooled-fund studies, lead states, peer exchanges, and scanning tours.
- Subject matter area/technical area should be included as an evaluation portal in the proposed R31 tool.
- There is a lot of research and a lot of new technology/information to absorb, to the point that agencies feel overloaded. The R31 tool should enable users to quickly and easily navigate to their destination (find and access desired content), with the ability to screen out products and information not wanted.
- The R31 tool should be dynamic, with updated links provided over time to allow users real-time access to the most recent content. This is critical.
- Problem/constraint identification and needs should be an evaluation portal, allowing the user to identify his or her specific problem that needs to be solved (or at least addressed by the available renewal products).
- The stage in the highway life cycle is important and needs to be considered in the evaluation process (possibly as a portal). Users will need the ability to consider the use of renewal products in a project several years prior to its actual implementation in the field. If a certain renewal product is identified at the design stage of the project, it may be too late to fully realize the benefits of the product.
- Once desired products are identified, there should be access to webinars and other forums for detailed information on the products as well as available resources (FHWA, AASHTO, or other funding mechanisms and/or assistance programs) to help the agency implement the products.
- The R31 tool needs to be able to quickly grab the attention of the user, and this can be done with a hook that goes to directly solving the user's problem. Another way to grab attention is to feature the latest technology buzz (what's the newest thing and how has it worked); this will be of greatest interest to the "up-and-comers," the ones who really want to move the agency forward.
- The tool needs to provide a platform for the more careful-minded user to evaluate the real benefits and costs of the product in comparison with how the agency currently does things. A rating system using benefit-cost ratio was suggested for inclusion in the tool.
- Tool usability is key, and an important component will be the ability to post results and comments by others regarding product implementation (including descriptions, successes, lessons learned, and cost-effectiveness).
- Risk assessment is key in the decision of whether to implement new technologies. Bigger/global innovations, like SuperPave, usually involve much greater risk and require upper-management decision-making, while smaller innovations usually involve lower risk and can be instituted at the functional level. Risk assessment must look at probable rewards/benefits and the associated costs. Also, speed of implementation can offset risk; bigger/global solutions may need more time in order to be sold.
- Key challenges/barriers to integrated implementation include risk, cost to implement, internal agency issues (lack of interoffice collaboration, turf protection, different

priorities among offices, organizational constraints), contractor and other stakeholder issues, lack of champions, and lack of clarity as to the latest standards. Consider Utah DOT's "Ideas to Practice" concept, where the DOT sends staff to TRB, and, upon return, they are requested to present on two new ideas learned there. The DOT tracks the various ideas and develops estimates of cost savings, which can then be considered with respect to implementation in their own state.

- Suggest contacting Leslie Tribelhorn (MT) on the Technical Committee on Cost Estimating to inquire about the data interface associated with the AASHTO TRNS*PORT program.

TRB Workshop 166

TRB Workshop 166 (Visualizing and Customizing Tools for Implementation of SHRP 2 Renewal Products) was conducted at the TRB Annual Meeting on the afternoon of Sunday, January 13, 2013. The primary goals of the workshop were to (a) familiarize participants with the renewal projects and products and the different ways in which they can be implemented on a highway project and/or adopted into highway practice, and (b) engage participants in discussions that would help further mold the vision for the integration tool.

The 3-hour workshop was facilitated by key members of the APTech team SHRP 2 staff. Attendance at the workshop varied, with full participation by 15 to 17 individuals and partial participation by another eight to 10. The participants represented a mix of backgrounds, including a few mid- to upper-level state highway agency (SHA) representatives, various SHRP 2 and FHWA staff, and consultants involved in SHRP 2 Renewal projects and the AASHTO-sponsored renewal product implementation project. The workshop consisted of four basic parts, as follows:

- Overview of SHRP 2 and introduction to R31.
- Overview of renewal projects and products (expanded summaries).
- Description and discussion of preliminary integration/packaging matrix and tool framework/process.
- Description and discussion of proposed web-based integration software/tool.

Table 3.3 provides a summary of the major comments and ideas conveyed in the workshop. This information and the information from the teleconference interviews provided the basis for refining the integration/packaging matrix and the tool framework/process, as described in the next section.

Revision of Integration/Packaging Matrix and Tool Framework/ Process

Identification of Problems/Constraints and Corresponding Needs

The SHRP 2 Renewal products have the potential to address many different needs within a highway agency, as well as needs among other stakeholders involved in the highway renewal process (e.g., contractors, consultants, utility companies, railroads). Although the proposed integration tool would effectively leverage the renewal products for a multitude of end users, the primary recipients of the tool are considered to be those within the highway agency who collectively provide for and maintain an operable highway system for the traveling public. These end users can be grouped into the following two audiences:

- Middle-Level Management and Technical Staff: This user group consists of front-line managers, supervisors, engineers, and other technical professionals within an agency who are responsible for carrying out the various functional aspects of highway renewal at the project, corridor, or network level.
- Executives and Upper-Level Management: This user group consists of high-level administrators and decision makers within an agency who are responsible for setting policies and defining the practices and standards for achieving highway renewal.

Table 3.3. Summary of Major Comments and Ideas Expressed in TRB Workshop 166

Discussion Topic	Workshop Comments
Product Implementation	▪ State highway agencies are looking for information and solutions that will make their job of constructing, operating, and maintaining highways easier. The process of implementing new products and technologies, such as those coming out of the SHRP 2 Renewal program, requires hard facts and bottom-line expected benefits regarding those products. The more hard facts and the greater the delta associated with a particular SHRP 2 product, the greater the likelihood of states implementing it. ▪ One of the key components in product implementation is getting authoritative buy-in from upper-level management. Some important approaches for achieving buy-in include: ➢ Education. Many of the DOT key decision makers don't often get to go to conferences/workshops, so it would be very worthwhile to take the product to the local level via workshops, demos, and other forums or types of outreach (e.g., ABC workshops for bridges). A two-pronged approach to education—higher-level general session for upper-level management and more detailed technical session for mid- to lower-level managers and engineers—is often quite successful. ➢ Biggest bang for the buck. A face-to-face meeting with a selected DOT staff covering the various aspects of the product, including the benefits as compared to the conventional agency strategy, can often generate enthusiasm and interest in the product. ➢ Risk and Risk Mitigation. Many SHAs do the same old thing, because there is little chance of repercussions if things fail. On the flip side, some agencies may be inclined to do implementations because they have nothing to lose (they are in desperate need).

Discussion Topic	Workshop Comments
	▪ A stepwise approach to product implementation should be considered for each product. An analogy to this is the implementation of a highway project, which begins with planning, goes to design, and then to construction. ▪ The real goal in product implementation is to push the use of the product to the level that it becomes standard practice. ▪ It's important to know what kind of structure and what kind of tools can provide for the most effective dissemination and use of Renewal products. ▪ An Executive Information Portal should be fully considered, along with the use of pod e-mails and YouTube animated videos (YouTube videos integrated into tool, if content available for high-level buy-in). ▪ Some DOTs get a great amount of benefit from attending webinars. Research managers often have a different source for information than high-level directors. ▪ It is recommended that notes from past implementation planning workshops (e.g., R09, R10, R26, and R15B) be reviewed to get further ideas about implementation. Also, it is important to know the boundary of SHRP 2 research that is not being implemented (e.g., R01).
Application of Tool for Different Project Scenarios	▪ It is important to know what kind of project delivery method (e.g., design-build, design-bid-build, warranty) and what kind of specs (e.g., performance specs) will be used, as this may provide greater opportunities for implementation of some products. ▪ It is also important to consider what drives a user to want to try something different. For instance, a user may foresee problems with the conventional approach/strategy on a particular project. ▪ It is imperative to know what the specific problem(s) is on a project, so that potential product options can be identified. ▪ Project managers may have a unique perspective to share on the impetus of doing something different.
Barriers/Challenges	▪ There are issues to be considered concerning where the R31 web-based software will reside and how it will be maintained/updated. ▪ The state feedback from the R31 teleconferences with AASHTO members is valuable and should be carefully considered. Although they may have expressed trepidation regarding the concept of integration, this can be overcome by showing DOTs the process through examples. ▪ It is important to have a good fix on the benefits of the products. It's not enough to just say that Product X will increase safety; there is a need to be specific about how the product will increase safety and to be able to show tangible evidence of the benefit. This will be a true challenge, and the work behind it is probably outside the scope of R31. ➢ Analyses have not really been done concerning additional initial costs associated with product, the long-term costs, and the quantifiable benefits. Data will be needed for a determination of whether the product is cost-effective or not.
Proposed Software Tool	▪ It is imperative that the integration tool be simple. It should not include a bunch of equations and a lot of text, as these will scare off many potential users. ▪ The use of project characteristics to define/drive the process (i.e., start from a project perspective) is desirable. This could be another portal (i.e., entry point into the evaluation process) within the tool. An example might be "I need to implement a highway project in 9 months. What SHRP 2 products are available that might help make this happen?" It is recommended that the project team define 20 to 30 project scenarios that cover different physical aspects, different stakeholder aspects, and different types of project delivery.

Discussion Topic	Workshop Comments
	▪ There are two different ways for implementation to occur. One is at the project or functional level; the other is at the central-office or program level. The tool should recognize this and allow for use by both types of users. ▪ A concern was expressed about the dependencies of the tool as it relates to research and technologies that are taking place outside of SHRP 2. For example, a user may want to implement a product from R04, but there may be related information from FHWA or other sources that would also be valuable. Questions such as "Which bridge project is a candidate for R04?" "Should the tool point the user to the FHWA tool?" and "Should the tool provide a Related Links button?" were posed. The SHRP 2 response to this concern was that the boundaries of the tool need to be limited to SHRP 2 and that this is what the project team was charged with doing. ▪ The tool should contain or provide access to decision-making tools and specifications to give confidence to agencies. ▪ The key to the tool is giving the agency user the ability to define a specific problem to be solved. It is also critical that the tool be able to show examples of implementing multiple products successfully (i.e., show full-delivery process versus 2 or 3 products implemented individually). ▪ A "lessons learned" or "recommendations" page would be of great value to some agencies. It was pointed out that innovation often comes out of an open-minded approach to trying things. With home runs come a fair share of duds. The tool should give users insight into what others have done and what the results have been. ▪ The tool should be people-driven and information-driven and should fully recognize who the audience is. ▪ The tool needs to recognize who the experts are at AASHTO and FHWA. It should reference these experts, so that tool users have a quality source for pursuing additional information. ➢ Cost aspects are critical. The tool should make pilot data and other data available and should include the ability to do cost-benefit analysis. It should be able to produce a simple single number by which to make a decision (e.g., above a certain number, the answer to "should we implement" will be yes; below that number, the answer will be no).

For each audience, a specific set of user needs were developed for which the renewal products have direct application and could be beneficial. Tables 3.4 through 3.8 list the user needs developed for the middle-level management and technical staff audience corresponding to each of the five renewal product areas. Use of the renewal products for this audience represents a functional/technical-level application (technical discipline application) involving lower levels of risk. As seen in these tables, the user needs have been grouped into the following user needs categories:

- Project scoping
- Strategy selection
- Preliminary design
- Final design

- Specifications
- Construction
- Evaluation/testing

Tables 3.9 through 3.13 list the user needs developed for the executives and upper-level management audience corresponding to each of the five renewal product areas. Use of the renewal products for this audience represents an administrative/program-level application (operational application [e.g., administrative direction, policy-related assistance, standards and criteria]) involving higher levels of risk. The user needs have been grouped into the following categories:

- Project scoping practices
- Strategy selection practices
- Design practices
- Specifications development
- Construction practices
- Maintenance practices
- Evaluation/testing practices
- Education/training
- Research/development/implementation

Revised Integration/Packaging Matrix

The established user needs and user needs categories listed in Tables 3.4 through 3.8 were incorporated into the preliminary integration/packaging matrix to produce a more effective and practical mechanism for product integration. Specific revisions included replacing the product benefits/highway needs criterion with the user needs categories, adding a few more potential end users at the functional/technical level, and repopulating the matrix by listing for each cell the combinations of renewal project and user need that would be applicable to the scenario of the cell. For instance, if the third user need listed for renewal project R05 (see Table 3.6)—"Suitability of PCP/modular pavement as a preservation/rehabilitation treatment (i.e., intermittent repairs and/or slab replacements) for an existing concrete pavement"—was deemed appropriate for a scenario, then the identification number 5-3 (Renewal project R05, user need 3) was entered for that cell.

Table 3.4. Functional/Technical-Level Needs Summary for NDT Area Renewal Projects

Project	User Needs (Needs Category)
R06	*The product of this study was a final report that provided recommendations to SHRP 2 for programming additional research funds for NDT in a variety of applications. Hence, the product does not address any project-level user needs.*
R06A	1. Identification of suitable NDT devices/tools for evaluating and detecting concrete bridge deck deterioration (specific distresses [e.g., delamination, corrosion, vertical cracking, concrete degradation] and overall condition), based on device/tool performance ratings for accuracy, repeatability, speed, ease of use, and cost (**Strategy Selection**). 2. Procedures and illustrations for using various NDT devices/tools to evaluate concrete bridge deck deterioration (**Evaluation/Testing**).
R06B	1. Standard of practice for identifying chemical admixtures in fresh PCC using the Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy device, and procedures for operating the ATR-FTIR spectroscopy device in the field (**Evaluation/Testing**). 2. Standard of practice for determining titanium content in traffic paints using the X-ray fluorescence (XRF) spectroscopy device and procedures for operating the XRF spectroscopy device in the field (**Evaluation/Testing**).
R06C	1. Identification of a suitable NDT device/tool for real-time monitoring of the quality of HMA paving mats, either immediately after mat placement (measurement of localized cold spots) and/or during mat compaction (measurement of density) (**Strategy Selection**). 2. Procedures and illustrations for using various NDT devices/tools to measure and evaluate in real time the quality of HMA paving mats (**Evaluation/Testing**). 3. Model specification information that can be used in developing quality control (QC) and/or quality assurance (QA) specifications for the PAVE-IR thermal profile measurement system (**Specifications**). (Note: Model specification is still under development). 4. Model specification information that can be used in developing QC and/or QA specifications for the GPR density measurement system (**Specifications**). (Note: Model specification is still under development).
R06D	*The anticipated products of the study (low-speed impact echo/spectral analysis of surface waves [IE/SASW] and high-speed GPR) exhibited limitations in the ability to identify delamination between HMA layers. Further development/refinement of each device is required before implementation can occur. Hence, the products do not currently address any project-level user needs.*
R06E	1. Procedures for using various non-contact, real-time profile measuring systems to measure the profile and compute the smoothness of new PCC pavement (**Evaluation/Testing**). 2. Model specification information that can be used in developing QC specifications (as part of a quality management plan [QMP]) for non-contact, real-time profile measuring systems for concrete paving (**Specifications**).
R06F	1. Procedures and illustrations for using high-speed continuous deflection equipment to collect deflection data and to analyze the data to support network-level pavement management activities (e.g., identifying structurally deficient/weak areas that can be investigated further at the project level, calculating a "structural health index" that can be incorporated into a PMS) (**Evaluation/Testing**).
R06G	1. Identification of suitable NDT devices/tools for conducting condition assessments of tunnel linings, based on device/tool performance ratings for accuracy, detection depth, deterioration mechanisms detected (e.g., moisture intrusion, delaminations and spalling, voids), and tunnel lining types (**Strategy Selection**). 2. Procedures and illustrations for using various NDT devices/tools to evaluate tunnel linings (**Evaluation/Testing**).

Table 3.5. Functional/Technical-Level Needs Summary for Bridges Area Renewal Projects

Project	User Needs (Needs Category)
R04	1. Design concepts, details, considerations, and guidance for a variety of ABC technologies (prefabricated bridge elements/systems and corresponding bridge movement techniques and equipment) for possible use in accelerated renewal of existing bridges (40- to 130-ft spans) (**Preliminary Design, Final Design**). 2. Sample standard plans and detail sheets that can be adapted for use in the construction plans of a bridge renewal project that will incorporate ABC technologies (**Final Design**). 3. Reference specification (recommended AASHTO-formatted) information that can be used in developing load and resistance factor design (LRFD) design specifications for ABC elements and systems (**Specifications**). 4. Reference specification (recommended AASHTO-formatted) information that can be used in developing LRFD construction specifications for ABC elements and systems (**Specifications**). 5. Procedures associated with ABC construction, including fabrication of elements, subsystems, and components off alignment and movement of the system into place using proper equipment (**Construction**).
R19A	1. Identification of suitable bridge system alternatives that satisfy project requirements and selection of optimum alternative based on assessment of cost-effectiveness (life-cycle cost analysis [LCCA]), performance, and other factors (**Strategy Selection**). 2. Design concepts, details, considerations, and procedures for systematically designing new and existing bridge systems (and their various elements, subsystems, and components) for service life and durability (**Preliminary Design, Final Design**). 3. Procedures associated with construction of long-life bridges and the various elements, subsystems, and components (**Construction**).
R19B	*The anticipated products are not currently available and limited information exists about them. Hence, they do not address any project-level user needs.*

Table 3.6. Functional/Technical-Level Needs Summary for Pavements Area Renewal Projects

Project	User Needs (Needs Category)
R02	1. Geoconstruction technologies that are the best options for a roadway project involving embankment construction over unstable soils or working platform improvement (**Strategy Selection**). 2. Expected cost of a geoconstruction technology identified as a candidate for a roadway project (**Project Scoping/Cost Estimating**). 3. Design details and procedures for a geoconstruction technology selected for a roadway project involving embankment construction over unstable soils or working platform improvement (**Preliminary Design, Final Design**). 4. Reference specifications (existing or example) information that can be used in developing material, system, and/or construction specifications for a geoconstruction technology selected for a roadway project (**Specifications**). 5. Construction procedures for a geoconstruction technology selected for a roadway project and QC/QA methods typically used for the technology (**Construction**).
R05	1. Structural design (thickness, joints, reinforcement, etc.) for PCP/modular pavement used as a preservation/rehabilitation treatment (intermittent full-depth repair and/or slab replacement application) for an existing concrete pavement (**Preliminary Design, Final Design**).

	2. Structural design (thickness, joints, reinforcement, etc.) for PCP/modular pavement used as a rehabilitation/reconstruction treatment (continuous application) for an existing concrete or asphalt pavement (**Preliminary Design, Final Design**). 3. Suitability of PCP/modular pavement as a preservation/rehabilitation treatment (i.e., intermittent repairs and/or slab replacements) for an existing concrete pavement (**Strategy Selection**). 4. Suitability of PCP/modular pavement as a rehabilitation/reconstruction treatment (i.e., continuous application) for an existing concrete or asphalt pavement (**Strategy Selection**). 5. The procedures associated with constructing (i.e., fabricating panels at the plant and installing them at the jobsite) PCP/modular pavement for a rehabilitation/reconstruction application (**Construction**). 6. The procedures associated with constructing (i.e., fabricating panels at the plant and installing them at the jobsite) PCP/modular pavement for a preservation/rehabilitation application (**Construction**). 7. Model specification information that can be used in developing material, panel fabrication, and panel installation specifications for the PCP/modular pavement technology selected for preservation/ rehabilitation (i.e., intermittent application) of an existing concrete pavement (**Specifications**). 8. Model specification information that can be used in developing material, panel fabrication, and panel installation specs for the PCP/modular pavement technology selected for rehabilitation/reconstruction (i.e., continuous application) of an existing concrete or asphalt pavement (**Specifications**).
R21	1. Structural design (thickness, joints, reinforcement, etc.) for a proposed long-life HMA/PCC or PCC/PCC composite pavement (new or reconstructed roadway) (**Preliminary Design, Final Design**). 2. Feasibility and cost-effectiveness of HMA/PCC or PCC/PCC composite pavement as a long-life pavement option on a new roadway project or a roadway reconstruction project (**Strategy Selection**). 3. Guide specification information that can be used in developing material and/or construction specifications for long-life HMA/PCC or PCC/PCC composite pavement selected for a new roadway or roadway reconstruction project (**Specifications**). 4. Procedures associated with constructing a long-life HMA/PCC or PCC/PCC composite pavement for a new roadway or roadway reconstruction project (**Construction**).
R23	1. Suitable long-life rehabilitation options (including reconstruction [removal/replace]) for an existing asphalt, concrete, or composite pavement (**Strategy Selection**). 2. Preliminary/approximate structural design (thickness, primarily) of different long-life rehabilitation options (including reconstruction [removal/replace]) for an existing asphalt, concrete, or composite pavement, as a basis for rehabilitation type selection (**Preliminary Design**). 3. Guide specification information that can be used in developing material and/or construction specifications for the long-life rehabilitation option (including reconstruction [removal/replace]) selected for an existing asphalt, concrete, or composite pavement (**Specifications**).
R26	1. Suitability of pavement preservation as a life-extending activity (functional and/or structural) for an existing asphalt, concrete, or composite pavement on a high-traffic road (**Strategy Selection**). 2. Suitability and cost-effectiveness of different preservation treatments as a life-extending activity (functional or structural) for an existing asphalt, concrete, or composite pavement on a high-traffic road (**Strategy Selection**).

Table 3.7. Functional/Technical-Level Needs Summary for Utilities/Railroads Area Renewal Projects

Project	User Needs (Needs Category)
R01	1. Identification of utility-locating/characterizing technology for use in a roadway project (**Project Scoping/Cost Estimating**).
R01A	1. Procedures/tools for tracking and evaluating utility installation data for a roadway project (**Preliminary Design**). (Note: Tool is still under development) 2. Procedures/tool for providing notification of changes in utility information or status within the right-of-way (**Preliminary Design, Final Design**). (Note: Tool is still under development).
R01B	*The anticipated products of the study (prototype utility detection systems [multi-antenna GPR and TEM]) require more R&D, as the incremental benefits they may provide are far outweighed by their costs. Hence, they do not address any project-level user needs.*
R01C	*The anticipated products of the study (prototype utility detection systems [acoustic locator and radio-frequency identification [RFID] tag]) did not work. Hence, they do not address any project-level user needs.*
R15	*The key product of the study is a final report with best practices for improving coordination between utility companies and highway agencies. The product is a program-level product. Hence, it does not address any project-level user needs.*
R15B	1. Tools for management of utility conflicts and relocation (**Preliminary Design**). 2. Procedures for tracking utility conflict resolution and milestones (**Construction**). 3. Communication and coordination of utility conflict information with stakeholders (utility owners, one-call providers) (**Construction**).
R16	1. Master project agreement between railroad and highway agency for roadway project that involves railway (**Project Scoping/Cost Estimating**). 2. Preliminary engineering agreement for reviews of roadway project that will cross a railroad right-of-way (**Preliminary Design**). 3. Model project agreements for typical areas where roadway projects impact railroads (resurfacing, highway overpass, warning devices, pipe and wire) (Strategy Selection).
R16A	1. Coordination of activities for a roadway project that will cross a railroad right-of-way (Construction).

Table 3.8. Functional/Technical-Level Needs Summary for Project Management/Delivery Area Renewal Projects

Project	User Needs (Needs Category)
R03	1. Procedures for performing a risk assessment of schedules and identifying alternatives that provide the lowest levels of risk while still maintaining the desired project schedule (Project Scoping/Cost Estimating, Preliminary Design). 2. Fatigue mitigation strategies, tools, and practices that can be put into place on a rapid renewal highway project that uses a construction scheduling approach with increased risk of worker fatigue (Preliminary Design, Construction).
R07	1. Suitability of using performance specifications on a particular rapid renewal project (Strategy Selection). 2. Guide specification information that can be used in developing a performance specification for HMA pavement (design [if applicable], materials, and construction) as part of a design-bid-build, design-build, or warranty type project (Specifications). 3. Guide specification information that can be used in developing a performance specification for PCC pavement (design [if applicable], materials, and construction) as part of a design-bid-build, design-build, or warranty type project (Specifications). 4. Guide specification information that can be used in developing a performance specification for precast/modular concrete pavement (materials, fabrication, and installation) as part of a design-bid-build project (Specifications). 5. Guide specification information that can be used in developing a performance specification for pavement (design, materials, construction, maintenance, and handback) as part of a design-build-operate-maintain project (Specifications). 6. Guide specification information that can be used in developing a performance specification for pavement foundation (embankment fill, subgrade, subbase) (equipment and construction) using roller-integrated compaction monitoring technology (Specifications). 7. Guide specification information that can be used in developing a performance specification for PCC bridge deck (design [if applicable], materials, and construction) as part of a design-bid-build or design-build project (Specifications). 8. Guide specification information that can be used in developing a performance specification for work zone traffic control (traffic management plan and construction sequence) (design, materials, and construction) as part of a rapid renewal project (Specifications).
R09	1. Risk register and procedures for identification, assessment, and analysis of project risk involved in a roadway project (Project Scoping/Cost Estimating). 2. Procedures for risk management and contingency planning (Strategy Selection).
R10	1. Five-Dimensional Project Management (5DPM) strategies, tools, and procedures for managing complex roadway projects (Project Scoping/Cost Estimating, Preliminary Design).
R11	1. Workzone Impacts and Strategy Estimator (WISE) tool to assess impacts of a roadway project on corridors/networks (Project Scoping/Cost Estimating). 2. Performance measures and decision support systems to evaluate the impacts of work zones in a roadway project (Preliminary Design). 3. Strategies for roadway projects to minimize disruption due to work zone impacts (Strategy Selection). 4. Operational scenarios and mitigation strategies for work zone impacts (Construction).

Table 3.9. Administrative/Program-Level Needs Summary for NDT Area Renewal Projects

Project	User Needs (Needs Category)
R06	*The product of this study was a final report that provided recommendations to SHRP 2 for programming additional research funds for NDT in a variety of applications. Hence, the product does not address any program-level user needs*.
R06A	1. Bridge deck NDT devices/methods that can be considered for adoption (or evaluated further) by a highway agency (Evaluation/Testing Practices).
R06B	1. Construction testing equipment/methods for verifying/quantifying construction material composition that can be considered for adoption (or evaluated further) by a highway agency (Evaluation/Testing Practices).
R06C	1. Construction testing equipment/methods for HMA paving mat quality that can be considered for adoption (or evaluated further) by a highway agency. (Evaluation/Testing Practices). 2. Model specification information that can be used in developing highway agency QC and/or QA specifications or provisions for HMA paving layer uniformity (Specifications Development). (Note: model specifications are still under development).
R06D	*The anticipated products of the study (low-speed impact echo/spectral analysis of surface waves [IE/SASW] and high-speed GPR) exhibited limitations in the ability to identify delamination between HMA layers. Further development/refinement of each device is required before implementation can occur. Hence, the products do not currently address any program-level user needs.*
R06E	1. Construction testing equipment/methods for PCC pavement smoothness that can be considered for adoption (or evaluated further) by a highway agency (Evaluation/Testing Practices).
R06F	1. Pavement structural condition continuous NDT devices/methods that can be considered for adoption (or evaluated further) by a highway agency (Evaluation/Testing Practices). 2. Research problem statements that can be used by a highway agency to sponsor additional research on the accuracy, capabilities, and limitations of continuous NDT equipment and determine if the technology should be adopted into practice (Research/Development/Implementation).
R06G	1. Tunnel lining NDT devices/methods that can be considered for adoption (or evaluated further) by a highway agency (Evaluation/Testing Practices).

Table 3.10. Administrative/Program-Level Needs Summary for Bridges Area Renewal Projects

Project	User Needs (Needs Category)
R04	1. Design concepts, details, considerations, and guidance for a variety of ABC technologies (prefabricated bridge elements/systems and corresponding bridge movement techniques and equipment) that can be considered for adoption (or evaluated further) by a highway agency (Design Practices). 2. Reference specification (recommended AASHTO-formatted) information that can be used in developing highway agency LRFD design and construction specifications or provisions for ABC elements and systems (Specifications Development). 3. ABC construction procedures (including fabrication of elements, subsystems, and components off alignment and movement of the system into place using proper equipment) that can be considered for adoption (or evaluated further) by a highway agency (Construction Practices Toolbox). 4. Training materials on ABC that can be used in a 1-day training course for agency staff (Education/Training). (Note: Training materials are still under development).
R19A	1. Long-life bridge system selection process (including LCCA) that can be considered for adoption (or further evaluated) by a highway agency (Strategy Selection Practices). 2. Design concepts, details, considerations, and procedures for long-life bridge systems (and their various elements, subsystems, and components) that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). 3. Long-life bridge construction procedures that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox).
R19B	*The anticipated products are not currently available and limited information exists about them. Hence, they do not address any program-level user needs.*

Table 3.11. Administrative/Program-Level Needs Summary for Pavements Area Renewal Projects

Project	User Needs (Needs Category)
R02	1. Geoconstruction technologies that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox). 2. Geoconstruction technologies selection process/tool (GEOTECH TOOLS Selection and Guidance System) that can be considered for adoption (or further evaluated) by a highway agency (Strategy Selection Practices). 3. Geoconstruction technology design guidance that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). 4. Reference specification information that can be used in developing highway agency specifications or provisions for certain geoconstruction technologies (Specifications Development).
R05	1. PCP/modular pavement technology that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox, Maintenance Practices Toolbox). 2. PCP/modular pavement structural design procedures that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). 3. Model specification information that can be used in developing highway agency specifications or provisions for PCP/modular pavement (Specifications Development). 4. Webinar (1.5 hours) on PCP/modular pavement technology that can be presented to agency staff (Education/Training).
R21	1. Composite HMA/PCC and/or composite PCC/PCC pavement technology that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox). 2. Composite HMA/PCC and/or composite PCC/PCC design procedures (mechanistic-empirical) and tools (Mechanistic-Empirical Pavement Design Guide [MEPDG] version 1.3000:R21 and revised AASHTO DARWin-ME) that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). 3. Sample specification information that can be used in developing highway agency specifications or provisions for composite HMA/PCC and/or composite PCC/PCC pavement (Specifications Development). 4. Training materials on composite HMA/PCC and PCC/PCC pavements that can be used in a training course for agency staff (Education/Training). (Note: Training materials are available from SHRP 2).
R23	1. Long-life rehabilitation treatment selection process/tool (*Guidelines for Long-Life Pavement Renewal* scoping tool) that can be considered for adoption (or further evaluated) by a highway agency (Strategy Selection Practices). 2. Long-life rehabilitation treatment types that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox). 3. Long-life rehabilitation design procedures that can be considered for adoption (or further evaluated) by a highway agency (Design Practices).
R26	1. Preservation treatments/strategies for high-volume roads that can be considered for adoption (or further evaluated) by a highway agency (Maintenance Practices Toolbox). 2. Preservation treatment/strategy selection process (i.e., evaluation criteria, selection matrices, life-cycle costing, etc.) for high-volume roads that can be considered for adoption (or further evaluated) by a highway agency (Strategy Selection Practices). 3. Webinar (1.5 hours) on preservation treatments/strategies for high-volume roads that can be presented to agency staff (Education/Training).

Table 3.12. Administrative/Program-Level Needs Summary for Utilities/Railroads Area Renewal Projects

Project	User Needs (Needs Category)
R01	1. Utility-locating/characterizing technologies that can be considered for adoption (or further evaluated) by a highway agency (Design Practices).
R01A	1. Utility data management tool that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). (Note: Tool is still under development).
R01B	*The anticipated products of the study (prototype utility detection systems [multi-antenna GPR and TEM]) require more R&D, as the incremental benefits they may provide are far outweighed by their costs. Hence, they do not address any program-level user needs.*
R01C	*The anticipated products of the study (prototype utility detection systems [acoustic locator and RFID Tag]) did not work. Hence, they do not address any program-level user needs.*
R15	1. Best practices/strategies for minimizing utility-related construction delays that can be considered for adoption (or further evaluated) by a highway agency (Design Practices).
R15B	1. Utility tracking and analysis tool (utility conflict matrix, utility conflict data model and database) that can be considered for adoption (or further evaluated) by a highway agency (Design Practices). 2. Procedures for tracking utility conflict resolution and milestones that can be considered for adoption (or further evaluated) by a highway agency (Construction Practices Toolbox). 3. Training materials on utility conflict matrix and management that can be used in a 1-day training course for agency staff (Education/Training).
R16	1. Master agreements between highway agencies and railroads that can be considered for adoption (or further evaluated) by a highway agency (Scoping Practices, Design Practices). 2. Webinar (1.5 hours) on best practices for expediting highway agency−railroad agreements that can be presented to agency staff (Education/Training).
R16A	1. Best practices and model processes for highway agency-railroad interactions that can be considered for adoption (or further evaluated) by a highway agency (Scoping Practices, Design Practices).

Table 3.13. Administrative/Program-Level Needs Summary for Project Management/Delivery Area Renewal Projects.

Project	User Needs (Needs Category)
R03	1. Fatigue mitigation strategies, tools, and practices that can be considered for adoption (or further evaluated) by a highway agency (Design Practices, Construction Practices Toolbox).
R07	1. Guide performance specification information that can be used in developing highway agency specifications or provisions for HMA, PCC, and precast/modular concrete pavements, pavement foundation (embankment fill, subgrade, subbase), PCC bridge deck, and work zone traffic control (Specifications Development). 2. Performance specification implementation guidelines for executives and project managers (Research/Development/Implementation). 3. Performance specification implementation guidelines for specification writers (Research/Development/Implementation). 4. Webinar (1.5 hours) on performance specifications that can be presented to agency staff (Education/Training).
R09	1. Risk management process/tool for achieving improved project performance that can be considered for adoption (or further evaluated) by a highway agency (Scoping Practices, Design Practices). 2. Training materials on risk management that can be used in a 2-day training course for agency staff (Education/Training). 3. Webinar (1.5 hours) on risk management that can be presented to agency staff **(**Education/Training).
R10	1. 5DPM strategies, tools, and procedures for managing complex roadway projects that can be considered for adoption (or further evaluated) by a highway agency (Scoping Practices, Design Practices). 2. Training materials on 5DPM methods that can be used in a training course for agency staff (Education/Training). 3. Webinar (1.5 hours) on 5DPM methods that can be presented to agency staff (Education/Training).
R11	1. Roadway project impact assessment tool (WISE) that can be considered for adoption (or further evaluated) by a highway agency (Scoping Practices, Design Practices). 2. Training materials on WISE tool that can be used in a training course for agency staff (Education/Training). 3. Webinar on WISE tool that can be presented to agency staff (Education/Training).

Table 3.14 shows an example cut-out of the revised matrix for functional/technical-level application. It lists the renewal project and user need combinations that would be pertinent to pavement assets covering users throughout the entire highway life cycle.

A similar integration/packaging matrix was also developed for administrative/program-level application using the established user needs and user needs categories provided in Tables 3.9 through 3.13. Table 3.15 provides an example cut-out of this matrix as it pertains to the bridges/structures asset item.

Case Study Examples

Several of the renewal projects included test sites, field demonstrations, pilot applications, or other activity to test the effectiveness of the product and to gauge its readiness for implementation. Some of these events were carried out as part of actual highway projects according to the highway life-cycle phase(s) for which the product is applicable.

To illustrate how renewal projects and products could be combined for complementary use in rapid highway renewal, two specific highway projects were identified from the renewal project literature to serve as examples for integrated implementation of renewal products. These projects are discussed below.

Table 3.14. Example Cut-Out of Revised Functional/Technical-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Pavements Asset Type

Asset Item	User Needs Category	Project Delivery (project/corridor-level application)											
		Project Development–Preliminary Design and Final Design									Contracting and Construction		
		Project Managers	Roadway Designers	Traffic and Safety Engineers	Bridge/ Structure Designers	Pavement Designers	ROW & Utilities Engineers and Railroad Liaisons	Environmental Engineers	Geotech Engineers	Specification Engineers	Contract/ Construction Managers	Construction Engineers	Materials Engineers
Pavement/ Shoulder Structures	Project Scoping/Cost Estimating	3-1, 9-1, 10-1, 11-1	3-1, 9-1, 10-1, 11-1	11-1		2-1			2-1		3-1, 9-1, 10-1, 11-1		
	Preliminary Design	3-2, 10-2, 11-2	3-2, 10-2, 11-2	11-2		2-2, 23-1			2-2		3-2, 10-2, 11-2		
	Strategy Evaluation/Selection (Construction, Rehab, Preservation)	7-1, 9-2, 11-3	7-1, 9-2, 11-3	7-1, 11-3		2-3, 5-1, 5-2, 7-1, 21-1, 23-2, 26-1, 26-2			2-3, 7-1		9-2, 7-1, 11-3		
	Final Design	3-3	3-3			2-4, 5-3, 5-4, 21-2			2-4		3-3		
	Specifications (Materials/Systems, Design, Construction)	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	7-8		2-5, 5-5, 5-6, 6C-3, 6C-4, 6E-2, 7-2, 7-3, 7-4, 7-5, 21-3, 23-3			2-5, 7-6	2-5, 5-5, 5-6, 5-7, 5-8, 6C-3, 6C-4, 6E-2, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3	7-2, 7-3, 7-4, 7-5, 7-6, 7-8	2-5, 5-5, 5-6, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3	2-5, 5-5, 5-6, 7-2, 7-3, 7-4, 7-5, 7-6, 7-8, 21-3, 23-3
	Construction Procedures	3-4, 11-4	3-4, 11-4	11-4		2-6, 5-7, 5-8, 21-4			2-6	2-6, 5-7, 5-8, 21-4	3-4, 11-4	2-6, 5-7, 5-8, 11-4, 21-4	2-6, 5-7, 5-8, 21-4
	Strategy Evaluation/Selection (Testing Tools)					6C-1				6C-1		6C-1	6C-1
	Evaluation/Testing Procedures (New Infrastructure)											6B-1, 6C-2, 6E-1	6B-1, 6C-2, 6E-1
	Evaluation/Testing Procedures (Existing Infrastructure)					6F-1							

(continued on next page)

Table 3.14. Example Cut-Out of Revised Functional/Technical-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Pavements Asset Type *(continued)*

Asset Item	User Needs Category	Program and System Management (network-level application)							
		Program and System Support		Asset Preservation				Program Development	
		Research/Materials Engineers	IT Professionals	Maintenance/ Preservation Engineers	Bridge/Structure Managers	Pavement Managers	Utilities Managers	Planners	Programmers
Pavement/ Shoulder Structures	Project Scoping/Cost Estimating	2-1	2-1					2-1, 3-1, 11-1	
	Preliminary Design	2-2, 23-1				23-1		3-2, 11-2	
	Strategy Evaluation/Selection (Construction, Rehab, Preservation)	2-3, 5-1, 5-2, 7-1, 21-1, 23-2, 26-1, 26-2	21-1, 23-1, 23-2	5-1, 26-1, 26-2		5-1, 5-2, 21-1, 23-2, 26-1, 26-2		5-1, 11-3, 21-1	5-1
	Final Design	2-4, 5-3, 5-4, 21-2							
	Specifications (Materials/Systems, Design, Construction)	2-5, 5-5, 5-6, 5-7, 5-8, 7-2, 7-3, 7-4, 7-5, 7-6, 21-3, 23-3		7-5		7-5			
	Construction Procedures	21-4							
	Strategy Evaluation/Selection (Testing Tools)	6C-1							
	Evaluation/Testing Procedures (New Infrastructure)	6B-1, 6C-2, 6E-1							
	Evaluation/Testing Procedures (Existing Infrastructure)	6F-1		6F-1		6F-1			

Note: Numbers listed in table cells are a combination of the renewal project number and the user need numbers provided in Tables 3-4 through 3-8 (e.g., 3-1 represents renewal project R03 and the first user need listed for R03 in Table 3.8).

Table 3.15. Example Cut-Out of Administrative/Program-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Bridges Asset Type

Asset Item	User Needs Category	Project Delivery (administrative/program-level application)								
		Project Development–Preliminary Design and Final Design								
		Project Management Director	Project Design Director	Traffic and Safety Director	Bridge/ Structure Design Chief	Pavement Design Chief	ROW & Utilities Director & Railroad Coordinator	Environmental Design Director	Geotech Design Chief	PS&E Chief
Bridge/ Culvert Structures	Scoping Practices	9-1, 10-1, 11-1	9-1, 10-1, 11-1							
	Strategy Selection Practices				19A-1					
	Design Practices	3-1, 9-2, 10-2, 11-2	3-1, 9-2, 10-2, 11-2	11-2	4-1, 19A-2				2-3	
	Specifications Development			7-1	4-2, 7-1				2-4, 7-1	2-4, 4-2, 7-1
	Construction Practices Toolbox	3-2	3-2		4-3, 19A-3				2-1	4-3, 19A-3
	Evaluation/Testing Practices			6A-1						6A-1
	Maintenance Practices Toolbox									
	Education/Training	9-3, 9-4, 10-3, 10-4, 11-3, 11-4	9-3, 9-4, 10-3, 10-4, 11-3, 11-4	7-4	4-4, 7-4				7-4	4-4, 7-4
	Research/Development/ Implementation			7-2, 7-3	7-2, 7-3				7-2, 7-3	7-2, 7-3

(continued on next page)

Table 3.15. Example Cut-Out of Administrative/Program-Level Integration/Packaging Matrix: Renewal Project and User Need Combinations Pertinent to the Bridges Asset Type *(continued)*

Asset Item	User Needs Category	Project Delivery			Program & System Management					
		Contracting & Construction			Asset Preservation		Planning & Program Development			
		Contracts/Construction Management Director	Construction Chief	Materials Chief	Maintenance/ Preservation Chief	Asset Management Director	Planning Director	Programming Director	Research Head	Information Technology Head
Bridge/ Culvert Structures	Scoping Practices	9-1, 10-1, 11-1								2-2
	Strategy Selection Practices					19A-1			19A-1	19A-1
	Design Practices	3-1, 9-2, 10-2, 11-2	4-1, 19A-2	4-1, 19A-2			3-1		4-1, 19A-2	
	Specifications Development		2-4, 4-2, 7-1	4-2, 7-1			7-1		4-2, 7-1	
	Construction Practices Toolbox	3-2	2-1, 4-3, 19A-3	4-3, 19A-3			3-2		4-3, 19A-3	
	Evaluation/Testing Practices	6A-1	6A-1	6A-1	6A-1	6A-1			6A-1	
	Maintenance Practices Toolbox									
	Education/Training	9-3, 9-4, 10-3, 10-4, 11-3, 11-4	4-4, 7-4	4-4, 7-4			7-4		4-4, 7-4	
	Research/Development/ Implementation		7-2, 7-3	7-2, 7-3			7-2, 7-3		7-2, 7-3	

Note: Numbers listed in table cells are a combination of the renewal project number and the user need numbers provided in Tables 3-4 through 3-8 (e.g., 4-1 represents Renewal project R04 and the first user need listed for R04 in Table 3.10.

Example 1: Missouri Route 141 Roadway Improvement Project

Background

The performance specifications developed under R07 were demonstrated as part of highway projects in three locations. These included a roadway improvement project on Route 141 in Chesterfield, Missouri, a bridge rehabilitation project on Route 208 in Spotsylvania and Louisa Counties in Virginia, and an HMA pavement resurfacing project on US-90 (Frontage Road) in Iberia Parish in Louisiana.

Although each of these projects could have served as a case study example, the Missouri Route 141 project was selected for its wide-ranging scope. This project was undertaken to reduce congestion, increase safety, and alleviate flooding problems throughout the 2.1-mi length from Ladue Road to Olive Road. A $65 million reconstruction project, it involved several stages of work between 2009 and 2012, including right-of-way acquisition, major grading operations, utility relocations, construction of two major interchanges containing various bridges and roadways, and construction of the mainline pavement (both PCC and HMA).

Renewal Product Implementation

The R07 demonstration took place during the grading stage and involved working with the Missouri Department of Transportation (MoDOT), the contractor, and an equipment provider to demonstrate earthwork QC/QA performance measurement technologies, including roller-integrated compaction monitoring (RICM) technology in combination with mechanistic-related QA testing methods (e.g., plate load tests, dynamic cone penetration [DCP] tests, and borehole shear tests).

Specific goals of the demonstration project were as follows (Scott et al. 2013):

- Identify suitable QA/QC testing technologies to improve test frequency and construction process control.
- Develop effective reporting, analysis, and evaluation protocols.
- Link the design approach with construction monitoring and the proposed statistical analysis framework and develop performance models that include a long-term performance aspect.
- Study the impact of contract delivery mechanism on the responsibilities and actions of parties involved.
- Assess the cost-benefit of implementing the performance specification.
- Improve the proposed earthwork and proof mapping performance specifications.

The results of the field testing phase of the project were used to evaluate the proposed earthwork performance and proof mapping specifications. One of the key attributes of the proposed specifications was the use of mechanistic-based performance measurements and the geospatially referenced RICM data. This approach eliminates traditional moisture/density testing with a nuclear gauge and requires the contractor to field control the operation around performance design values.

Some of the key outcomes from the demonstration project included the following (Scott et al. 2013):

- Traditional nuclear density testing results are not necessarily repeatable between the QC and QA agents. Further, the RICM measurement values are not well correlated to percent relative compaction or moisture content.
- Alternative in situ testing methods, including plate load testing, lightweight deflectometer testing, and dynamic cone penetration testing, provide quality measurements of support conditions.
- Final acceptable procedures based on proof rolling with a loaded dump truck can be replaced with RICM proof mapping. Using RICM eliminates the need to use loaded trucks, provides integrated measurements, and is faster with greater coverage.
- Challenges remain with implementation of RICM and alternative testing methods due to lack of training and accepted specifications.

Integrated Implementation of Renewal Products

The large scope of the Route 141 roadway improvement project would have presented many opportunities for using other SHRP 2 Renewal products in a complementary fashion. For example, in addition to using the R07 geotechnical performance specifications as part of the grading work, the R07 performance specifications for PCC and HMA paving could have been used to ensure a more equitable balance between pavement cost and performance. Likewise, the R07 bridge deck performance specifications could have been applied to the construction of the various bridges included in the project. The R02 *Web-Based Guidance and Selection System* could have been used to explore the possibility of employing one or more of the 46 geoconstruction technologies in the R02 toolkit.

Other SHRP 2 products that could have been implemented on the Route 141 project include the GOMACO GSI and Ames RTP concrete paving profiler devices developed under R06E (Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction) and the GPR and IR technologies from R06C (Using Both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers). The utility relocation effort could have been enhanced using utility-locating equipment identified from the R01 SAULT selection tool. Additional applications could have included using one or more of the 13 project management tools comprised by 5DPM as outlined by R10 (Project Management Strategies for Complex Projects) and using the worker fatigue risk assessment/mitigation practices developed under R03 (Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments).

Based on project requirements, the tool framework of SHRP 2 R31 would be able to provide recommendations and supporting information on combining these products for complementary implementation.

Example 2: Washington State I-5 Pavement Rehabilitation

Background

The Washington State Department of Transportation (WSDOT) applied the R23 project scoping tool (Guidelines for Long Life Pavement Renewal) to the rehabilitation of a 12-mi stretch of I-5 in the WSDOT northwest region. The existing pavement consisted of jointed plain concrete (JPC) pavement originally built in 1966 and subsequently overlaid with hot-mix asphalt (HMA). Rehabilitation was needed due to significant faulting at the JPC joints, leading to reflective cracking through the asphalt overlay.

Several factors influenced the WSDOT decision to implement R23 research products. A rapid renewal strategy was needed to meet the project schedule and minimize disruption. In order to fix the problem, the rehabilitation design had to provide a long-life solution in a cost-effective manner. The R23 products were identified as tools that could support rapid renewal with a long-life solution. At the same time, WSDOT needed to minimize risk and ensure that best practices were followed as part of its renewal strategy.

Because the rehabilitation was supported by federal funding as a shovel-ready project, WSDOT needed to move it forward quickly, with a target of getting the project to contract within 4 months. As a result, a pavement design solution was needed that could be developed immediately. Meanwhile, WSDOT also needed to keep the project within a $25 million budget. In order to identify a cost-effective solution, WSDOT followed the R23 guidelines for long-life pavement renewal, as well as using a web-based scoping tool that was one of the key research products developed as part of R23.

Renewal Product Implementation

In identifying potential rehabilitation practices and techniques for the project, WSDOT had initially considered a mill-and-fill option of the existing asphalt, but this solution would have a relatively short service life. This did not meet project requirements, which included targeting a pavement design life of 50 years. An alternative was to look at a full rebuild, pulverizing the existing pavement structure and placing a 10.5-in. overlay of either HMA or PCC, but this approach would have been more expensive. Instead, using the R23 scoping tool, WSDOT was able to objectively identify a crack-and-seat overlay as the recommended rehabilitation solution. With an 8-in. HMA overlay, the projected life-cycle cost of the rehabilitation treatment was $22.7 million, compared to $27 million for an HMA rebuild or $31.8 million for a PCC rebuild. This approach would fit within the available budget while still providing the desired design life.

Although the R23 scoping tool indicated a crack-and-seat overlay was the best solution based on the resources available, WSDOT still had questions about the approach. The northwest region office had little experience with cracking and seating and needed to feel comfortable that it could be a viable option. Fortunately, because the R23 products also included guide specifications, best practices, and other references, enough technical documentation was available to overcome WSDOT's lack of experience with this rehabilitation technique. Since the R23 scoping tool provided reasonable recommendations, which WSDOT confirmed by consulting with experts and performing its own checks on the proposed design, the decision was made to proceed with the crack-and-seat approach.

Implementing the R23 research products helped WSDOT identify a renewal strategy and to successfully complete this rehabilitation project. The scoping tool allowed WSDOT to select a design that saved over $4 million in life-cycle costs compared to the next best alternative and that could be implemented as a rapid renewal project. Road user costs were also reduced, as the recommended crack-and-seat overlay design significantly reduced the number of traffic closures compared to the rebuild options. To overcome resistance to change and lack of experience with an unfamiliar renewal strategy, the R23 tools helped WSDOT feel comfortable that it could successfully carry out the project.

Integrated Implementation of Renewal Products

For this project, WSDOT implemented R23 as a stand-alone product, but it could have also been applied in conjunction with other SHRP 2 Renewal products. For example, products from R07 (Performance Specifications for Rapid Renewal) could have been used to specify performance goals as part of the implementation of the renewal strategy recommended by R23. Additionally, risk management approaches could have been identified and applied using the risk manual from R09 (Guide for the Process of Managing Risk on Rapid Renewal Contracts). To evaluate project construction while maintaining the rapid renewal timeline, products from R06 (A Plan for Developing High-Speed, Nondestructive Testing Procedures for both Design Evaluation and Construction Inspection) could have also been considered, such as the GPR and IR technologies from R06C (Using Both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers).

Again, based on project requirements, the tool framework of SHRP 2 R31 would be able to provide recommendations and supporting information on combining these products for complementary implementation.

Benefits of Integrating Renewal Products

The SHRP 2 Renewal focus area includes an abundance of products with the potential to improve existing infrastructure renewal practices. The traditional approach of implementing a single product at either the functional/technical level or administrative/technical level will certainly be used by many highway agencies as a way of ensuring that a product is effective and is providing the types of benefits expected of the product. Another approach, however, can and should be considered by agencies, and it includes implementing a single product or a combination of products that can address multiple needs.

Integrated application of renewal products can provide a more efficient means for putting the products to use to address real agency needs and can help maximize the return on investment from the SHRP 2 Renewal research program. The following are some of the more specific benefits anticipated from the integrated use of products:

- Ability to define and characterize a particular project and identify products with the potential to address the various needs of the project.

- Ability to prioritize which products to implement, based on the relative importance of different needs, the perceived value of each product in addressing the needs, and the perceived risk of implementing each product.
- Opportunity to save additional time (accelerated project performance), money (reduced project costs and/or user costs), and/or lives (reduced fatalities and injuries), beyond what implementation of single product to address a single need would provide.
- Improved communication and interaction between divisions/offices within a highway agency and greater use of a team approach toward addressing problems and issues confronted by the agency.
- Greater understanding by individuals within the different divisions/offices of the importance of using new technologies to improve the business of transportation.

Barriers/Challenges to Implementation of Renewal Products

There are many expected barriers and/or challenges to the implementation of renewal products. These barriers include the ones identified for each renewal project, as described in the expanded summaries in Appendix A, as well as barriers created when trying to address multiple needs within an agency. Presented below are some of the more significant barriers/challenges and suggested ways of overcoming them.

Barriers to Implementation of a Single Renewal Product to Address a Single Need

- *Implementation Readiness*: The implementation or deployment of a product/technology works better if it is not labeled as experimental. Contractors are reluctant to invest in or deploy experiments if they aren't assured that there's some long-term requirement or payoff. To ensure maximum use of the renewal products, it is important that the tool only include those products that have passed the experimental stage. In addition, there must be transparency about the degree of readiness of the product, as defined by the amount of actual usage of the product, the number of pilot or trial applications performed and the corresponding results, and/or the level of industry acceptance (as a general practice or actual standard).
- *Market Impacts*: Occasionally, the implementation of a product/technology into practice can give substantial favor to one industry group over another or one stakeholder over another (e.g., increased market share, advantages in the bidding or construction process). This can often lead to disputes and complaints by the group or stakeholder who will be negatively impacted. It is important to emphasize that the renewal products are first and foremost intended to help agencies achieve rapid renewal of their highway assets and that, for the most part, the renewal products pertain to a wide range of stakeholders. It is also important to identify situations where this issue could arise and specific steps that could be taken to avoid problems.
- *Lack of Resources and Staff*: Highway agencies are continually asked to do more with less and, more often than not, to continually improve the conditions and performance of

the highway system. This often has the effect of refocusing money, people, and equipment to accomplishing the bare essential tasks, which in turn constrains the ability to innovate and try new ideas. The key to overcoming this barrier is to clearly convey and demonstrate the benefits of using a particular product, both in terms of the agency's work processes and functions and the transportation infrastructure.

- *Lack of Knowledge and/or Training*: It is expected that most of the potential users of renewal products will have had limited or no exposure to the products. Thus, a huge educational gap exists that must be filled so that the users are fully informed about the products and provided the necessary training in the use of the products. Hence, it is important that an emphasis be placed on the availability of webinars, workshops, training courses, demonstrations, and other technology transfer events.
- *Internal Resistance to Change*: Human nature is generally inclined toward doing things the same old way or ever so gradually adapting to new ways of doing things. There can be a variety of reasons for resistance to change, but it often pertains to the time, resources, and staff required to make a change, the uncertainty and perceived risk of making the change, and the concern of being taken out of the current comfort zone and having to establish a new comfort zone. To help garner interest in the renewal products and a willingness to try them, it is critical that they be clearly described and effectively demonstrated, so potential users are made fully aware of what the product is and what it can do for them.

Barriers to Single/Integrated Implementation of Renewal Products to Address Multiple Needs

- *Lack of a Champion or Multi-Discipline Leader*: The different groups (i.e., divisions, offices, sectors) within a highway agency are frequently not familiar with the practices of the other groups, and the different groups usually have very different transportation goals and priorities. In addition, at the executive and upper-management level, the priorities are often concentrated on identifying transportation needs, securing funding to satisfy those needs, administering the various programs for implementing transportation projects, and managing the agency's many business units, people, and resources. To implement renewal products so that they address multiple needs, a champion (or two) is needed who can be a voice and facilitator for the cause of cross-cutting implementation. This individual should have a good understanding of the needs and business practices of the different groups and have the ability to bring together leaders from those different groups to identify integrated implementation opportunities.
- *Increased Effort, Time, and Costs*: The more products or technologies to be incorporated into a project, the greater the effort and time that is required to obtain buy-in and commitment from the involved groups and to receive approval from upper management. In addition, with more products comes a higher cost to secure those products for use. Unless a golden opportunity arises, a very measured approach to integrated implementation should be taken early on involving either single-product implementation

that addresses two or three needs or an integrated implementation that also addresses only two or three needs.

- *Increased Uncertainty and Risk*: The more products or technologies to be incorporated into a project, the higher the level of uncertainty and risk. This is particularly true if the products have an overlapping effect on the outcomes of the project, making it difficult to discern what works and what doesn't. To minimize this uncertainty and risk, it is advisable that the multiple needs being addressed in a project are quite different and that the implementations would result in independent outcomes that can be closely examined by the groups involved.
- *Selling Issues*: Global or comprehensive solutions are harder to sell than smaller or individually focused solutions, primarily for the above-mentioned reasons. Although greater resistance will be encountered in selling the global approach, it is important to understand that global solutions can be sold, but they generally need more time.

Chapter 4
Conceptualized Integration Tool

Introduction

In order to apply the renewal research program results in a systematic and integrated fashion, the ability of transportation agencies to apply rapid renewal could be enhanced through development of a Project Builder Application (PBA) tool. The concept for this tool is a web-based application that would assist agency users in determining which renewal products might be suitable for their agency's needs.

The framework for the PBA tool is based on assessing technical user needs in order to provide guidance in matching appropriate research products with specific infrastructure renewal projects. Alternatively, agency staff focused on rapid renewal at an administrative or program level can use the tool to evaluate the renewal research program results more broadly and to determine which, if any, of the products should be considered for adoption by the agency. By interacting with the user through a series of simple questions and menu options, the PBA will determine precisely what products are most relevant to the user's needs. Although the tool is still a conceptualized model, its elements are described below in sufficient detail to allow its development as a working software application.

Framework/Model Description

In designing the framework for the PBA tool, the primary focus is on getting users connected to the relevant product information from the renewal research program. This model requires that the tool analyze user needs and interests and determine what subset of products could assist with those needs. Because of the variety of products available, it is appropriate to consider that different groups of users will be interested in different aspects of the overall program, depending on their roles and responsibilities.

By tailoring the approach to each group of users, the PBA tool framework will be able to gather user input in a way that allows the tool to tailor its results to the individual user. As illustrated in Figure 4.1, defining the user audience helps the PBA tool focus on the strategic objectives that are most important to that group. Based on these objectives, the tool can interact with the user to determine his or her specific requirements. To facilitate this, the PBA tool framework incorporates a number of user requirements into its design, which should cover many of the potential use cases for the renewal research program results. The interaction allows the tool to narrow down the user requirements and translate them into functional requirements for the application. Implementing the functional requirements takes the user to a customized set of results covering specifically those research products most relevant to the user's needs.

Figure 4.1. Outline of the PBA tool framework.

User Audiences

The PBA tool framework is designed to serve user audiences across multiple levels of agency organizations and with varying areas of responsibility. At administrative and program-oriented levels, it can be a resource for agency executives and directors to evaluate research products for adoption within their agencies. For agency personnel at the functional or technical level, such as designers and engineers, the PBA can identify specific products to help with an upcoming project or resolve a current problem.

The user audience roles in this framework are meant to be descriptive and may correspond to different titles within an agency's organizational structure. The subsequent analysis with respect to strategic objectives and user requirements will help the tool validate that the results it provides are appropriate to individual users in their specific roles.

Strategic Objectives

For each audience, the PBA framework was developed by identifying strategic objectives to reflect the high-level outcomes that group of users would need from the tool. The strategic objectives indicate which benefits the user might expect to achieve from the renewal research program results. In addition, the objectives help the PBA guide its interaction with the user and better refine the requirements to be addressed.

User Requirements

The user requirements within the PBA framework expand on the strategic objectives to more precisely define needs according to the user's job function. A different set of requirements may apply based on the type of need (project-level, network-level, or program-level), the agency infrastructure involved (pavements, bridges, tunnels, etc.), and the phase of project development (scoping and preliminary design, final design, or contracting and construction). Many of these requirements correspond closely to the user needs identified in Chapter 3. The PBA framework builds on the user needs categories to align these requirements with the related strategic objectives.

Functional Requirements

In the PBA framework, the functional requirements describe how the tool gathers the information necessary to identify a specific user's requirements and match these to the appropriate research products. Based on user responses to specific questions and selection of different options, the tool will filter through all of the renewal research program results. Using an automated flexible algorithm, the PBA then sorts out specific product options for consideration by the user.

Together with user input, the functional requirements determine the output of the PBA tool. This framework calls for output in the form of a custom guide or implementation kit, which presents the user with product recommendations and indicates what needs could be addressed with each product. The tool display should include information on the format in which the products are available, such as specifications, software, testing equipment, or training courses, as well as including links to additional resources and to the products themselves.

Features and Functionality

Using the outline of the PBA framework, the features and functionality of the tool are described in more detail in Tables 4.1 through 4.20. Each user audience, ranging from a general user to an upper-management director to a particular technical professional, has one or more strategic objectives identified, together with a set of user and functional requirements within each objective.

Table 4.1. Strategic Objectives and Tool Requirements for the General User

User Requirements	Functional Requirements
Strategic Objective 1: Identify tools and research products that support the application of rapid renewal to agency infrastructure.	
• Design concepts and treatment selection processes to support rapid renewal projects. • Guidance for application of innovative tools in a rapid renewal context.	• Collect input to indicate focus areas of particular agency need on a program or project level. Based on this input, recommend information from SHRP 2 Renewal projects to include, corresponding to focus areas for pavements, bridges, utilities and railroads, nondestructive testing, and project delivery strategies. • Collect input regarding agency experience with rapid renewal and existing design approaches. Based on this input, recommend appropriate design concepts from SHRP 2 R02, R04, R05, R19A, and R21.
Strategic Objective 2: Support implementation of new project strategies relevant to the assets and systems involved in a rapid renewal project.	
• Reference specifications, model procedures, and other best practices related to construction of rapid renewal projects. • Tools for risk management and fatigue mitigation on rapid renewal projects with innovative approaches and accelerated schedules.	• Collect input to determine need for model specifications and construction procedures in renewal focus areas. Recommend appropriate resources from SHRP 2 R02, R04, R05, R06C, R19A, and R21. • Collect input regarding approach to risk management and construction scheduling. Recommend appropriate resources from SHRP 2 R03 and R09.

Table 4.2. Strategic Objectives and Tool Requirements for the Director/Administrator

User Requirements	Functional Requirements
Strategic Objective 1: Evaluate innovative tools and approaches to rapid renewal projects for potential agency adoption.	
• Information to support further evaluation of research products being considered for adoption by a highway agency.	• Collect input regarding focus areas where the agency is seeking improvements, such as pavements, bridges, utilities and railroads, nondestructive testing, and project delivery strategies. Based on this input, include or exclude information from SHRP 2 Renewal projects for those areas.
Strategic Objective 2: Enable implementation of new procedures and facilitate change by encouraging agency personnel through transition.	
• Training materials and best practices to provide agency staff with the resources necessary to implement new research products into existing business processes. • Master agreements and coordination strategies for collaborating with other stakeholders on rapid renewal projects.	• Assess agency program interests to include or exclude consideration of products related to accelerated bridge construction, PCP/modular pavement, composite pavements, and preservation treatments for high-volume roads. Based on this input, recommend appropriate webinars and training materials from SHRP 2 R04, R05, R21, and R26. • Collect input regarding agency use of performance specifications, 5-dimensional project management, risk management processes, roadway project impact assessment, and utility conflict management. Based on this input, recommend appropriate webinars and training materials from SHRP 2 R07, R09, R10, R11, and R15B. • Collect input regarding existing processes for highway agency-railroad interactions. Recommend master agreements and best practices for interaction from SHRP 2 R16 and R16A.

Table 4.3. Strategic Objectives and Tool Requirements for Research/Information Technology

User Requirements	Functional Requirements
Strategic Objective 1: Develop criteria to evaluate innovative devices and tools for rapid renewal projects.	
• Geoconstruction technologies selection process/tool (GEOTECH TOOLS Selection and Guidance System) that can be considered for adoption (or further evaluated) by a highway agency. • Long-life rehabilitation treatment selection process/tool (Guidelines for Long-Life Pavement Renewal scoping tool) that can be considered for adoption (or further evaluated) by a highway agency. • Preservation treatment/strategy selection process (i.e., evaluation criteria, selection matrices, life-cycle costing, etc.) for high-volume roads that can be considered for adoption (or further evaluated) by a highway agency.	• Collect input regarding geoconstruction technology selection process and include or exclude tools from SHRP 2 R02. • Collect input regarding long-life rehabilitation treatment selection process and include or exclude tool from SHRP 2 R23. • Collect input regarding preservation treatment selection process and include or exclude recommendations from SHRP 2 R26.
Strategic Objective 2: Identify changes required in existing systems and new processes that require integration into those systems.	
• Information on new technologies that can be considered for adoption by a highway agency and	• Collect input on nondestructive testing devices/tools agency would consider adopting and provide information

require technical support for integration into agency systems. • Recommended changes in procedures that impact technical workflows or affect existing information architectures.	regarding technical capabilities from SHRP 2 R06A, R06B, R06C, R06E, R06F, and R06G. • Collect input regarding approach to bridge renewal and include or exclude technical considerations for accelerated bridge construction (ABC) technology from SHRP 2 R04. • Collect input regarding agency experience with PCP/modular pavement and provide information about design and production technology from SHRP 2 R05.

Table 4.4. Strategic Objectives and Tool Requirements for Project Managers

User Requirements	Functional Requirements
Strategic Objective 1: Improve and accelerate decision-making on rapid renewal projects.	
• Strategies, tools, and procedures for managing complex roadway projects.	• Collect input regarding factors being included in project management, such as cost, schedule, and quality. Based on inclusion of context and financing factors, evaluate project complexity and need for 5-dimensional project management from SHRP 2 R10.
Strategic Objective 2: Develop appropriate construction schedules while mitigating risks.	
• Procedures for performing a risk assessment of schedules and identifying alternatives that provide the lowest levels of risk while still maintaining the desired project schedule. • Fatigue mitigation strategies, tools, and practices that can be put into place on a rapid renewal highway project that uses a construction scheduling approach with increased risk of worker fatigue.	• Evaluate aggressiveness of construction schedule and collect input regarding anticipated construction closures. Recommend potential to add fatigue training and countermeasures based on SHRP 2 R03. • Collect input on construction crew work shifts and provide schedule guidance for night shifts, extended work, and irregular shifts based on SHRP 2 R03.

Table 4.5. Strategic Objectives and Tool Requirements for Project Designers/Engineers

User Requirements	Functional Requirements
Strategic Objective: Apply risk management methods to project development process.	
• Risk register and procedures for identification, assessment, and analysis of project risk involved in a roadway project. • Procedures for risk management and contingency planning.	• Establish project baseline assumptions in order to proceed with risk identification and management based on information from SHRP 2 R09. • Collect project risk factors to include for analysis using SHRP 2 R09.

Table 4.6. Strategic Objectives and Tool Requirements for Traffic/Safety Engineers.

User Requirements	Functional Requirements
Strategic Objective 1: Reduce traffic disruption and mitigate road user impacts from rapid renewal projects.	
• Tools to assess impacts of a roadway project on corridors/networks. • Performance measures and decision support systems to evaluate the impacts of work zones in a roadway project.	• Collect input on construction closures and work zone impacts. To analyze corridor and network effects, identify

• Strategies for roadway projects to minimize disruption due to work zone impacts. • Operational scenarios and mitigation strategies for work zone impacts.	decision support system using software tools from SHRP 2 R11.

Table 4.7. Strategic Objectives and Tool Requirements for Bridge/Structure Designers

User Requirements	Functional Requirements
Strategic Objective 1: Design bridge systems for extended service life (beyond 100 years).	
• Design concepts, details, considerations, and procedures for systematically designing new and existing bridge systems (and their various elements, subsystems, and components) for service life and durability. • Identification of suitable bridge system alternatives that satisfy project requirements and selection of optimum alternative based on assessment of cost-effectiveness (LCCA), performance, and other factors. • Procedures associated with construction of long-life bridges and the various elements, subsystems, and components.	• Collect input regarding bridges that are included in project, if any. • Collect bridge characteristics related to components such as deck joints, columns, and piles. Recommend consideration of service life factors based on information from SHRP 2 R19A. • For existing bridges, recommend preservation strategies and activities based on SHRP 2 R19A.
Strategic Objective 2: Apply accelerated bridge construction (ABC) techniques to rapid renewal projects.	
• Design concepts, details, considerations, and guidance for a variety of ABC technologies (prefabricated bridge elements/systems and corresponding bridge movement techniques and equipment) for possible use in accelerated renewal of existing bridges (40- to 130-ft spans). • Sample standard plans and detail sheets that can be adapted for use in the construction plans of a bridge renewal project that will incorporate ABC technologies. • Reference specification (recommended AASHTO-formatted) information that can be used in developing LRFD design specifications for ABC elements and systems. • Reference specification (recommended AASHTO-formatted) information that can be used in developing LRFD construction specifications for ABC elements and systems. • Procedures associated with ABC construction, including fabrication of elements, subsystems, and components off alignment and movement of the system into place using proper equipment.	• Collect input regarding project schedule and bridge characteristics to identify potential bridge replacements that could benefit from ABC based on SHRP 2 R04. • Collect input regarding renewal of existing bridges and apply guidelines for decision making on whether to consider ABC approach using SHRP 2 R04. • Collect concepts for existing bridge components and recommend appropriate ABC design plans and construction specifications using SHRP 2 R04.
Strategic Objective 3: Identify tools and procedures to evaluate concrete bridge deck deterioration.	
• Identification of suitable NDT devices/tools for evaluating/detecting concrete bridge deck deterioration (specific distresses [e.g., delamination, corrosion, vertical cracking, concrete degradation] and overall condition), based on device/tool performance ratings for accuracy, repeatability, speed, ease of use, and cost. • Procedures and illustrations for using various NDT devices/tools to evaluate concrete bridge deck deterioration.	• Collect project input regarding concrete bridge decks and recommend tools for evaluating bridge deck condition using SHRP 2 R06A.

Table 4.8. Strategic Objectives and Tool Requirements for Pavement Designers

User Requirements	Functional Requirements
Strategic Objective 1: Identify and evaluate structural design considerations and select appropriate options for design concepts and procedures.	
• Suitability of using performance specifications on a particular rapid renewal project.	• Collect input regarding agency use of method specifications or performance specifications. Provide framework for assessing viability of performance specifications for project from SHRP 2 R07.
Strategic Objective 2: Determine the suitability of modular pavement systems for preservation, rehabilitation, and reconstruction projects.	
• Suitability of PCP/modular pavement as a preservation/rehabilitation treatment (i.e., intermittent application) for an existing concrete pavement. • Suitability of PCP/modular pavement as a rehabilitation/reconstruction treatment (i.e., continuous application) for an existing concrete or asphalt pavement. • Structural design (thickness, joints, reinforcement, etc.) for PCP/modular pavement used as a preservation/rehabilitation treatment (i.e., intermittent application) for an existing concrete pavement. • Structural design (thickness, joints, reinforcement, etc.) for PCP/modular pavement used as a rehabilitation/reconstruction treatment (i.e., continuous application) for an existing concrete or asphalt pavement.	• Collect input regarding agency experience with PCP/modular pavement and provide design guidelines based on SHRP 2 R05. • Collect input regarding agency experience with PCP/modular pavement and provide design guidelines based on SHRP 2 R05. • Collect project design requirements and recommend decision-making process to evaluate whether project is a suitable candidate for PCP/modular pavement using SHRP 2 R05. • Collect project design requirements and recommend decision-making process to evaluate whether project is a suitable candidate for PCP/modular pavement using SHRP 2 R05.
Strategic Objective 3: Design new composite pavements to increase performance and achieve long life.	
• Feasibility and cost-effectiveness of HMA/PCC or PCC/PCC composite pavement as a long-life pavement option on a new roadway project or roadway reconstruction project. • Structural design (thickness, joints, reinforcement, etc.) for a proposed long-life HMA/PCC or PCC/PCC composite pavement (new or reconstructed roadway).	• Collect input for project life-cycle cost analysis and evaluate potential for composite pavement as the preferred alternative. Recommend guidelines for comparing conventional pavements with composite pavements from SHRP 2 R21. • Collect project design requirements and recommend suitable composite pavement designs if appropriate based on SHRP 2 R21.
Strategic Objective 4: Identify renewal approaches to achieve long life that use existing pavements in place.	
• Preliminary/approximate structural design (thickness primarily) of different long-life rehabilitation options (including reconstruction [i.e., remove/replace]) for an existing asphalt, concrete, or composite pavement, as a basis for rehabilitation type selection. • Suitable long-life rehabilitation options (including reconstruction [i.e., remove/replace]) for an existing asphalt, concrete, or composite pavement. • Guide specification information that can be used in developing material and/or construction specifications for the long-life rehabilitation option (including	• Collect input regarding condition of existing pavement and identify whether it can be used in place based on SHRP 2 R23. • Collect project design requirements and evaluate potential for long-life pavement designs using existing pavement in place. Recommend narrowing down specific designs using scoping tool from SHRP 2 R23.

reconstruction [i.e., remove/replace]) selected for an existing asphalt, concrete, or composite pavement.	

Table 4.9. Strategic Objectives and Tool Requirements for ROW Engineers.

User Requirements	Functional Requirements
Strategic Objective 1: Coordinate activities related to utilities, railroads, and other features within the project right-of-way.	
• Communication and coordination of utility conflict information with stakeholders (utility owners, one-call providers). • Coordination of activities for a roadway project that will cross a railroad right-of-way.	• Collect input regarding availability of utility location information and coordination with utility stakeholders. Recommend decision support tool and best practices based on SHRP 2 R01 and R01A. • Collect input on agency practices for utility conflict management. Recommend appropriate tools and best practices such as a utility conflict matrix based on SHRP 2 R15B. • Collect project information to include or exclude involvement of railroad right-of-way. Based on this input, recommend appropriate model agreements based on SHRP 2 R16.

Table 4.10. Strategic Objectives and Tool Requirements for Utilities Engineers.

User Requirements	Functional Requirements
Strategic Objective 1: Locate and track utility installations located within a rapid renewal project.	
• Identification of utility-locating/characterizing technology for use in a roadway project. • Procedures for tracking and evaluating utility installation data for a roadway project. • Procedures for providing notification of changes in utility information or status within the right-of-way.	• Collect input regarding availability of utility location information and recommend decision support tool to select utility-locating methods from SHRP 2 R01. • Collect information on existing utility tracking practices and recommend utility database model based on SHRP 2 R01A.
Strategic Objective 2: Manage and resolve utility conflicts as part of project activities.	
• Tools for management of utility conflicts and relocation. • Procedures for tracking utility conflict resolution and milestones. • Communication and coordination of utility conflict information with stakeholders (utility owners, one-call providers).	• Collect input on agency practices for utility conflict management. Recommend appropriate tools and best practices, such as a utility conflict matrix based on SHRP 2 R15B.

Table 4.11. Strategic Objectives and Tool Requirements for Railroad Liaisons

User Requirements	Functional Requirements
Strategic Objective: Facilitate relationships and agreements related to roadway projects that impact railroads.	
• Master project agreement between railroad and highway agency for roadway project that involves railway. • Preliminary engineering agreement for reviews of	• Collect project information to include or exclude involvement of railroad right-of-way. Based on this input, recommend appropriate model agreements based on SHRP 2 R16.

roadway project that will cross a railroad right-of-way. • Model project agreements for typical areas where roadway projects impact railroads (resurfacing, highway overpass, warning devices, pipe and wire). • Coordination of activities for a roadway project that will cross a railroad right-of-way.	• Collect input regarding project coordination between agency and railroad. Provide guidelines for best practices based on SHRP 2 R16A.

Table 4.12. Strategic Objectives and Tool Requirements for Environmental Engineers

User Requirements	Functional Requirements
Strategic Objective: Expedite approvals required on rapid renewal projects.	
• Identification of project agreements that may contain environmental requirements. • Coordination of project plans and activities that may be subject to environmental review.	• Collect project information to include or exclude involvement of railroad right-of-way and provide review of appropriate model agreements based on SHRP 2 R16.

Table 4.13. Strategic Objectives and Tool Requirements for Geotechnical Engineers

User Requirements	Functional Requirements
Strategic Objective: Evaluate and specify geoconstruction technology options for projects dealing with unstable soils.	
• Expected cost of a geoconstruction technology as a candidate for a roadway project. • Design details and procedures for a geoconstruction technology selected for a roadway project involving embankment construction over unstable soils or working platform improvement. • Geoconstruction technologies that are the best options for a roadway project involving embankment construction over unstable soils or working platform improvement. • Reference specification (existing or example) information that can be used in developing material, system, and/or constructions specifications for a geoconstruction technology selected for a roadway project. • Construction procedures for a geoconstruction technology selected for a roadway project and QC/QA methods typically used for the technology.	• Collect input regarding project activities involving construction over unstable soils, working platform stabilization, or widening and expansion of existing roadways. Based on this input, include or exclude appropriate geoconstruction technology options from SHRP 2 R02. • Collect input parameters for project dimensions and calculate expected costs for geoconstruction technology based on parameters and information from SHRP 2 R02. • Identify project mitigation strategies for dealing with unfavorable subsurface conditions and recommend guidance for design and specifications based on SHRP 2 R02.

Table 4.14. Strategic Objectives and Tool Requirements for Plan Specifications and Engineering (PS&E) Engineers

User Requirements	Functional Requirements
Strategic Objective 1: Develop effective specifications for rapid renewal projects for various pavement types and different contracting scenarios (design-build, design-bid-build, etc.).	
• Suitability of using performance specifications on a particular rapid renewal project. • Guide specification information that can be used in developing a performance specification for HMA pavement (design [if applicable], materials, and construction) as part of a design-bid-build, design-build, or warranty type project. • Guide specification information that can be used in developing a performance specification for PCC pavement (design [if applicable], materials, and construction) as part of a design-bid-build, design-build, or warranty type project. • Guide specification information that can be used in developing a performance specification for precast/modular concrete pavement (materials, fabrication, and installation) as part of a design-bid-build project. • Guide specification information that can be used in developing a performance specification for pavement (design, materials, construction, maintenance, and handback) as part of a design-build-operate-maintain project. • Guide specification information that can be used in developing a performance specification for pavement foundation (embankment fill, subgrade, subbase) (equipment and construction) using roller-integrated compaction monitoring technology.	• Collect input regarding agency use of method specifications or performance specifications. Provide framework for assessing viability of performance specifications for project from SHRP 2 R07. • Identify project delivery approach, such as design-build, design-bid-build, design-build-operate-maintain. Recommend suitable performance specification elements and risk allocation based on SHRP 2 R07. • Collect input on project parameters and construction requirements. Recommend guidance for identifying parameters critical to performance based on SHRP 2 R07. • Collect project-specific information to include or exclude elements such as HMA or PCC pavement, concrete bridge decks, embankment or pavement foundation, precast/modular pavement, and work zone traffic control. Provide corresponding performance specification templates from SHRP 2 R07.
• Guide specification information that can be used in developing a performance specification for PCC bridge deck (design [if applicable], materials, and construction) as part of a design-bid-build or design-build project. • Guide specification information that can be used in developing a performance specification for work zone traffic control (traffic management plan and construction sequence) (design, materials, and construction) as part of a rapid renewal project.	•
Strategic Objective: Identify and allocate risks of performance specifying to all parties, including project owner, contractor, and suppliers.	
• Risk register and procedures for identification, assessment, and analysis of project risk involved in a roadway project. • Procedures for risk management and contingency planning.	• Collect base project description and recommend risk management planning tools based on SHRP 2 R09. • Collect input on project objectives. Suggest contracting and risk allocation methods based on information from SHRP 2 R09.

Table 4.15. Strategic Objectives and Tool Requirements for Contract/Construction Managers

User Requirements	Functional Requirements
Strategic Objective 1: Identify tools to reduce costs for rapid renewal projects.	
• Risk register and procedures for identification, assessment, and analysis of project risk involved in a roadway project. • Procedures for risk management and contingency planning. • Strategies, tools, and procedures for managing complex roadway projects.	• Collect input regarding project risks. Recommend appropriate risk management forms and templates from SHRP 2 R09. • Collect input regarding project cost drivers and constraints. Identify tools for managing cost uncertainty and quantifying contingencies from SHRP 2 R10.
Strategic Objective 2: Implement desired project schedule while mitigating risks.	
• Procedures for performing a risk assessment of schedules and identifying alternatives that provide the lowest levels of risk while still maintaining the desired project schedule. • Fatigue mitigation strategies, tools, and practices that can be put into place on a rapid renewal highway project that uses a construction scheduling approach with increased risk of worker fatigue.	• Evaluate aggressiveness of construction schedule and collect input regarding anticipated construction closures. Recommend potential to add fatigue training and countermeasures based on SHRP 2 R03. • Collect input on construction crew work shifts and provide schedule guidance for night shifts, extended work, and irregular shifts based on SHRP 2 R03.

Table 4.16. Strategic Objectives and Tool Requirements for Construction Engineers

User Requirements	Functional Requirements
Strategic Objective 1: Apply model specifications and procedures for projects involving modular pavements.	
• Model specification information that can be used in developing material, panel fabrication, and panel installation specifications for PCP/modular pavement technology selected for preservation/rehabilitation (i.e., intermittent application) of an existing concrete pavement. • Model specification information that can be used in developing material, panel fabrication, and panel installation specifications for PCP/modular pavement technology selected for rehabilitation/reconstruction (i.e., continuous application) of an existing concrete or asphalt pavement. • Procedures associated with constructing (fabricating panels at the plant and installing them at the jobsite) PCP/modular pavement technology selected for preservation/rehabilitation (i.e., intermittent application) of an existing concrete pavement. • Procedures associated with constructing (fabricating panels at the plant and installing them at the jobsite) PCP/modular pavement technology selected for rehabilitation/reconstruction (i.e., continuous application) of an existing concrete or asphalt pavement.	• Collect input regarding agency experience with PCP/modular pavement. Recommend model specifications and procedures from SHRP 2 R05. • Collect existing agency practices for PCP/modular pavement and provide fabrication and installation guidelines from SHRP 2 R05.
Strategic Objective 2: Apply model specifications and procedures for long-life composite pavements.	
• Guide specification information that can be used in developing material and/or construction specifications for long-life HMA/PCC or PCC/PCC composite pavement selected for a new roadway or roadway reconstruction project. • Procedures associated with constructing a long-life HMA/PCC or PCC/PCC composite pavement selected for a new roadway or roadway reconstruction project.	• Collect project design requirements and recommend suitable composite pavement designs if appropriate based on SHRP 2 R21. • Collect input regarding available composite pavement materials. Recommend performance models, specifications, and software programs from SHRP 2 R21.
Strategic Objective 3: Identify tools for real-time monitoring of the quality of HMA paving mats.	
• Identification of a suitable NDT device/tool for real-time monitoring of the quality of HMA paving mats, either immediately after mat placement (measurement of localized cold spots) and/or during mat compaction (measurement of density). • Procedures and illustrations for using various NDT devices/tools to measure and evaluate in real time the quality of HMA paving mats. • Model specification information that can be used in developing quality control (QC) and/or quality assurance (QA) specifications for the Pave-IR thermal profile measurement system. • Model specification information that can be used in	• Collect input regarding processes for evaluating uniformity of HMA during paving operations and recommend devices/tools for collecting measurements from SHRP 2 R06C. • Collect input on framework for project QC/QA of density for HMA paving mats. Provide guidelines for integrating NDT devices/tools that measure quality and uniformity into specifications based on SHRP 2 R06C.

developing QC and/or QA specifications for the GPR density measurement system.	
Strategic Objective 4: Identify tools and procedures for real-time measurement of PCC pavement smoothness.	
• Procedures for using various non-contact, real-time profile measuring systems to measure the profile and compute the smoothness of new PCC pavement. • Model specification information that can be used in developing QC specifications (as part of a quality management plan [QMP]) for non-contact, real-time profile measuring systems for concrete paving.	• Collect project PCC pavement smoothness requirements. Recommend guidelines and specifications for smoothness from SHRP 2 R06E. • Collect input regarding PCC pavement smoothness measurement processes and recommend real-time smoothness measurement technologies based on SHRP 2 R06E.

Table 4.17. Strategic Objectives and Tool Requirements for Materials Engineers

User Requirements	Functional Requirements
Strategic Objective 1: Reduce quality assurance burden during rapid renewal projects.	
• Identification of suitable NDT devices/tools for real-time measurement and evaluation of construction materials. • Procedures and model specification information that can be used in developing QC/QA specifications involving various NDT devices/tools.	• Collect project input regarding concrete bridge decks and recommend tools for evaluating bridge deck condition using SHRP 2 R06A. • Collect input on procedures for monitoring quality of HMA paving mats. Provide guidelines and recommend tools that measure quality and uniformity based on SHRP 2 R06C. • Collect input on procedures for monitoring smoothness of PCC pavements. Provide guidelines and recommend tools for real-time measurement based on SHRP 2 R06E.
Strategic Objective 2: Apply spectroscopy to analyze the chemical composition of complex mixtures.	
• Standard of practice for identifying chemical admixtures in fresh PCC using the Attenuated Total Reflectance Fourier Transform Infrared (ATR-FTIR) spectroscopy device, and procedures for operating the ATR-FTIR spectroscopy device in the field. • Standard of practice for determining titanium content in traffic paints using the X-ray fluorescence (XRF) spectroscopy device, and procedures for operating the XRF spectroscopy device in the field.	• Collect information regarding use of chemical admixtures in PCC and the need to verify concentrations. Recommend including or excluding spectroscopy for identification of admixtures based on SHRP 2 R06B. • Collect information regarding quality control process for traffic paints and testing of metal content. Recommend including or excluding spectroscopy for fingerprinting of paints based on SHRP 2 R06B.

Table 4.18. Strategic Objectives and Tool Requirements for Maintenance/Preservation Engineers

User Requirements	Functional Requirements
Strategic Objective 1: Evaluate pavement structural condition and identify candidates for preservation or rehabilitation.	
• Procedures and illustrations for using high-speed continuous deflection equipment to collect deflection data and to analyze the data to support network-level pavement management activities (e.g., identifying structurally deficient/weak areas that can be investigated further at the project level, calculating a "structural health index" that can be incorporated into a pavement management system [PMS]).	• Determine availability of pavement condition screening data for project and recommend continuous deflection-measurement technology for investigation from SHRP 2 R06F.
Strategic Objective 2: Identify pavement preservation strategies for application on high-traffic-volume roadways.	
• Suitability of pavement preservation as a life-extending activity (functional and/or structural) for an existing asphalt, concrete, or composite pavement on a high-traffic road. • Suitability and cost-effectiveness of different preservation treatments as a life-extending activity (functional and/or structural) for an existing asphalt, concrete, or composite pavement on a high-traffic road (also, identification of the preferred treatment).	• Collect input regarding pavement condition and potential for preservation treatments. Recommend best practices for preservation based on SHRP 2 R26. • Describe project selection process and provide guidelines for identifying suitable treatments when project is a good candidate for preservation using SHRP 2 R26.

Table 4.19. Strategic Objectives and Tool Requirements for Asset Managers

User Requirements	Functional Requirements
Strategic Objective 1: Assess impacts of rapid renewal projects at the corridor and network level.	
• Tools to assess impacts of a roadway project on corridors/networks. • Performance measures and decision support systems to evaluate the impacts of work zones in a roadway project. • Strategies for roadway projects to minimize disruption due to work zone impacts. • Operational scenarios and mitigation strategies for work zone impacts.	• Collect input on construction closures and work zone impacts. To analyze corridor and network effects, identify decision support system using software tools from SHRP 2 R11.
Strategic Objective 2: Assess the condition of tunnel linings.	
• Identification of suitable NDT devices/tools for conducting condition assessments of tunnel linings, based on device/tool performance ratings for accuracy, detection depth, deterioration mechanisms detected (e.g., moisture intrusion, delaminations and spalling, voids), and tunnel lining types). • Procedures and illustrations for using various NDT devices/tools to evaluate tunnel linings.	• Collect project tunnel characteristics and recommend tools to assess tunnel linings based on SHRP 2 R06G.

Table 4.20. Strategic Objectives and Tool Requirements for Planners

User Requirements	Functional Requirements
Strategic Objective 1: Expedite planning in order to keep rapid renewal projects on schedule.	
• Procedures for performing a risk assessment of schedules and identifying alternatives that provide the lowest levels of risk while still maintaining the desired project schedule. • Tools to assess impacts of a roadway project on corridors/networks.	• Collect input regarding anticipated construction closures and evaluate aggressiveness of construction schedule based on SHRP 2 R03. • Collect input on work zone impacts and identify software tools to analyze corridor and network effects using SHRP 2 R11.

Visualized Applications

To illustrate how the Project Builder Application (PBA) tool would operate, high-level visualized examples of the application input screens were created. These examples indicate how a user might interact with the tool through a sequence of steps. At each step, the tool would gather information according to the PBA framework that helps the user identify which research products to implement or investigate further.

To begin with, the PBA tool would request general information to identify which audience role(s) to assign the user (see Figure 4.2). From this starting point, the tool would determine whether the user is likely to focus on project-level information or prefer a broader program-oriented approach. To follow up, the tool looks to narrow down which aspects of infrastructure assets are most relevant to the user (see Figure 4.3).

The initial input from the user suggests what user requirements may be appropriate. At this point, the tool asks for further input to validate those requirements as it displays for review the assumptions that took it there (see Figure 4.4).

Figure 4.2. Sample PBA tool interface for identifying the user audience role.

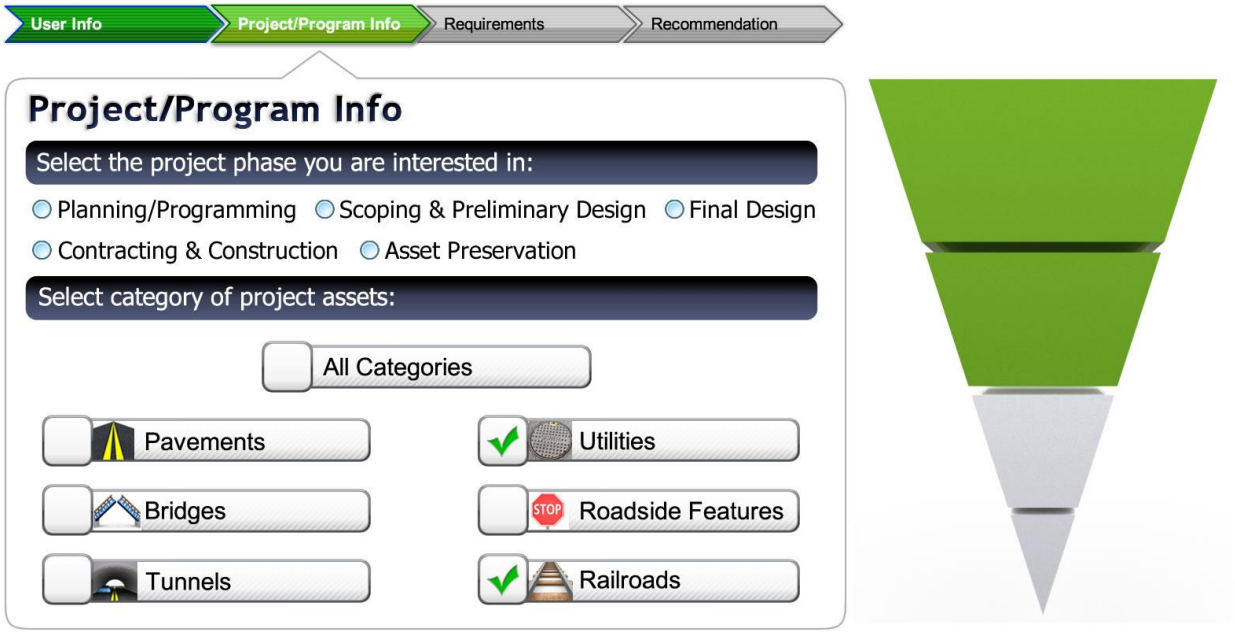

Figure 4.3. Sample interface showing user interaction with PBA tool.

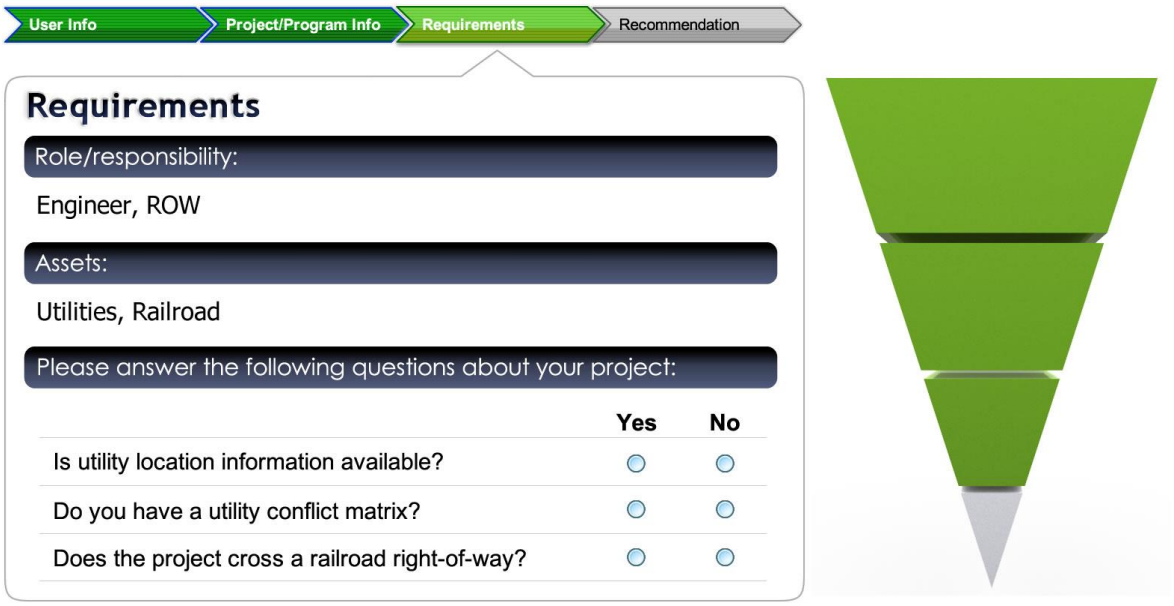

Figure 4.4. Sample PBA tool interface for identifying user requirements.

After analyzing and validating the user input, the tool generates a customized recommendation (see Figure 4.5). This may include specific products to consider for implementation as well as resources for further investigation.

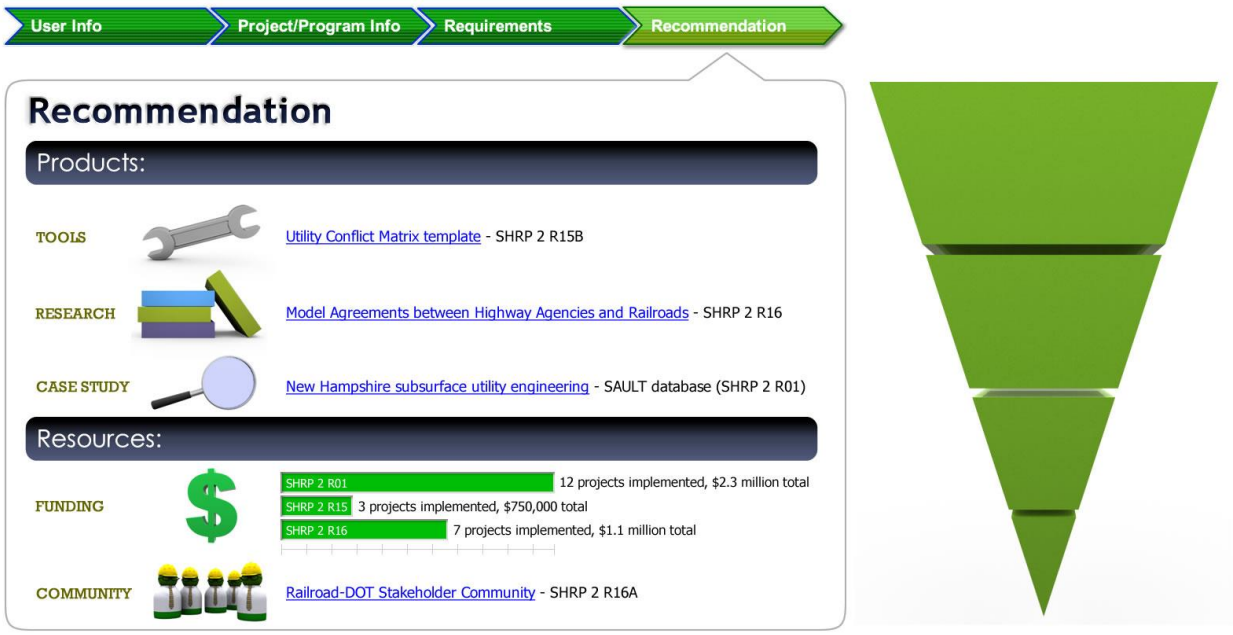

Figure 4.5. Sample PBA tool interface showing recommendation based on user requirements.

Benefits of Integration Tool

The PBA tool provides a number of potential benefits to agencies and individual users. It is designed to offer a simple, streamlined process through which users can identify the products that are relevant to their specific needs and interests. The tool does not assume that the user will need to bring significant prior knowledge related to the research, gather information not readily available, perform complex calculations, or engage in other preparations in advance. Instead, the framework builds off the user's existing knowledge to provide results that should make sense intuitively to the user.

By integrating all of the renewal research program results under a single framework, the PBA facilitates packaging multiple products together. It helps users discover relationships between products and identify ways in which they might complement each other to the benefit of the agency. The integration and packaging is further supported by maintaining the simplicity of the framework; by filtering out superfluous results, the tool focuses attention on those products that are most likely to address user needs.

The PBA tool also maintains the integrity of the products by including support materials and resources in the recommendation provided to the user. This ensures that implementation does not happen without the education necessary for success. It can also provide the agency with knowledge of delivery strategies and demonstration projects that may be needed to make the case for implementation.

Barriers to Implementation of Integration Tool

Implementation of the PBA tool can be expected to face certain barriers and challenges during the development process. These include ensuring user adoption, maintaining the relevance of the tool, providing real value, and having institutional support. Important considerations for each of these aspects include the following:

- *User Adoption*: The impact of the tool depends on growing a significant user population. This requires that the tool have attention-grabbing capability to stimulate interest initially, while also providing a user-friendly experience to convert that interest into ongoing engagement.
- *Tool Relevance*: If the tool is released but not properly maintained, its usefulness is likely to have a short shelf life. Key features should include dynamic updating capabilities and real-time access so that users have all of the latest information available to them.
- *Providing Value*: The tool needs to demonstrate that it provides a valuable resource by integrating the renewal research program results. It will not succeed if it lacks products that can really address user needs.
- *Institutional Support*: Successful development of the PBA tool will require additional resources dedicated to the project. The integration tool cannot move forward without a committed owner or host agency.

Recommended Program Format

In order to deal with these potential barriers, the recommended format for implementing the Project Builder Application is a web-based system, which would make the tool accessible from any location at any time. The technical requirements for providing access involve web hosting in an environment that can provide 24/7 uptime. Cross-platform support for mainstream browsers is required to make the tool accessible on multiple devices and multiple operating systems.

At the user level, the program needs to provide a secure, personalized environment with support for a connected environment in which users can share information from the tool. The initial recommendation assumes a desktop environment in which the user has a laptop or personal computer and an available Internet connection. However, a version 2.0 of the tool should be considered with additional features to support mobile devices. For example, this would need to include enabling a responsive web design front-end with interface snap points so that the tool display is visually scalable from large computer monitors to the smaller screens on mobile devices.

To provide a personalized environment, the PBA will support individual user accounts with a configurable dashboard that can be personalized by the user. The technical requirements for this include a front-end business logic to provide a configurable user interface and a back-end database to store user account information. Data from the front-end interface will be saved to the back-end database system on an account-level basis.

For security, the PBA implementation entails a system of secure user account access while enabling a mixture of open content areas and secure content areas. To provide encrypted user login pages, this system requires a 128-bit Secure Sockets Layer (SSL) protocol, with account information stored in database tables representing username and MD5-encrypted password values. Support for SSL also involves installing an SSL certificate issued by a recognized certificate authority on the web server. Additional security requirements include role-based access control (RBAC) with an interface for the site administrator to manage user roles and set site policy. The RBAC will maintain secure content by checking user permissions whenever the user requires access.

Sharing of information will require features such as giving users the ability to e-mail reports to others when the report content is secure and not openly accessible. Technical requirements for this include: (1) enabling a simple mail transfer protocol (SMTP) mail server in a hosted environment, (2) creating unique tokens that can be e-mailed to grant access to the recipient of the report, (3) ability for the user to specify whether the token should expire after a single use or multiple uses, and (4) database tables to store and manage token attributes.

Ongoing operation of the PBA means that the implementation must be scalable and provide for the tool to be maintained. In order to accommodate growth in tool demand, the implementation needs to allow for both user growth and bandwidth increases in a scalable fashion. Technical requirements to support scalability include: (1) implementing a horizontal central processing unit (CPU) scaling strategy so that additional servers can be added and load-balanced and (2) enabling a network scaling schema that provides additional network throughput to meet bandwidth needs.

Maintaining the PBA also involves keeping the tool content up to date. In following a versioning approach to development, the program anticipates that subsequent releases will be able to add content, such as a new pilot project or implementation case study. Content can also be provided by tool users depending on their role. At the technical level, this could involve features such as creating a "what you see is what you get" (WYSIWYG) interface for users to author content, or a document-tagging scheme to allow easy references to relevant sections of research documentation. The RBAC will allow the site administrator to control which users can add or modify content, creating the potential for a constantly improving information resource.

As a web-based program, this system may also incur additional technical requirements in order to meet federal web guidelines. Availability for individuals with disabilities will involve compliance with Section 508 in order to satisfy accessibility requirements. A search function and links to additional information regarding privacy and web records will need to be provided.

Component Architecture

The system architecture of the PBA tool includes the following components:

- User interface
- Web server
- Application server
- Database server

As shown in Figure 4.6, these components create a connected system that allows the user to interact with the tool to send and request data via the Internet.

The selection of components provides a number of options, as each component is available in a number of technology implementations. Various combinations of these technology options can be implemented together as part of the stack that supports the web application, providing additional options and flexibility.

In addition, the server operating system must be selected. Popular server operating systems include Linux, Microsoft Windows Server, and BSD, each of which is available in different "flavors" catering to preferences such as a particular user interface or method of installing software packages.

User Interface

On the client side, the user interface for a traditional web-based application renders the user's view into the tool capabilities. This view is provided via a web browser that displays information transmitted from the tool servers via hypertext transfer protocol (HTTP) and hypertext transfer protocol secure (HTTPS) protocols. Popular web browsers include Internet Explorer, Chrome, Safari, and Firefox (see Table 4.21). Common client-side scripting languages include Javascript and XML.

Web Server

The web server is software that handles HTTP and HTTPS requests from client-side web browsers and provides responses as determined by the tool. The response may include returning static information to the user, such as static HTML pages and Cascading Style Sheets, as well as requesting dynamic information, such as data-driven content from the application servers. Popular web servers include Apache, Nginx, and Microsoft IIS (Internet Information Services) (see Table 4.22).

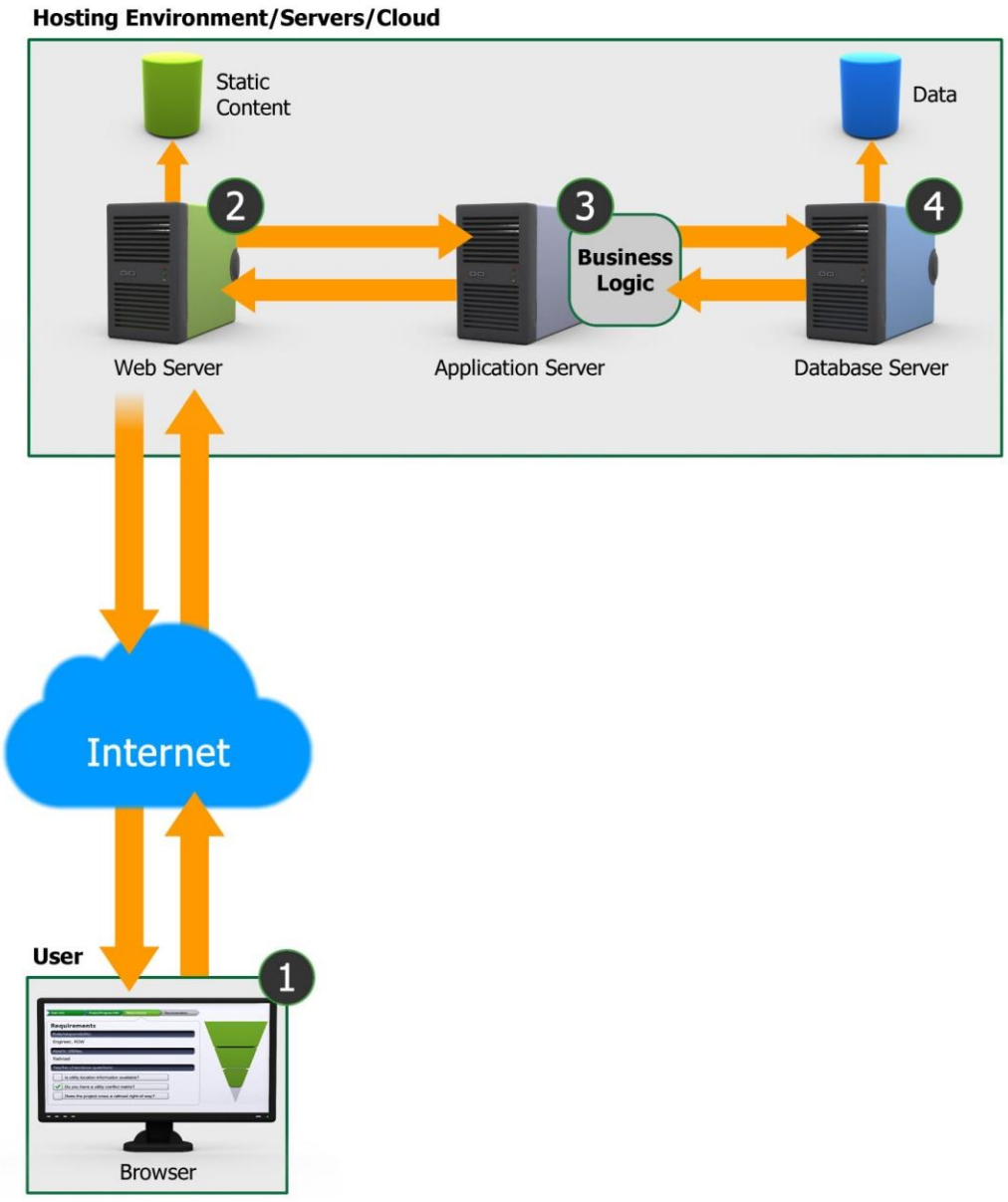

Figure 4.6. Schematic representation of PBA component architecture.

Table 4.21. U.S. Market Share of Common Web browsers (StatCounter 2013)

Browser	Market Share (as of Sept. 2013)
Internet Explorer	40.81%
Chrome	27.98%
Safari	14.34%
Firefox	13.94%

Table 4.22. U.S. Market Share of Web Servers on Active Sites (Netcraft 2013)

Web Server	Market Share (as of Sept. 2013)
Apache	52.3%
Nginx	12.86%
Microsoft	10.62%

Database Server

The database server handles requests made by the application server's business logic for structured information stored in the database. This allows the web application to use and display dynamic content stored in the database. The database also allows the application to save information in a structured manner. Popular database servers include MySQL, PostgreSQL, Oracle, SQL Server, DB2, and Sybase.

Stack Options

When taken together, the number of options for each component creates a large number of possible permutations for the stack, which is the combination of technologies underlying the web application. The most popular combinations, which provide the predominant environment for web applications running today, include the LAMP stack, the WISA stack, and the Java stack.

The LAMP stack is based on open source technology and consists of the following components:

- Operating system: Linux
- Web server/Application server: Apache
- Database server: MySQL
- Scripting language: PHP

The WISA stack uses proprietary technology from Microsoft and consists of the following components:

- Operating system: Windows
- Web server/Application server: IIS

- Database server: SQL Server
- Scripting language: ASP.NET

The Java stack is based on open source technology and consists of the following components:

- Operating system: Linux or Solaris
- Web server/Application server: Apache Tomcat
- Database server: SQL
- Scripting language: JSP

Minimum User System Requirements

For successful deployment of the PBA tool, certain baselines need to be instituted in terms of minimum user system requirements. These ensure that users of the tool will interact with the application successfully and have a system that is fully capable of utilizing all essential tool features. The basic requirements include system hardware, operating system, and web browser.

Hardware

System hardware components that affect tool performance include CPU, memory, and screen resolution. In addition, a pointing device is needed for the user to navigate the tool interface. Minimum hardware requirements for the PBA tool include the following:

- CPU: at least 1 GHz
- Memory: at least 1 GB of system memory
- Screen resolution: at least 1024x768 (until development of version 2.0 responsive web design for mobile devices)
- Pointing device: 2-button mouse or emulator

Operating System

The initial design of the PBA framework is for desktop operating systems, with the potential to support mobile devices in version 2.0. Operating systems to be supported for the PBA include the following:

- Windows XP, Vista, Windows 7, or Windows 8
- OS X 10.4 or later

In a version 2.0, mobile operating systems to be supported include the following:

- Android 4.0 or later
- iOS 6 or later

Browser

Minimum requirements for web browsers refer to the installed version of the browser on the user's operating system. Anticipated minimum requirements for the most common web browsers include the following:

- Internet Explorer 7 or later
- Chrome 28 or later
- Safari 3.1 or later
- Firefox 22 or later

CHAPTER 5
Conclusions and Recommendations

The research described in this report is part of the SHRP 2 Renewal focus area, which addresses the need to complete long-lasting highway projects in a quick fashion with minimal disruption to the traveling public. The research focused on developing a detailed integration/packaging matrix for grouping renewal products to satisfy multiple needs and developing a highly conceptualized and visualized tool model. Key work activities included the following:

- Review of SHRP 2 Renewal projects and products, and development of expanded summaries.
- Identification of various aspects/features of the renewal projects that can serve as a basis for product groupings (e.g., asset type involved, life-cycle phase impacted, technical area) and the different renewal product types (e.g., manuals, software, specifications).
- Development of a preliminary integration/packaging matrix and tool framework/process.
- Outreach to stakeholders and targeted users, via interviews with selected members of various AASHTO subcommittees and a half-day workshop at the TRB Annual Meeting.
- Revision of integration/packaging matrix and tool framework/process.
- Development of conceptualized integration tool and tool development plan.

Conclusions

The following are the major conclusions of the study:

- The SHRP 2 Renewal focus area has included many substantive research projects that have developed (or will soon develop) products intended to help highway agencies achieve rapid highway renewal through various strategic objectives. The products are targeted to users at the functional/technical level (technical staff and low- to mid-level managers) and administrative/program levels (executives and other upper-level managers), are applicable to a variety of highway assets (e.g., bridges, pavements, tunnels), and can be used to address different needs throughout the highway life cycle. The products fall under several product categories, such as manuals and guideline documents, training and demonstration products, software tools, and informational products.
- Many of the Renewal projects included a field testing component to evaluate the effectiveness of its product(s) and determine additional development needs. In addition, several included webinars and/or workshops to engage practitioners about product use and suggested improvements. Although only a few of the renewal projects (e.g., R01B, R05, R06C, R09, R21) appear to have had some level of implementation occur outside of the project, the AASHTO/FHWA/SHRP 2 Implementation Assistance Program is quickly changing that for some projects (e.g., R04, R07, R09, R10, R26).

- Product/technology implementation can take place in several ways and at different levels within an agency. Interviews with AASHTO subcommittee members indicated that single-product implementation is usually led by the appropriate technical area, whereas integrated implementation is most likely to occur at the upper-management level but could happen at lower levels if there is high collaboration among the divisions/offices involved.
- The concept of integrated implementation of Renewal products and the development of a software tool for identifying products for complementary use is viewed as very appealing, but very challenging. AASHTO member interview responses suggested that an integration software tool would be very valuable from the standpoint of being able to quickly and easily navigate to the desired information for one or more products. Major recommendations for such a tool included that it be (a) dynamic and updatable, (b) centered around problem/constraint identification and needs, (c) informative about product benefits and costs, (d) sharing or forum-oriented, and (e) attention grabbing. TRB workshop inputs cited the need for a simple tool with hard facts, bottom-line expected benefits, and sound information about the risks of implementation and ways to mitigate the risks.
- Several barriers to the implementation of Renewal products exist. They include the barriers associated with implementing a single product to address a single need (e.g., implementation readiness, market impacts, lack of resources and/or staff, lack of knowledge and/or training, internal resistance to change), as well as the barriers associated with implementing a single product or multiple products to address multiple needs (e.g., lack of a champion or multi-discipline leader, increased effort, time and costs, increased uncertainty and risk, and selling issues).
- The Renewal products address potential needs and concerns across a variety of agency activities. This means that, taken collectively, the size of the potential audience increases substantially over that of any one project individually. In order to conceptualize a tool that can serve this audience effectively, it is necessary to begin by approaching the broadest possible group and identify suitable filters (audience roles, project characteristics, agency priorities, etc.) that can help guide users through the results. This process will channel the audience into more narrowly defined groups and match them up with products that satisfy their specific requirements.

Recommendations

The SHRP 2 Renewal focus area includes an abundance of options with the potential to improve existing infrastructure renewal practices. To maximize the return on investment from this research program, these products need to be efficiently integrated at all levels within transportation agencies. The list below summarizes key recommendations to enable increased application of the Renewal research program products.

- *Create an integration tool that will help agencies identify Renewal research program products that fit their needs*. The scope of this research is sufficiently large that agencies will need assistance in sorting through the products for implementation. Particularly in the context of rapid renewal, integrating the research results into agency processes is critical in order for them to be incorporated into actual projects. Decision makers need additional information in order to evaluate products prior to implementation. In the process, they will also benefit if the tool can quickly filter out results that are not relevant to their situation.
- *Help agencies discover research products easily by maintaining a simple approach that does not demand significant advance knowledge or preparation from the user*. The practical adoption of an integration tool will depend significantly on its usability. Given the breadth of the Renewal research program, it is best not to expect agency users to be familiar with all aspects of the program. Similarly, it may not be practical to require the collection of detailed information prior to accessing the research. As a result, the tool should be streamlined so that users can find appropriate resources with a minimum of effort.
- *Focus on offering solutions to existing agency problems where research can be implemented*. One area agencies can be counted on to know better than anyone else is what their current challenges and problems are. Using this knowledge to identify solutions is an excellent way to ensure that new research results are readily welcomed and have real practical impact at the agency level. A solution-focused approach allows the information an agency already possesses about its situation and its concerns to shape the ultimate recommendation.
- *Promote integration of products (where appropriate) by identifying potential relationships and packaging multiple products together*. Agencies can increase efficiency and promote quicker adoption of Renewal research program results by taking advantage of opportunities to implement multiple products. Some research products will frequently be paired with natural companions while also combining with other products on occasion, as the situation dictates. Recommending a bundle that includes several research products may be particularly suitable for complex renewal projects. Combined with an emphasis on solving existing problems, this allows the circumstances of a project or a specific set of agency needs to determine when and where products should be combined for implementation.
- *Provide guidance and additional resources for users who need to learn more about a specific product prior to deployment*. A well-designed integration tool can provide recommendations even with fairly minimal input, but agencies will typically want support materials for further evaluation before making a final decision. In addition, guidelines and documentation will be needed to plan the actual implementation and support product deployment. While technical details are best avoided during the initial phase of identifying products that are candidates for implementation, they should be made available to allow a thorough evaluation once a research product has been selected.

Agencies will benefit from a complete understanding of product capabilities and may have previous research of their own to assist in the evaluation.

All of these elements can be achieved within the framework proposed for the PBA tool. Since the tool framework incorporates all of the research results together, agencies can use it to create customized recommendations based on their specific needs and address their biggest challenges. The design of the tool enables a streamlined process for integrating research products while also making available the detailed information backing the recommendations. Because of the extensive needs for renewal of existing highway infrastructure, agencies are likely to benefit significantly from such a tool to accelerate and improve the quality of their decision making.

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APPENDIX A
Renewal Project Expanded Summaries

Expanded Summary for Renewal Project R01 (*Encouraging Innovation in Locating and Characterizing Underground Utilities*)

SHRP 2 Program Officer	Monica Starnes
Contractor and PI Info	Louisiana Tech University (LTU): Ray Sterling (retired) (for technical information, contact Erez Allouche at Trenchless Technology Center)
Project Status and Time Frame	Completed January 2007 through January 2010 (support ongoing for further refinement of software tool)
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ The knowledge of the location and character/condition of existing utilities can help in avoiding potential conflicts during construction and reduce contractor delays and project redesign time. More efficient utility planning shortens construction zone delays for the traveling public and improves highway operational efficiency. ➢ Maintaining existing utility location data and keeping it current within the DOT right-of-way (ROW) decreases the scope of future utility investigations and reduces the risk to construction contractors, leading to lower project costs. • Saves Lives ➢ The knowledge of where utilities are located and their condition improves project safety (reduces accidents to workers and/or users).
Project Objectives	• To document today's technologies for locating and characterizing various types of underground utilities (cable [communications or electric] or pipe [storm/sanitary sewer, water, gas, steam] utilities), by exploring underground utility-locating and characterization practices. • To identify new, emerging, or potential technologies and develop a research plan that will encourage the development of these technologies into useful tools for transportation agencies, consultants, utility owners, and construction personnel. • To develop a software tool to help identify effective utility-locating methods for particular site or project environments.
Summary of Findings	• It is unlikely that the technology to locate and characterize utilities will ever present a comprehensive solution for all site conditions; a large toolbox of location devices will be necessary. • Recent advances in global positioning systems (GPS) and geographic information systems (GIS) technologies can increase the quality and efficiency of storing, retrieving, and utilizing utility records. • Multi-sensor platforms that combine two or more existing technologies may provide more reliable performance for utility locating across a variety of soil conditions. • The development of guidelines and other tools for the conduct of utility investigations for transportation projects would allow transportation designers/planners to get the most out of the subsurface utility engineering (SUE) data they receive so as to maximize the benefit/cost to the agency.

	• Smart tagging (e.g., ball markers, radio-frequency identification [RFID]) and documentation of utilities during initial installation and when exposed during excavations for various purposes would improve in-field identification of utility location, type, and characteristics. • Initiation of educational, training, and dissemination activities aimed at increasing the awareness of transportation engineers to utility-locating issues is necessary. • Locating technologies that target deep or stacked utilities would be useful. • Technologies capable of locating and characterizing external soil voids may help road settlement and sinkholes risk management. • Test facilities to provide independent information on the capabilities of different types of detection equipment would be beneficial. • Technologies capable of characterizing the cross-sectional deformation of buried pipes and culverts over time will allow the ability to track gradual deterioration of utilities constructed with ductile utility materials.
Product Description(s)	(1) Final Report (*Encouraging Innovation in Locating and Characterizing Underground Utilities*, SHRP 2 Report S2-R01-RW). Documents the state of the practice of utility location (surface marking in the field and measuring/documenting its 3-D location) and characterization (i.e., utility type, owner, size, material, age, pressure, voltage, capacity, condition, or activity status), and gaps in the technology and process. The information presented is derived from a detailed review of national and international literature and ongoing research. The report also provides a listing of areas where further research or study may be of assistance in reducing project delivery times as they relate to the issues of existing utilities location data. Appendix B contains a case history of transportation-related projects that represent successful applications of SUE technologies and practices. (2) Reference Document (*Development of the Selection Assistant for Utility Locating Technologies [SAULT]*, SHRP 2 Report S2-R01-RW-2): As part of Phase 1 of SHRP 2 Renewal Project R01, an extensive database designed to serve as a quick technical reference tool for existing and emerging utility-locating and characterization methods was developed. For each locating technology, the reference database provided a short description, a comprehensive list of performance characteristics, typical applications, and an image. The database was originally developed to serve as a stand-alone application. After reviewing the database, the SHRP 2 Technical Coordinating Committee for Renewal Research recommended further development of this electronic database into a software tool for decision support. This document details the development of the SAULT expert-based system to deal with the complexity and multi-attribute nature of subsurface utility engineering and geophysical tools. Any expert-based system attempts to reproduce the performance of one or more human experts in a particular field. (3) Web-Based Software Tool (*Selection Assistant for Utility Locating Technologies [SAULT]*): This is a decision support tool. With SAULT, the user operates the expert system through an interactive dialogue that guides the user through a series of choices to solicit the needed input. At the end of the analysis, the user receives a summary report listing all the utility-locating methods deemed suitable for the project under consideration and any condition improvements that may facilitate the locating activities. The tool also contains three reference databases: Utility Locator Technology Database (provides specific utility-locating equipment organized by classes of locating technology), Case Studies Database (provides examples of the successful application of the SUE approach to utility-locating activities), and Utility Strikes (contains real-world examples of utility damage, their causes, and impacts). The primary use of this tool was envisioned to be educational rather than operational. Results from the tool selection process are not a replacement for in-field professional judgment. (4) Webinars—On August 10, 2011, SHRP 2 conducted a webinar entitled "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research," which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15.
Product Status	(1) Final Report (*Encouraging Innovation in Locating and Characterizing Underground Utilities*, SHRP 2 Report S2-R01-RW). Ready for use. Available online at

	http://onlinepubs.trb.org/onlinepubs/shrp2/shrp2_S2-R01-RW.pdf, and as a hard copy through the TRB bookstore. (2) Reference Document (*Development of the Selection Assistant for Utility Locating Technologies [SAULT]*, SHRP 2 Report S2-R01-RW-2). Ready for use. Available online at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R01-RW-2.pdf, and as a hard copy through the TRB bookstore. (3) Web-Based Software Tool (*Selection Assistant for Utility Locating Technologies [SAULT]*): Ready for use (support ongoing for further refinement). Available online at http://138.47.37.187/sault/home.asp. (4) *Webinars: Ready for viewing.* "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research" a*vailable online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf.

Target Audience	• Highway Agency
	  ➢ Project planners.
	  ➢ Project designers.
	  ➢ Utility coordinators.
	  ➢ ROW coordinators.
	  ➢ Construction managers.
	  ➢ Construction engineers.
	• Other Stakeholders: Utility owners, consultants, contractors.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development: Planning. • Project Development: Initial site conditions assessment, all phases of design. • Contracting and Construction: Construction. • Management, Maintenance, and Operations: Asset management.
Pertinent Technical Areas	• Utility Location and Characterization Equipment/Technology Selection/Data and Project Processes.

Implementations	• Implementations Performed as part of R01 Project
	  ➢ Project Level: None.
	  ➢ Program Level: Webinar ("Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research"), conducted August 2011, explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B.
	• Post R01 Project Implementations
	  ➢ Project Level: None. R01 was not conceived as an implementation project; rather, it is an educational tool for new and existing personnel who are involved in any of the myriad of tasks that are impacted by existing utilities. R01 formulated recommendations for a path forward to deal with the continuing problems created by the difficulty in determining the location and characterization of existing utilities and the lack of a professional engineering focus in utility engineering. Three subsequent Renewal projects were moved forward as a result of R01: R01A, R01B, and R01C.
	  ➢ Program Level: Value could be gained at the DOT engineering level across all departments affected by utilities (drainage, structures, environmental, traffic, pavements, right-of-way, construction, planning, geotechnical) by using the R01 report as required reading or internal course development/training in utility issues. The following initiatives have been undertaken, with the R01 report offering support and need justification:
	  ▪ Canadian Standards Association (CSA): Development and publication of CSA 250 S-11 (*Mapping of Underground Infrastructure*). This Canadian consensus standard details the process for creating and storing utility as-builts for new utility infrastructure.
	  ▪ American Society of Civil Engineers (ASCE): Approval and formation of a U.S. national engineering standard committee for the development of a process for creating utility as-builts.
	  ▪ American Association of State Highway and Transportation Officials (AASHTO)/ASCE.

	Initiative to develop a formal professional path to create an engineering discipline involving all aspects of utilities. One result is the ASCE Utility Engineering Committee. A second result is a continuing educational and awareness outreach of the need for such a discipline at AASHTO, TRB, and other industry functions.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints; Corresponding Needs • Urban road/street in poor condition has been approved for reconstruction; the project has entered the design stage and there is a need to determine/ascertain what utilities exist along the project and where. Need to identify what utility-locating/characterization technologies would be helpful to the project. Project Characteristics • Project Type: Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category: Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate): Any setting (but usually urban or suburban); any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any • Highway System: Any • Functional Class: Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints; Corresponding Needs • Lack of knowledge about available tools for utility location. Need to establish and conduct training for field personnel and low- to mid-level managers.
Barriers/Challenges and Ways to Overcome Them	• Utilities affect almost every aspect of a highway project, yet highway agencies typically do not begin to address their location and effect on the project until too late in the project development process. Utility companies are often are blamed for utility problems, rather than the highway designers who do not consider the effects of existing utilities on their project design, sequencing of work, and constructability. ➢ One potential solution, touted in this report and many others, is that DOTs need to take more responsibility for the utilities within their rights-of-way as far as knowing their location and character and managing and updating that data. This is a paradigm shift in attitude and will take upper-level management commitment to change current policies and procedures to accomplish this solution. • There is no formalized training or career path for utility engineers. There has been slow but steady progress made over the past several decades in educating engineers in utility issues. ➢ This report was designed to continue that progress.
Project Key Words	Locating, surveys, one-call, geographic information systems (GIS), ground-penetrating radar (GPR), utility mapping, radio-frequency identification (RFID), condition assessment, utilities, right-of-way (ROW), subsurface utility engineering (SUE).

Project Cost: $389,993

Expanded Summary for Renewal Project R01A (*Technologies to Support the Storage, Retrieval, and Utilization of 3-D Utility Location Data*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Gas Technology Institute (Des Plaines, IL): Bill Gale
Project Status and Time Frame	Ongoing: September 2009 through August 2013
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Improved coordination, reduced risk of redesigns and delays (and, therefore, cost overruns), and reduced excavation damage through: ▪ Facilitated mapping of utilities by keeping utility mapping work current. ▪ Reduction in redesign and/or conflict remediation time by notifying designers of changes to the existing utility mapping information during the project design. ▪ Better and faster planning of future projects in the same area as a previous one by having up-to-date utility information available. ▪ Better visualization of utility systems by developing standardized ways to populate depth (z) data in 3D systems. • Saves Lives ➢ Accurate underground utility location data helps prevent unsafe contact with utility facilities during construction operations.
Project Objectives	• To identify best practices for modeling, structuring, storing, retrieving, visualizing, and integrating 3-D utility data and to develop an innovative approach/strategy for leveraging recent technology advances (including but not limited to global positioning systems [GPS] ground-penetrating radar [GPR], and geographical information systems [GIS]) to: ➢ Reduce project delays by keeping utility mapping data current throughout the life cycle of the project development process. ➢ Reduce necessity for re-performing complete utility mapping for the next project in the same area (no matter how long in the future that project occurs) by tracking all utility-related data in that area (i.e., reduce time spent on repeatedly "refinding" known utilities). ➢ Reduce excavation damage to utility lines during construction phase. The project will develop and demonstrate the data model, data integration and rendering process, field data collection technologies, and supporting policies and procedures in an extended pilot project.
Summary of Findings	Not currently available. The Phase 1 report has been under revision and review for more than a year. 3D database development is underway.
Product Description(s)	Currently available products include: (1) Webinars: On August 10, 2011, SHRP 2 conducted a webinar entitled "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research," which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15. On February 15, 2012, SHRP 2 conducted a similar webinar entitled "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis," which explored new tools for underground utility location, data collection, and analysis. This webinar was again based on SHRP 2 Projects R01A, R01B, R01C, and

	R15B. Anticipated, but not currently available products include: (2) Pilot implementation project (Virginia Department of Transportation [DOT]) for evaluating/demonstrating the data model and system architecture of the preferred strategy. (3) Final report that includes a presentation kit, a data model (i.e., a preferred standard/specification for data capture, data display, model visualization, and maintenance management), and user guide (for the data model).
Product Status	(1) Webinars: *Ready for viewing*. "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research" a*vailable online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf. "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis available online at http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2012-02-15.pdf. (2) Pilot Implementation Project: Two projects started in northern Virginia, but not yet complete. (3) Final Report: Not yet in development.
Target Audience	• Highway Agency ➢ Project subsurface utility engineers. ➢ Project designers. ➢ Project planners. ➢ Utility coordinators. ➢ ROW coordinators. ➢ Construction engineers. • Other Stakeholders: Utility owners, one-call utility notification centers, consultants, contractors.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development: Planning. • Project Development: Initial site conditions assessment, all phases of design. • Contracting and Construction: Construction. • Management, Maintenance, and Operations: Asset management, one-call responses.
Pertinent Technical Areas	• 3-D Utility Location and Characterization Data Storage and Retrieval System
Implementations	• Implementations Performed as part of R01A Project ➢ Project Level: None. ➢ Program Level ▪ Webinar ("Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research") conducted August 2011 explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. ▪ Webinar ("New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis") conducted Feb 2012. • Post R01A Project Implementations ➢ Project Level: None. ➢ Program Level: The FHWA has initiated a parallel research project to determine the willingness of state DOTs to manage utility data within their rights-of-way, their use of 3D design and 3D utility mapping, and their use of RFID technology. This project is expected to be complete in 2014.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly an upper-level manager can implement or further test the product(s) as part of an actual highway	Problems/Issues/Constraints—Corresponding Needs • There are several paths to partial implementation of this at the project level. All of them start with a thorough ASCE 38 Utility Quality Level B mapping of the existing utilities on a project. Consequent to that function, a rigorous notification by the DOT permitting department that a new utility is being installed, or that a utility is being relocated, must be made to a DOT utility database manager. The new data must be compared to the old data, and either added, deleted, or modified to provide the most current and accurate snapshot of correct utility information. The complete utility data must be maintained somewhere within the DOT GIS or document control system.

project)	• A second path might be to require all utility installers to accurately survey any new or relocated utilities and immediately make that information available to DOT designers, retain that data, and make continuous updates as they happen. <u>Project Characteristics</u> • Project Type: Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category: Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate): Any setting (but usually urban/suburban); Any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any • Highway System: Any • Functional Class: Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • In order for a DOT to successfully implement this product/process, they must: ➢ Establish a single person to track all new utility installations, or changes to existing utilities, on every project and evaluate the data against previous data to see if it is more accurate or reliable, and then make a change in a utility database to that effect. ➢ Make certain there is a policy in place for the DOT to be notified immediately for every change to a utility location, new utility, or change in a utilities' status within their right-of-way. ➢ Develop or adopt a standard for either DOT personnel, consultants, or utility owners to accurately develop locational record drawings of new or relocated utilities (a viable and accurate as-built policy) in every instance (Note: ASCE is currently developing a national standard that will address how this could be done). ➢ Provide training to designers on utility conflict issues. ➢ Develop a mechanism to immediately notify designers of a change in utility information during the project. ➢ Change consultant contracts, in-house procedures, and utility company permitting to require 3D utility database population rather than standard MicroStation/CADD 2D representation. ➢ Change consultant contracts to require a "z" component to be placed on all utility data (Note: ASCE 38 is being revised to give standardized guidance on this issue). ➢ Work with the state one-call center to develop a mechanism to produce project limit polygons on state DOT projects and then provide one-call tickets that occur within those polygons to the utility data gate-keeper to identify any utility-related construction activity within the ongoing or previous project limits.
Barriers/Challenges and Ways to Overcome Them	• A recent FHWA survey indicated a vast majority of state DOTs are unwilling to take responsibility for managing utility location data within their rights-of-way. DOTs expect utility owners to know exactly where their utilities are located, know it immediately, and share all that information in acceptable formats with the DOT and their designers. Unfortunately, utility owners do not see it the same way. Until this understanding is mutual, utility data within the rights-of-way will continue to be inaccurate, untimely, and out-of-date. ➢ The best way to overcome this barrier is to develop successful programs in those states that are willing and then promote the success with documented metrics and value studies.
Project Key Words	Locating, surveys, utility mapping, utilities, right-of-way (ROW), subsurface utility engineering (SUE), asset management, one-call, utility database.

Project Cost: $969,147

Expanded Summary for Renewal Project R01B (*Utility Locating Technology Development Utilizing Multi-Sensor Platforms*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Underground Imaging Technologies, LLC (UIT): Gary Young
Project Status and Time Frame	Ongoing: October 2009 through October 2013
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Provides additional tools (but not replacement tools) for the identification and mapping of existing underground utilities and enhanced depth measurement of specific utilities, which can reduce costs and time. ➢ May provide some additional underground imaging for paving and substrate thickness, voids, underground structure geometry, water table, depth to bedrock, septic systems, cemeteries, tree roots, and soil profiles.
Project Objectives	• To design an assembly of systems/tools aimed at the advancement/enhancement of utility detection by geophysical means in all geologic and cultural environments. The specialized requirements of a multi-sensor platform for underground utility detection and mapping include: ➢ Detection, identification, and mapping underground utility pipes and conduits. ➢ Resolution of pipes and conduits as small as 3 in. in diameter at depths of 12 ft below surface or deeper. ➢ Operation on either paved streets or roadways or on flat unobstructed surfaces. ➢ Compact hardware configuration adaptable to efficient mobile operation on streets, roadways, and adjacent terrains. ➢ Functional capabilities for providing on-site utility survey maps suitable for direct use by utility system designers and/or construction or maintenance contractors. ➢ Compatibility with other co-located utility detection technologies to implement multi-sensor surveys.
Summary of Findings	Not currently available. The Phase 1 report is under revision and review. It should be noted that there were originally three systems/tools under research and development with hardware and software components, consisting of (a) enhanced multi-antenna ground-penetrating radar (GPR), (b) enhanced Time-Domain Electro-Magnetic Induction (TEM), and (c) a seismic system. The seismic system was discontinued after some initial S-wave testing. Field testing for the GPR and TEM systems was initiated in July 2012. Results clearly show that these systems/tools by themselves will not be adequate to perform a complete and comprehensive utility mapping task and will only be able to add capabilities to existing tools under certain site conditions.
Product Description(s)	<u>Currently available products include:</u> (1) Webinars: On August 10, 2011, SHRP 2 conducted a webinar entitled "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research," which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15. On February 15, 2012, SHRP 2 conducted a similar webinar entitled "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis," which explored new tools for underground utility location, data collection,

	and analysis. This webinar was again based on SHRP 2 Projects R01A, R01B, R01C, and R15B. Anticipated, but not currently available products, include the following (Note: These products are prototypes and there will need to be some additional work performed in order to bring the products for commercial use): (2) Prototype Utility Detection System/Tool. Descriptions of the tool options are as follows: a) Multi-Antenna GPR: This tool uses the existing UIT Terravision™ as a base system. Although no direct improvements are being applied to the multi-channel GPR hardware under this research project, geophysical detection methodologies utilizing GPR techniques are an integral component of the multi-sensor platform concept and thus worth a brief description. Terravision™ is a 14-channel, cart-based GPR unit that is typically towed behind a vehicle during survey operations. The GPR system consists of two banks of seven antennas each with a fixed spacing of 0.4 ft between each antenna module. GPR data acquired by each of the 14 channels is densely spaced in the direction of travel. The central frequency and approximate bandwidth of each GPR antenna element is 400 MHz, a combination that provides both good penetration and high resolution. The 14-channel system is capable of imaging a 5.12-ft wide data swath in a single pass. Cart speed is about 3 mph and is limited to unobstructed flat surfaces. There are planned improvements to the software that will allow quicker and easier interpretation of the data; the ratio of data acquisition time to data-processing time is currently about 1:3. Currently, highly trained operators are required to collect the data, and specialized geophysicists are required to analyze the data. b) TEM: The stand-alone product is a time-domain electromagnetic interference (EMI) (TEM) sensor array. The array, which is towed behind a utility vehicle, consists of 5 transmit (Tx) and receive (Rx) coil pairs with maximum coverage dimensions of 1.31 ft by 6.56 ft. The TEM array has fully programmable Tx and Rx parameters and employs modern digital electronics. As usually configured for characterizing buried objects, it measures the EMI decay from 0.04 to 25 msec. The complete set of TEM array data can be processed and interpreted using both monostatic and bistatic recorded measurements, and a 3D block of EMI data can be produced representing the full range of time gate EM responses within a single graphical window. The complete set of response parameters forms a unique feature vector that can be used for reliable identification of underground utility lines. Still under development are EMI inversion algorithms to determine the basic set of parameters that characterize a linear utility's EMI response. Classification will be implemented using a library-matching procedure wherein the utility line's EMI axial and transverse response characteristics are compared with those of previously measured utility items. As this library is built through a battery of controlled static measurements, the depth and direction of the line may be recovered as part of the inversion process. Traffic must be completely stopped within 15 ft of the sensors to avoid interference. Overhead conductors are also sources of interference, as is reinforcing metal in concrete. The data requires highly trained interpreters. (3) Final report that includes a user manual for the prototype utility detection system/tool and estimated costs for construction/maintenance of prototype system/tool
Product Status	(1) Webinars: *Ready for viewing. "*Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research" a*vailable online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf. "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis available online at http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2012-02-15.pdf. (2) Prototype Utility Detection System/Tool: GPR and TEM in-field trials. (3) Final Report: Expected available in Spring 2014.
Target Audience	• Highway Agency ➢ Utility coordinators. ➢ ROW coordinators. ➢ Construction engineers. ➢ Environmental engineers.

	➢ Archeologists. ➢ Geotechnical engineers. • Other Stakeholders: Utility owners, one-call utility notification centers, consultants, contractors.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development: Initial site conditions assessment, all phases of design. • Contracting and Construction: Construction. • Management, Maintenance, and Operations: Asset management.
Pertinent Technical Areas	• Utility Location and Characterization Equipment
Implementations	• Implementations Performed as part of R01B Project ➢ Project Level: Proof-of-concept testing in actual underground utility projects was conducted in Virginia and Georgia, as described below. ▪ Virginia DOT Implementation: The R01B GPR tool (TerraVision II) was ineffective in the Virginia clay soils and was unable to image utilities, and therefore no depth readings were obtained. The TEMS tool was considerably more effective and was able to detect 43 percent of the utilities found by the SUE mapping firm in the covered project area. The TEMS tool found 93 percent of the metallic water and 33 percent of the metallic gas lines in the areas covered in the test. Only 10 percent of underground communication systems were detected. None of the electric facilities were found by the TEMS unit. However, the TEMS tool also triggered responses on the in-paving traffic control sensor loops, which in turn required considerable time and effort in unnecessary data interpretation for utilities out of scope. The TEMS also found 210 ft of unknown utilities. Additional review determined these included a water line installed after the initial mapping and storm drainage that was out of the original mapping scope of work. Due to terrain issues, only about 50 percent of the total project area would have been capable of utilizing the R01B tools, given their size and towing restrictions. ▪ Georgia Department of Transportation (DOT) Implementation: Both the TEMS and GPR (TerraVision II) tools were effective in the project soils. The TerraVision II imaged utilities to an effective depth of about 5 ft. Metallic utilities were responsive to both the TEMS and TerraVision II in most cases, providing a good correlation to the previously mapped via traditional means ASCE 38 quality level B (QL-B) results. Both tools found a majority of the metallic water and metallic gas lines in the areas covered. TerraVision II had some success on the non-metallic sewer lines. Neither tool had great success on the communication systems, although bits and pieces were able to be imaged. There is some question whether the small bits and pieces could be interpreted and identified without the benefit of a completed QL-B plan set at hand. Where the tools did identify utilities, there was good correlation with the existing QL-B data. Overall, within the covered project areas, the R01B tools found 47 percent of the QL-B utilities in scope that were not identified previously as unknowns. They also found an additional 12 percent of the utilities. Approximately half of that 12 percent consisted of drainage culverts that were out of scope and easily visually identified. The R01B tools also found remnants of what appears to be a previously un-designated utility "ghost" system in one side street for which there were no utility records or structures—a true unknown. Due to the location, configuration, and fragmented nature of this utility, and as a result of the test holes it is believed to be an abandoned water or gas distribution system. There were also several locations where the original QL-B investigation showed an "end of geophysical information (EOI)" where the R01B tools detected a signal somewhat further. Perhaps the greatest advantage of the TerraVision II tool is that of a continuous depth profile of an imaged utility. A total of 13 test holes were dug to correlate the TerraVision II depths with actual field excavated measured depths. The agreement in depth ranged from .03 ft to 2.05 ft. However, most depths were in agreement by approximately 0.5 ft. There does not appear to be any correlation between type of utility, actual depth, or material type to explain the variation in TerraVision II depths to the actual exposed measured depth. It should be noted that the test hole depths ranged from .33 ft to 4.24 ft, in other words, very shallow utility systems on this

	project. A second significant feature of both the TerraVision II and TEMS tools was the ability to image geotechnical anomalies and actually see some amount of structure within those anomalies. For a 300 ft stretch of Talbotton Road, an area of both very high conductivity and reflected impedance was discovered. This large area has some significant and repeating 7 ft by 7 ft structures (anomalies) that could represent conductive concrete slabs, as determined by test holes. ➢ Program Level: Webinar ("Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research"), conducted August 2011, explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. • Post R01B Project Implementations ➢ Project Level: The GPR and TEMS prototypes were used on two Florida Department of Transportation (DOT) projects in the summer of 2013. Results were very similar to the field trial results of the Georgia Department of Transportation (DOT). There were no new utilities identified that had not already been identified by traditional pipe and cable locators and single channel GPR. Only approximately 40 percent of existing utilities were able to be imaged by the new geophysics, at a cost of about double a normal utility mapping project. However, there was a good ability to place a "z" value on the utility data for those 40 percent of the utilities that were imaged. In several cases, additional data were obtained, such as the presence of reinforced concrete. However, pavement thickness data were not able to be obtained in many places. ➢ Program Level: None.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints; Corresponding Needs</u> • It is critical that the correct project be selected. There must be flat, unobstructed paving surfaces, sandy dry soil, and lots of lead time for data processing, before the data are delivered. Furthermore, a full regular SUE ASCE 38 investigation should be performed in conjunction with, or before, the survey with these new R01B tools. <u>Project Characteristics</u> • Project Type: Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category: Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate): Any setting (but usually urban/suburban); Any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume or Average Daily Traffic (ADT), and Vehicle Composition): Any • Highway System: Any • Functional Class: Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints: Corresponding Needs</u> • The only requirement for application of these new tools is to specifically incorporate the concept of 3D radar and TEMS into the traditional SUE utility mapping scope. • Maximum value may be derived from these tools by incorporating the results into the full range of complementary environmental and geotechnical studies.
Barriers/Challenges and Ways to Overcome Them	• Less than 50 percent of the soils in the United States are conducive to good results. Deep utilities, or small utilities at normal depths, will not be imaged. Costs for a competent utility mapping survey will be increased by about 100 percent, with advantages for the extra costs being the possibility of fewer test holes for depth verification.

Project Key Words	Locating, surveys, utility mapping, utilities, right-of-way (ROW), subsurface utility engineering (SUE), utility coordination, utility relocation, utility accommodation, utility conflicts, site assessment, paving assessment, environmental assessment, geotechnical assessment.

Project Cost: $1,997,336

Expanded Summary for Renewal Project R01C
(*Innovation in Location of Deep Utility Pipes and Tunnels*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Gas Technology Institute (Des Plaines, IL): Chris Ziolkowski
Project Status and Time Frame	Ongoing: October 2009 through October 2013
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time ➢ Reduced project schedules and lane-closure times and reduced potential for delays through the use of additional tools (not replacement tools) for identifying and mapping deep and stacked utilities. • Saves Money ➢ Reduced costs by avoiding expensive uncovering operations and by preventing utility conflicts during construction.
Project Objectives	• To design an assembly of tools aimed at the advancement of utility detection by geophysical means for the specific cases of excessive depth (> 15 ft) and/or utilities stacked under another utility that may mask their presence with traditional locating tools.
Summary of Findings	Not currently available. The Phase 1 report is under revision and review. It should be noted that there were originally five tools under research and development with hardware and software components, consisting of (a) inertial positioning insertion devices, (b) a scanning electromagnetic device, (c) an acoustic system, (d) a seismic system, and (e) radio-frequency identification (RFID) tags. The inertial positioning system has been discontinued after the bankruptcy of its subcontractor. The scanning electromagnetic device has been discontinued after a problem with antenna coil interference. The seismic device concept was abandoned. The acoustic device had either hardware or software failure during field testing in Georgia. The RFID tags are in a prototype stage. The RFID system consists of two types of tags (one for deep utilities, and one for shallower utilities), two types of tag readers, and a software program for writing information to the tags. The tags have an expected battery life of 20–30 years. The deep tag may be detectable up to 40 ft in depth, while the shallower tag may be detectable up to 20 ft of depth. The tags are attached to a utility during installation of the utility, or during exposure of the utility. The tags can then be identified at a future date. If installed with careful attention to the tag orientation, its location at the surface may coincide with the location at depth. Only one type of tag reader was field tested so far. This was a hand-held device that identifies the presence of a tag when in close horizontal proximity (about 10 ft during field trials) and can then be used to narrow the location once a specific tag has been identified. The tag identification consists of a preset ID number. Information about a specific utility can be associated with this ID number and accessed from a database, if data are programmed into the database.
Product Description(s)	<u>Currently available products include:</u> (1) Webinars: On August 10, 2011, SHRP 2 conducted a webinar entitled "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research," which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15. On February 15, 2012, SHRP 2 conducted a similar webinar entitled "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis," which explored new tools for underground utility location, data collection,

	and analysis. This webinar was again based on SHRP 2 Projects R01A, R01B, R01C, and R15B. <u>Anticipated, but not currently available products include:</u> (2) Prototype Utility Detection System/Tool: Descriptions of the tool options are as follows: a) Acoustic Locator: Consists of six sensors approximately of the size of a small traffic cone, software connected to a laptop computer, and a small sound source that attaches to the laptop. The sensors are placed over a suspected utility, while the sound source is placed directly contiguous to an open empty pipe or conduit. At this time, the sound source is attached via gravity only, so only pipes that are standing upright at an exposure point can be attempted to be found. Pipes or conduits that are filled with fluid will block the acoustic signal at the first point where the fluid completely fills the pipe. Continuous nearby traffic noise may negatively influence the signal. Once the sound source is activated, the wireless sensors collect data and send it back to the laptop, where it is processed. After approximately 5 minutes, the software indicates how the sensors should be repositioned. This process iterates until a symmetrically hyperbolic curve of signal strength is determined. At the center of this curve will be the interpretation that the center of the pipe is directly below. Then the sensors are repositioned once more (moved closer together) and another acoustic signal is generated. The software then generates a depth reading. b) RFID Tag: The deep RFID tag is approximately 8 in. long, 1 in. in diameter, and cylindrical in shape. The prototype was not waterproof, but this may be addressed if the system is ever commercialized. The tag for shallower operations is similar in appearance but only 6 in. long. The hand-held reader consisted of an antenna attached to an iPod Touch. The unit is similar in shape and size to a standard pipe and cable locator. A second reader consists of a square antenna that can be coupled with a laptop for mobile operations such as attached to the SHRP R01B GPR cart. This antenna was not tested. (3) Final report that includes recommendations for further development/refinements of the prototype system/tool and a user manual for the prototype system/tool.
Product Status	(1) Webinars: *Ready for viewing. "*Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research" a*vailable online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf. "New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis available online at http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2012-02-15.pdf. (2) Prototype Utility Detection System/Tool. a) Acoustic Locator: Unknown after failed field test. b) RFID Tag: 20 prototype tags manufactured; 10 each for deep and shallow utilities. Reader developed. System still in prototype stage; product available for licensing and commercialization. (3) Final report: Under development. (expected Winter 2013/2014)
Target Audience	• Highway Agency ➢ Utility coordinators. ➢ ROW coordinators. ➢ Construction engineers. • Other Stakeholders: Utility owners, one-call utility notification centers, consultants, contractors.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development: All phases of design. • Contracting and Construction: Construction. • Management, Maintenance, and Operations: Asset management.
Pertinent Technical Areas	• Utility Location and Characterization Equipment
Implementations	• Implementations Performed as part of R01C Project

	➢ Project Level: None. ➢ Program Level: Webinar ("Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research") conducted August 2011 explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. • Post R01C Project Implementations ➢ Project Level: None. ➢ Program Level: None.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints: Corresponding Needs • Not applicable currently. Project results do not lend themselves to full and immediate implementation of the tools; further R&D and validation testing is needed.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • Not applicable currently. Project results do not lend themselves to full and immediate implementation of the tools; further R&D and validation testing is needed.
Barriers/Challenges and Ways to Overcome Them	• Not applicable currently. Project results do not lend themselves to full and immediate implementation of the tools; further R&D and validation testing is needed.
Project Key Words	Locating, surveys, utility mapping, utilities, right-of-way (ROW), subsurface utility engineering (SUE), asset management.

Project Cost: $1,614,316

Expanded Summary for Renewal Project R02
(Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Working Platform)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Iowa State University: Vernon R. Schaefer
Project Status and Time Frame	Ongoing: September 2007 through December 2014 (Note: Project actually completed September 2011, but additional time required for making enhancements to the web-based system and for hosting the system on Iowa State's server)
SHRP 2 Renewal Product Category	• Pavements
Highway Asset Area	• Pavements • Structures (bridges)

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Decreased construction time by using In Situ materials rather than borrow materials and innovative techniques.
	• Saves Money
	  ➢ Reduced costs associated with over-design and/or more costly geotechnical options.
	  ➢ Improved long-term pavement performance by improving unstable soils.
	• Saves Lives
	  ➢ Prevention of failures of walls, shoring, and berms, thus reducing construction-related accidents.

Project Objectives	• To identify existing alternative materials and systems for constructing embankments and roadways over unfavorable ground conditions. • To develop or compile design guidelines, procedures, and QA/QC test procedures for construction of ground improvements. • To develop performance-based construction specifications for selected soil improvement technologies. • To determine which existing and emerging technologies offer promise for treating areas of unfavorable subsurface conditions.

Summary of Findings	• Working off the results of Phase I, which identified 40 promising geotechnical materials, systems, and technologies that best achieve rapid renewal with minimal disruption and long-life, Phase II catalogued 46 technologies and developed—for each technology—mitigation strategies and detailed guidance for design, construction QC/QA, cost estimating, and specifications. The 46 geoconstruction technologies, which are applicable to three project elements—construction of new embankments and roadways over unstable soils, widening and expansion of existing roadways and embankments, and stabilization of the working platform—include:
	  ➢ Aggregate Columns
	  ➢ Beneficial Reuse of Waste Materials
	  ➢ Bio-Treatment for Subgrade Stabilization
	  ➢ Blasting Densification
	  ➢ Bulk-Infill Grouting
	  ➢ Chemical Grouting/Injection Systems
	  ➢ Chemical Stabilization of Subgrades and Bases
	  ➢ Column-Supported Embankments
	  ➢ Combined Soil Stabilization with Vertical Columns
	  ➢ Compaction Grouting
	  ➢ Continuous Flight Auger Piles

	➢ Deep Dynamic Compaction ➢ Deep Mixing Methods ➢ Drilled/Grouted and Hollow Bar Soil Nailing ➢ Electro-osmosis ➢ Excavation and Replacement ➢ Fiber Reinforcement in Pavement Systems ➢ Geocell Confinement in Pavement Systems ➢ Geosynthetic Reinforced Construction Platforms ➢ Geosynthetic Reinforced Embankments ➢ Geosynthetic Reinforcement in Pavement Systems ➢ Geosynthetic Separation in Pavement Systems ➢ Geosynthetics in Pavement Drainage ➢ Geotextile-Encased Columns ➢ High-Energy Impact Rollers ➢ Hydraulic Fill with Geocomposite and Vacuum Consolidation ➢ Injected Lightweight Foam Fill ➢ Intelligent Compaction ➢ Jet Grouting ➢ Lightweight Fill ➢ Mechanical Stabilization of Subgrades and Bases ➢ Mechanically Stabilized Earth Wall System ➢ Micropiles ➢ On-site Use of Recycled Pavement Materials ➢ Partial Encapsulation ➢ Prefabricated Vertical Drains and Fill Preloading ➢ Rapid Impact Compaction ➢ Reinforced Soil Slopes ➢ Sand Compaction Piles ➢ Screw-in Soil Nailing ➢ Shoot-in Soil Nailing ➢ Shored Mechanically Stabilized Earth Wall System ➢ Traditional Compaction ➢ Vacuum Preloading with and without Prefabricated Vertical Drains ➢ Vibrocompaction ➢ Vibro-Concrete Columns
Product Description(s)	(1) Phase I final report (*Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform: Phase 1 Report*, Draft, August 2008). Includes a description and discussion of five key tasks involving identification and discussion of issues related to geotechnical materials, systems, and construction methods for improvement of transportation infrastructure. Such tasks included a kickoff meeting/workshop and detailed technology assessments for 47 different geoconstruction technologies. The report identifies 17 technical issues and project development pros and cons that interfere with more widespread use of geoconstruction technologies, as well as 15 nontechnical issues and project-specific parameters limiting use of the technologies. (2) Phase II final report (*Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform: Final Phase 2 Summary Report*, Pre-Publication Draft, February 2012): Documents the Phase II research efforts and the development of the end-user products, which consist of eight product types—fact sheets, photographs, case histories, design procedures, construction QC/QA procedures, cost estimating, specifications, and bibliography—for the 46 geoconstruction technologies. The report describes the products and the development of background information for the products, describes the development of the web-based software tool, and provides implementation recommendations that center on additional activities (website maintenance and functionality,

	content enhancement, training/education and marketing) to produce a fully functional website for the general transportation professional. The report includes summaries for nine development projects completed during the research to fill gaps for certain technologies and applications (e.g., a compaction roadeo field demonstration for roller-integrated compaction monitoring and subgrade geosynthetic reinforcement, a statistical analysis study of case history projects involving settlement methods for stone columns). An appendix to the report contains several end-user product/tool examples, such as a technology fact sheet for prefabricated vertical drains with/without fill preloading, a case history for column-supported embankments (Minnesota Highway 241 Widening), design guidance for mechanically stabilized earth walls, and specifications for geosynthetic reinforced embankments. (3) Web-Based Software Tool (*GEOTECHTOOLS Geo-Construction Information and Technology Selection Guidance for Geotechnical, Structural, and Pavement Engineers*): Contains detailed information on the 46 geoconstruction technologies that allow for technology screening, applying/selecting, designing, cost estimating, specifying, and monitoring. The guidance and selection system consists of the following four components: ➢ Catalogue of technologies: provides a listing of all the technologies and links to all the products and tools for the respective technologies. ➢ Technology selection: contains a listing of technologies by classification and an interactive tool to identify candidate technologies for specific geoconstruction applications using project information and constraints. ➢ Geotechnical design process: presents an overview of the considerations involved in evaluating site conditions and implementing a geoconstruction technology. ➢ Abbreviations and glossary: presents terms that have been compiled to assist in understanding the acronyms and terminology used throughout this website and in its documents. The web-based system utilizes the combination software of Adobe ColdFusion®, JavaScript, and Microsoft Access®. (4) System Development Report (*Web-Based Information and Guidance System Development Report*, Pre-Publication Draft, February 2012): Describes the web-based information and guidance system developed in the study, including workshops and reviews of the proposed program, programming and initial development of the system in 2010, previewing and testing of the initial system at a TRB 2011 workshop, demonstration and more rigorous testing at an April 2011 workshop at the Louisiana Department of Transportation and Development (DOTD), revision and alpha testing through summer 2011 meetings at Iowa State University and Virginia Tech University, and final revisions of the program. The report describes limitations of the web-based program and includes recommendations for future enhancements of the website. Appendix A of the report contains a user's guide for the web-based system.
Product Status	(1) Phase I Report (*Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform: Phase 1 Report*, Draft, August 2008). Available online through the GEOTECHTOOLS website at www.geotechtools.org. (2) Phase II Report (*Geotechnical Solutions for Soil Improvement, Rapid Embankment Construction, and Stabilization of the Pavement Working Platform: Final Phase 2 Summary Report*, Pre-Publication Draft, February 2012). Available online at www.trb.org/Main/Blurbs/168148.aspx. (3) Web-Based Software Tool (*GEOTECHTOOLS Geo-Construction Information and Technology Selection Guidance for Geotechnical, Structural, and Pavement Engineers* (Web-based Guidance and Selection System). Beta test version 1.0 available online at www.geotechtools.org/. A password protected link appears to be available to those with the password: www.intrans.iastate.edu/geotechsolutions/ (4) Guide Document (*Web-Based Information and Guidance/Selection System Development Report*). Available online at www.trb.org/Main/Blurbs/168246.aspx.

Target Audience	• Highway Agency
	  ➢ Geotechnical engineers (primary target).
	  ➢ Design engineers.
	  ➢ Pavement engineers.
	  ➢ Project managers.
	  ➢ Construction engineers.
	  ➢ Procurement, research, and maintenance specialists.
	• Other Stakeholders: Contractors, consultants, academicians.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development: Preliminary and final design. • Contracting and Construction: Procurement, construction. • Management, Maintenance, and Operations: Asset management, system maintenance and preservation.
Pertinent Technical Areas	• Geoconstruction Technology Evaluation and Selection (feasibility, costs, case histories, etc.) pertinent to (a) construction of new embankments and roadways over unstable soils, (b) widening and expansion of existing roadways and embankments, and (c) stabilization of the working platform. • Geoconstruction Technology Design (preliminary and final). • Geoconstruction Technology Specifications. • Geoconstruction Technology Construction Procedures and QC/QA Methods.

Implementations	• Implementations Performed as part of R02 Project
	  ➢ Project Level: None.
	  ➢ Program Level: Training/demonstrations of the web-based guidance and selection system at regional state DOT geotechnical engineering meetings, meetings with individual state DOTs, and national/international conferences.
	• Post R02 Project Implementations: None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints: Corresponding Needs</u> • A two-lane highway is to be widened to four lanes to accommodate traffic and increase safety. Because of the unstable soils in the area, there is concern for substantial differential settlement between the new embankment and the existing one. Need to determine if there is a geoconstruction technology available that can cost effectively reduce the risk of differential settlement. • An engineer from a neighboring state highway agency mentioned having success with a particular geoconstruction technology (e.g., geotextile-encased columns) on a particular type of highway project. The engineering aspects of the technology, its applicability in different situations, and its costs are not readily available. Need information on what the technology is, what its applications are, what costs to expect, and how to specify its use. <u>Project Characteristics</u> • Project Type: Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category: Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate): Any setting; Any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any • Highway System: Any • Functional Class: Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Resistance to change within the DOT regarding use of non-traditional geoconstruction technologies. Need to make geotechnical and other related staff more cognizant of the various technologies and the applications most conducive for the technologies, and foster discussions about which technologies could be added to the DOT's toolkit and what customizations might be

manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	needed. • Lack of knowledge and/or inadequate resources among contractors with regard to technologies not typically specified by DOT. Need to establish a collaborative process between DOT and contractors to increase the knowledge base and address equipment and material constraints associated with the new technologies.
Barriers/Challenges and Ways to Overcome Them	Barriers to more widespread use of web-based system: • Inappropriate application of system by inexperienced personnel. ➢ Emphasize (through disclaimers and product training) that the user must be responsible for independently cross-checking system results with other methods and examining the reasonableness of the results with engineering knowledge and experience. • Information provided in the web-based system is current as of the time of report and system/website release, however it could become outdated in the future. Also, the number of technologies included in the system (although numerous) is not a comprehensive list of the technologies available. ➢ Through follow-on contracts, provide intermittent updates to the system for content enhancement purposes.
Project Key Words	Roadway, pavement, bridges, geotechnical, geoconstruction, embankment, rapid embankment construction, unstable soils, stabilization, soil improvement, database, deep foundations, shallow foundations, working platforms, fill, mechanically stabilized earth (MSE) walls

Project Cost: $3,000,000

Expanded Summary for Renewal Project R03 (*Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments*)

SHRP 2 Program Officer	Jerry DiMaggio
Contractor and PI Info	Battelle Memorial Institute/Pacific Northwest National Laboratory: Tom Sanquist
Project Status and Time Frame	Ongoing: October 1, 2009 through June 30, 2013
SHRP 2 Renewal Product Category	• Project Delivery/Construction
Highway Asset Area	• Pavements • Structures (bridges) • Roadway Features • Utilities • Railroads
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Reduced workforce fatigue associated with rapid renewal working conditions (e.g., work done during off-peak hours, continuous weekend construction, extended night-time operations, work zones adjacent to traffic), leading to: ▪ Reduced on-site accidents. ▪ Increased overall productivity. ▪ Higher degree of work quality. ▪ Reduced construction costs. ▪ Improved workforce health and family life.
Project Objectives	• To gain a better understanding of the factors associated with workforce fatigue and stress in the rapid renewal environment, so that the risks to worker safety and construction productivity can be managed and reduced. • To develop a best practices toolbox that can be used in reducing workforce fatigue on rapid renewal projects. The toolbox will include: (1) recommendations for reducing workforce fatigue and improving safety, (2) fatigue risk management plans; and (3) guidelines for implementation and training materials, including those for management that address team fatigue and increased stress.
Summary of Findings	• Fatigue is clearly present in rapid renewal environments and presents considerable safety risks. • Existing fatigue risk management programs cannot be used in rapid renewal environments; development of a tailored suite of tools and implementation facilitation is required. • The tools developed in this project have great potential for addressing the fatigue problems identified in this project, but must be introduced to relevant stakeholders and end users in a clear and supportive manner. • Outreach would consist of a broad communications effort aimed at both scientific/technical audiences, as well as industry stakeholder groups. • Outreach activities should be accompanied by an implementation effort to pilot test the materials developed in this product, evaluate their value and usefulness, and revise them to reflect stakeholder and end-user feedback.
Product Description(s)	(1) Final Report (*Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments*, Pre-Publication Draft, January, 2013). Documents the project research activities (consisting of a Phase I literature review and field research and Phase II product

development) and findings and presents conclusions and recommendations. Provides comprehensive information on fatigue in occupational settings, reports on the field study performed on fatigue factors in three rapid renewal projects (FL SR-50 Corridor Improvement Project [Orange and Eastern Counties, FL, 2011], NY I-287 Corridor Improvement Project, [Westchester County, NY, 2006-2010], WA SR-520 Eastside Transit and High-Occupancy Vehicle (HOV) Project [King County, WA, 2011-2013]), discusses the fatigue risk management critical issues for the highway construction industry, and presents an organizational approach to fatigue risk management in rapid renewal highway construction. Includes Appendix A (Rapid Renewal Scenario Descriptions) that presents/describes 13 highway construction rapid renewal projects in six states (California, Florida, Illinois, New York, Utah, and Washington) selected as potential examples for the study of fatigue factors. The 13 projects selected are shown below; detailed field research was only performed for the FL SR-50, NY I-287, and WA SR-250 projects.

- Tampa Airport Interchange Improvement Corridor (Tampa, FL, 2005-2010).
- FL SR-50 Corridor Improvement Project (Orange and Eastern Counties, FL, 2011).
- NY Route 9P Bridge Replacement Project (Saratoga Springs, NY, 2010-2011).
- NY I‐287 Corridor Improvement Project, Phase III (Westchester County, NY, 2006-2010).
- IL I-290 Resurfacing Project (Cook and DuPage Counties, IL, 2010).
- IL I-80 Bridge Repairs Project (Moline, IL, 2009-2010).
- WA I-5 Seattle Reconstruction Project (Seattle, WA, 2005).
- WA I-90 Homer Hadley Bridge Expansion Joint Replacements Project (Seattle, WA, 2009-2010).
- WA SR‐520 Eastside Transit and HOV Project (King County, WA, 2011-2013).
- UT I-15 Corridor Expansion (Salt Lake City, UT, 2010-2012).
- Replacement of the 4500 South Bridge (Salt Lake City, UT, 2007).
- CA I-15 Ontario Rehabilitation Project (Ontario, CA, 2009-2010).
- CA I-680 Walnut Creek Rehabilitation Project (Alameda and Contra Costa Counties, CA, 2010-2011).

The final report recommends outreach in the form of (1) a broad communications effort aimed at both scientific/technical audiences, as well as industry stakeholder groups, and (2) an implementation effort to pilot test the materials developed in the project, evaluate their value and usefulness, and revise them to reflect stakeholder and end-user feedback.

(2) Guide Document (*Fatigue Risk Management Guide for Rapid Renewal Highway Construction Projects*, Pre-Publication Draft, 2013). Provides a resource for safety and training managers seeking more detailed technical information concerning worker fatigue, and tools for implementing and evaluating components of fatigue risk management for renewal projects involving the following construction scheduling approaches:

- Extended workday: 8+ hours.
- 48- to 55-hour workweeks.
- Double shifts.
- Change shift to night work in middle of week.
- Night work.
- Long-term night shifts.
- Weekend work.
- Extended weekend work: 33- to 55-hour closures.
- Operations in close proximity to traffic.

The guide is intended for use by safety managers, persons involved in creating employee work schedules, DOT personnel, and others interested in applying specific and practical safety measures. It consists of five chapters that will allow users to develop and implement fatigue risk management:

- Chapter 1, Introduction. Describes the basic risk factors of rapid renewal construction schedules and the organizational processes and steps for implementing fatigue risk management.
- Chapter 2, Organizational Practices Guidance. Outlines selected organizational practices, such as assessing the corporate approach to fatigue risk management, building fatigue management

	into the operation, assessing specific schedule risks, formalizing the risk assessment process, and implementing fatigue countermeasures. ➢ Chapter 3, Technical Reference Material. Describes the underlying physiology of human sleep and circadian rhythms; and the fundamental mechanisms that contribute to fatigue and work schedule interactions. Also, contains a compilation of fatigue countermeasures; those that are more effective, those that are less effective, and some that are in the preliminary research phase and not ready for widespread implementation. ➢ Chapter 4, Training Material. Contains comprehensive training about fatigue that addresses the specific risk factors and operational constraints of the work domain. The chapter includes two modules of training slides: "Basic Fatigue Training," intended for use all persons involved in highway construction (laborers, supervisors, managers, and DOT personnel) and "Manager Training," meant to provide a larger organizational context, processes, and implementation steps for addressing fatigue risk management. ➢ Chapter 5, Fatigue Risk Management Schedule Guidance and Work Practices. Contains specific shift schedule and work practice guidance for use by managers planning and executing projects. (3) Training Material (Chapter 4 of Guide document): See above.
Product Status	(1) Final Report (*Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments*, Pre-Publication Draft, January, 2013). Available online at www.trb.org/Main/Blurbs/168767.aspx. (2) Guide Document (*Fatigue Risk Management Guide for Rapid Renewal Highway Construction Projects*, Pre-Publication Draft, 2013). Available online at www.trb.org/Main/Blurbs/168766.aspx. (3) Training Material (Chapter 4 of Guide document). Available online at www.trb.org/Main/Blurbs/168766.aspx.
Target Audience	• Highway Agency ➢ Planners. ➢ Project managers. ➢ Designers. ➢ Construction managers. ➢ Construction engineers and technicians. • Other Stakeholders: Construction firm/contractor personnel (managers, supervisors, laborers).
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development: Planning, all phases of design. • Contracting and Construction: Construction.
Pertinent Technical Areas	• Project development/design (staging, layout, work operations, etc.). • Construction work scheduling (extended work shifts, night shifts, irregular work shifts, etc.).
Implementations	• Implementations Performed as part of R03 Project ➢ Project Level: None (3 Rapid Renewal highway construction projects used as study examples regarding fatigue exposures/experiences). ➢ Program Level: None (training materials developed). • Post R03 Project Implementations ➢ Project Level: None. ➢ Program Level: None.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway	<u>Problems/Issues/Constraints; Corresponding Needs</u> • A major bridge is programmed to undergo deck repairs and floor-beam end-section replacements that will require closure of the bridge's two outside lanes. To limit the time period for lane closure, an aggressive incentive contract has been established and awarded, which will cause the contractor to work multiple crews and double shifts to get the work done as quickly as possible. Need to establish a collaborative work plan that will limit worker fatigue (contractor and DOT personnel) and the risk of an accident.

project)	• A 10-mi long corridor of interstate pavement is being reconstructed and, because of weather and other events, has fallen behind schedule. The DOT has offered an incentive to the contractor that would entail completing the construction work in four 55-hour weekend closure stages. The weekend closure approach will entail non-stop 12-hour shifts for crews (and DOT personnel) that result in overtime beyond the normal 40-hour work week. Need to establish effective fatigue countermeasures that will reduce the risk of an accident. <u>Project Characteristics</u> • Project Type: Greenfield, Reconstruction, Rehabilitation, Preservation/Maintenance • Asset Type/Renewal Product Category: Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate): Any setting; Any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any • Highway System: Any • Functional Class: Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Onus of combatting worker fatigue placed on contractors; little recognition given to things the DOT can do to prevent accidents associated with worker fatigue. Need to build awareness of risk factors within the DOT and work toward identifying reasonable mitigation strategies at the planning, design, and construction stages of project development. • Lack of worker fatigue safety protocols and/or inadequate resources to enforce safety protocols among DOTs and contractors. Need to establish a collaborative process between DOT and contractors to identify appropriate project conditions/scenarios for enacting certain protocols and ensuring they are followed.
Barriers/Challenges and Ways to Overcome Them	• Fatigue is a safety issue not "owned" by a specific stakeholder; highway construction safety performance is not in the purview of an independent federal regulatory agency, such as OSHA. ➢ Institute policies and training that emphasize the consequences of fatigue in safety and performance and the key elements of both preventive and operational approaches to reducing fatigue. • Fatigue risk management programs may be over-sophisticated for the contracting industry; organizational development and resources may be inadequate for implementation of a fatigue risk management system. ➢ Enact "push" measures and/or educate contractors as to the business value of fatigue risk management processes. • Safety data are extremely limited in relation to the effectiveness of interventions, such as training and more sophisticated fatigue risk management systems. ➢ More case studies are needed that produce the data and illustrate effectiveness • A credible dissemination pathway for fatigue risk management tools is needed; a simple website is insufficient for widespread outreach. ➢ Website needs to be recognized and linked by major national organizations, such as AASHTO, ARTBA, Associated General Contractors of America (AGC), and OSHA/FHWA Work Zone Safety website.
Project Key Words	Workforce fatigue, worker fatigue, inspector fatigue, manager fatigue, fatigue mitigation, stress, construction safety, construction productivity, fatigue risk management.

Project Cost: $999,087

Expanded Summary for Renewal Project R04
(Innovative Bridge Designs for Rapid Renewal)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	HNTB: Ken Price
Project Status and Time Frame	Ongoing: October 2007 through October 2013 (two additional pilot projects currently being performed; final report and tool kit available from SHRP 2)
SHRP 2 Renewal Product Category	• Bridges
Highway Asset Area	• Structures (bridges)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Reduced costs due to mass production of components, repetitive application on multiple projects; increased construction season. Materials are pre-manufactured off-site in controlled plant conditions. ➢ Improved asset performance/quality: manufactured bridge systems, enhanced quality control, repeatability, controlled conditions, durability. ➢ Improved use of resources and reduction of environmental impacts, including impacts on adjacent infrastructure. • Saves Lives ➢ Improved work zone safety for users and constructors. Minimized traffic disruption and reduced on-site construction increases safety.
Project Objectives	• To develop standardized approaches to designing, constructing, and reusing (including the future widening) complete bridge systems that address rapid renewal needs and efficiently integrate modern construction equipment. Such standardized approaches represent a departure from custom-engineered, cast-in-place (CIP) solutions to bridges.
Summary of Findings	• The best way to experience accelerated bridge construction (ABC) is by getting involved in all phases of an ABC project. Collaborative designs can utilize the ABC design standards prepared by the R04 Team to show how the entire project delivery, including design and construction, can be accelerated. • Promote collaborative ABC designs between bridge owners and the R04 team as a way to transfer ABC technologies to the end user. • Owner involvement in the design phase will produce more converts to the ABC way of building bridges.
Product Description(s)	Currently available products include: (1) Final Report (*Innovative Bridge Designs for Rapid Renewal*, Pre-Publication Draft, November 2012). Documents and presents the results of the SHRP 2 R04 project, including: • Phase I: ABC information gathering through literature reviews and identification of current impediments and challenges to greater use of ABC through surveys, interviews, and focus group meetings with owners and contractors. Promising concepts identified included precast substructure systems (abutments, piers, segmental columns), precast decks and complete superstructure system (modular beam systems, precast decks, segmental systems), and ABC construction technologies including launching, sliding, and shifting; jacking and mining; and equipment (wheeled carriers/self-propelled modular transporter [SPMT], above-deck carriers/straddle carriers, temporary trusses). • Phase II: Critical evaluation of Phase I findings regarding ABC concepts that can be advanced to standard plans in Phase III. The evaluation was carried out using an evaluation matrix consisting of criteria such as initial cost, durability, system simplicity, market readiness for rapid construction, and ease of evaluation for overload permits. Based on the evaluation, a short list of design concepts

	was prepared and the design of a demonstration bridge project was performed. • Phase III: Included conduct of a 2011 bridge demonstration project and workshop (US Highway 6 bridge over Keg Creek in Pottawattamie County, Iowa, a three-span 210-ft by 47-ft steel/precast modular bridge with decked steel modules, precast substructures, and precast bridge approaches, that shortened the normal replacement period of 6 months down to 2 weeks of traffic disruption), development of standard plans and details for the most useful prefabricated modular technologies (precast modular abutment systems [integral abutments, semi-integral abutments, precast approach slabs], precast complete pier systems [conventional pier bents, straddle pier bents], modular superstructure systems [concrete deck bulb tees, concrete deck double tees, decked steel stringer system], and ABC bridge erection systems [above-deck driven carriers, launched temporary truss bridge]), development of AASHTO-formatted LRFD design specifications, analysis methods, details, standard plans, and design examples, and development of an ABC toolkit containing the ABC design standards, detailed design examples, recommended LRFD design specifications, and recommended LRFD construction specifications. The report highlights two different ABC approaches: (a) accelerated construction of bridges in place using prefabricated bridge elements and systems (including foundations and substructures) and (b) the use of bridge movement technology (e.g., lateral sliding, rolling and skidding, incremental launching) and equipment (cranes, self-propelled modular transporters [SPMTs]) to move completed superstructures from an off-alignment location into the final position. The ABC system focuses on three strategies: • As light as possible ➢ Is sized in a manner to be manageable for transportation and installation. ➢ Simplifies transportation and erection of bridge components. ➢ Could improve the load rating of existing piers/foundations. • As simple as possible ➢ Fewer girders. ➢ Fewer field splices. ➢ Fewer bracing systems. ➢ No temporary bracing to be removed. • As simple to erect as possible ➢ Fewer workers on-site. ➢ Fewer cast-in-place operations. ➢ No falsework structures required for prefabricated elements and systems. ➢ Simpler geometry. The ABC design concepts were classified into five tiers based on implementation duration (i.e., mobility impact time): • Tier 1: Traffic impacts within 1 to 24 hours. • Tier 2: Traffic impacts within 3 days. • Tier 3: Traffic impacts within 2 weeks. • Tier 4: Traffic impacts within 3 months. • Tier 5: Overall project schedule is significantly reduced by months to years. Typical designs for superstructure and substructure modules were grouped into three spans: • 40 ft ≤ span ≤ 70 ft. • 70 ft ≤ span ≤ 100 ft. • 100 ft ≤ span ≤ 130 ft. The final report includes discussion of innovative project delivery and contracting provisions for ABC projects (e.g., design-build, construction manager, A+B bidding, A+B+C bidding, incentive/disincentive clauses) and appendixes containing case studies/histories featuring ABC techniques (Appendix A), documentation of the field demonstration project construction (Appendix D), ABC standard plans (Appendix E), recommended ABC design specifications (Appendix G), and recommended ABC construction specifications (Appendix H). (2) Project Brief (*A Toolkit for Accelerated Bridge Construction*): This four-page document gives an overview of Project R04 and highlights the new ABC toolkit. It also discusses the Keg Creek Bridge demonstration project.

	(3) Toolkit (*Innovative Bridge Designs for Rapid Renewal: ABC Toolkit*, SHRP 2 Report S2-R04-RR-2): Contains design concepts for innovative foundation systems, substructures and superstructure systems, subsystems and components (Chapter 2 and Appendix A); design examples and analysis methods (Chapter 3 and Appendix B); sample standard plans and detail sheets for prefabricated modular systems and construction technologies (Chapter 2 and Appendix A); sample standard plans and detail sheets for bridge movement technology (not SPMT) (Chapter 2 and Appendix A); recommended AASHTO-formatted LRFD design specifications (Appendix C); and recommended AASHTO-formatted construction specifications for ABC (Appendix D). (4) Sample Design Calculations (R04 Mathcad and CADD Files): The R04 Mathcad and CADD files for the Innovative Bridge Designs for Rapid Renewal: ABC Toolkit illustrate the sample ABC design calculations and serve as training tools for engineers to increase familiarity with ABC design issues and criteria. Three sample design calculations are provided to illustrate the ABC design process for the following prefabricated modular systems: (a) decked steel girder, (b) decked precast prestressed girder, and (c) precast pier. (5) Demonstration Projects (ongoing): Development and conduct of demonstration projects for ABC systems and techniques. First demonstration project conducted under Phase III in fall 2011 was US-6 over Keg Creek near Council Bluffs, Iowa (accompanied by Highways for Life workshop). A second demonstration project under development (letting in 3rd quarter of 2012) includes the I-84 bridge over Dingle Ridge Road in eastern New York. Additionally, several bridges in Vermont damaged by Tropical Storm Irene are being replaced using the ABC toolkit. Based on the demonstrations, the ABC toolkit will be updated. (6) Webinars: On January 17, 2012, TRB cosponsored a webinar that focused on the ABC toolbox developed under SHRP 2 R04. The presentation also included a design example. (7) Videos: Three videos were created that document the Keg Creek Bridge project near Council Bluffs, Iowa: the 18-minute and 39-second video, *ABC for Everyday Bridges*; the 9-minute and 46-second video, *One Design—10,000 Bridges*; and 1-minute and 30-second time-lapse video. Videos of the New York and Vermont demonstrations will be made available in the future. <u>Anticipated, but not currently available products include:</u> (8) Training Materials—Development of technical content for a 1-day ABC course that will be suitable for incorporation into a NHI course for deployment nationally. The presentation materials meeting National Highway Institute (NHI) standards will have to be developed separately by NHI.
Product Status	(1) Final Report (*Innovative Bridge Designs for Rapid Renewal*, Pre-Publication Draft, November 2012). Available online at www.trb.org/Main/Blurbs/167693.aspx. The report will be updated following the New York and Vermont bridge demonstration projects in 2014. (2) Project Brief (*A Toolkit for Accelerated Bridge Construction*). Available online at www.trb.org/Main/Blurbs/169082.aspx. (3) Toolkit (*Innovative Bridge Designs for Rapid Renewal: ABC Toolkit*, SHRP 2 Report S2-R04-RR-2)—Available online at www.trb.org/Main/Blurbs/168046.aspx. The toolkit will be updated following the New York and Vermont bridge demonstration projects in 2014. (4) Sample Design Calculations (R04 MathCAD and CADD Files)—Available online at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/R04_MathCADFiles_715.aspx. (5) Demonstration Projects (ongoing): First demonstration project (Keg Creek Bridge near Council Bluffs, IA) with associated documentation completed and is included in the R04 final report. Second demonstration project (I-84 bridge over Dingle Road in eastern NY) with associated documentation under Phase IV and is scheduled for completion in October 2013 (Note: A visualization of the lateral slide technique being used on this project is available at https://www.dot.ny.gov/NYI84CT). Additional demonstration projects in Vermont planned for 2013. (6) Webinars: A recording of the webinar is available online at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/RenewalWebinars.aspx. (7) Videos: Available online at http://www.trb.org/Main/Blurbs/167693.aspx. (8) Training Materials: To be completed as part of Phase IV.
Target Audience	• Highway Agency

	➢ Bridge program/project managers. ➢ Bridge design engineers. ➢ Bridge construction engineers. • Other Stakeholders: Bridge constructors/fabricators, contractors, consultants.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development: Engineering, safety and environmental studies; preliminary and final design; PS&E. • Program Development: System planning; programming. • Management, maintenance, and operations: Asset/program performance monitoring and management.
Pertinent Technical Areas	• Bridge design (including design calculations, plans and standard details, and bridge removal and erection techniques for modular superstructure systems, segmental superstructure systems, precast decks, precast modular abutment systems, precast complete pier systems, segmental columns/piers, above-deck driven carriers, launched temporary truss bridge, SPMTs and other wheeled carriers, and launching, sliding, and lateral shifting). • Bridge specification development. • Bridge project delivery and contracting provisions.
Implementations	• Implementations performed as part of R04 Project ➢ Project Level: field demo of ABC Bridge Replacement Project in fall 2011 (Keg Creek Bridge near Council Bluffs, IA). A second field demo of ABC Bridge Project is under development (I-84 bridge over Dingle Ridge Road in New York) and additional demonstration projects in Vermont are planned. ➢ Program Level ▪ Highways for Life ABC Workshop accompanied the Keg Creek Bridge Field Demo. ▪ Webinar conducted Jan 2012 focusing on ABC toolkit. ▪ Videos produced and put online documenting Keg Creek Bridge Demo. • Post R04 Project Implementations ➢ Additional demonstration projects are being planned. ➢ AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 1): R04 Implementation Assistance Program announced in 2/7/13 web conference. Application process runs from 2/15/13 thru 3/15/13. Announcement of recipients in April 2013. Nine agency awards made include: ▪ Arizona DOT: Lead Adopter assistance on IR7 Gila River Bridge project. ▪ California Department of Transportation (DOT): Lead Adopter assistance on Fort Goff Creek Bridge project. ▪ Kentucky Transportation cabinet (TC): Lead Adopter assistance on KY-6 Stewarts Creek project. ▪ Maine DOT: Lead Adopter assistance on Kittery Overpass project. ▪ Michigan DOT/Fed Lands Hwy: Lead Adopter assistance on Seney National Wildlife Refuge project. ▪ Missouri DOT: Lead Adopter assistance on Bridge A-0087 project. ▪ Nebraska Department of Roads (DOR): Limited technical assistance. ▪ Rhode Island Department of Transportation (DOT): Lead Adopter assistance on Warren Avenue project. ▪ Wisconsin Department of Transportation (DOT): Lead Adopter assistance on I-39/I-90 Expansion project.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Existing bridge on busy local route is substantially deteriorated and in need of rapid replacement such that traffic is not disrupted for more than 2 weeks. Need to identify ABC technologies that would be suitable for the circumstances of the project and could be utilized to meet the traffic impact constraints. • A set of ABC technologies has been selected for a project, and now the design details must be

product(s) as part of an actual highway project)	developed. Need to use the LRFD design specifications for ABC elements and systems, as well as ABC design guidelines to perform the structure design. • Construction plans and specifications for an ABC bridge project must be prepared for bid. Need to use the sample standard plans and detail sheets contained in the ABC toolkit, as well as the LRFD construction specifications, to develop the required documents. <u>Project Characteristics</u> • Project Type: Reconstruction, Rehabilitation. • Asset Type/Renewal Product Category: Bridges. • Geographic Location (Setting and Climate): Any setting; Any climate. • Geometrics: Limited to spans between 40 and 130 ft. • Conflicting Features: Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any. • Highway System: Any. • Functional Class: Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints; Corresponding Needs</u> • ABC technologies and applications are not well known among agency bridge designers and/or are not deeply rooted within agency bridge practices. Need to consider planning and conducting an ABC demonstration project, workshop, and/or training course to educate agency personnel and industry.
Barriers/Challenges and Ways to Overcome Them	• ABC has to be utilized on specific types of projects or portions of projects in order to reap the benefit. ➢ Need to identify potential bridge replacements that could benefit from ABC and/or evaluate existing bridge designs (potentially through a value engineering [VE] study) to look for components of the construction that would benefit from ABC. • Lack of system-wide identification of ABC can limit its use. ➢ Need to develop criteria where ABC can be utilized based on average daily traffic (ADT), detour route, travel times, and other factors. • Current agency documentation may not be acceptable for ABC. ➢ Need to modify any contracts and standards manuals to accommodate ABC construction techniques. • Buy-in from upper-level management is required. ➢ Need to evaluate other agencies' use of ABC, through the demonstration projects, and look for a successful way to begin implementation within an agency.
Project Key Words	Accelerated bridge construction (ABC), bridges, prefabricated bridge elements and systems, placement, procurement, manufactured bridges.

Project Cost: $2,500,000

Expanded Summary for Renewal Project R05
(*Modular Pavement Technology*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Fugro Consultants, Inc. (Fugro): Shiraz Tayabji
Project Status and Time Frame	Completed February 2008 through August 2012
SHRP 2 Renewal Product Category	• Pavements • Project Delivery/Construction
Highway Asset Area	• Pavements
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Improved durability and long-term pavement performance. ➢ Reduced user delay and traffic disruptions. ➢ Minimize effects of weather-related delays. ➢ Overall reduction in pavement life-cycle costs (repair and reconstruction). • Saves Lives ➢ Reduced accidents through decreased lane-closure times.
Project Objectives	• To develop tools for public agencies to use for the design, construction, installation, maintenance, and evaluation of modular pavement systems. It is anticipated that these tools should include, at a minimum: ➢ Guidance on the potential uses of modular pavement systems for specific rapid renewal applications. ➢ Generic design criteria. ➢ Project selection criteria. ➢ Guidelines and draft or model specifications for construction, installation, acceptance, and maintenance. ➢ A long-term evaluation plan to assess the performance of modular systems and lead to refinements in designs and materials.
Summary of Findings	• Two primary types of precast concrete pavement (PCP) systems are available and used in the US: ➢ Jointed systems: jointed precast concrete pavement (JPrCP) and incrementally connected precast concrete pavement (ICPCP). ➢ Prestressed systems: precast prestressed concrete pavement (PPCP). • PCP systems are used for intermittent/localized full-depth repairs and full panel replacements, as well as for continuous applications (usually for short stretches of road up to 1,000 ft). • Field testing (condition surveys, smoothness testing, faulting and joint width measurements, and deflection testing) conducted on 15 installed/in-service PCP projects indicate good performance, which demonstrates the viability of the technology. Four key attributes were identified as critical to their effective installation and long-term performance: ➢ Overall constructability. ➢ Concrete durability. ➢ Effective joint load transfer. ➢ Uniform panel support. • A number of refinements to PCP technology are proposed, including the adoption of the Mechanistic-Empirical Pavement Design Guide (MEPDG) for design (using precast pavement specific distress criteria), improved bedding procedures and support materials, use of relative deflection criteria to judge effectiveness of load transfer devices, use of narrow-mouth dowel slots to allow opening to traffic before the slot is patched, and the provision of incrementally connected

	systems to reduce the number of active joints. • The use of PCP systems is hard to justify from a first-cost standpoint unless reductions in lane-closure times are obtained and long-life, low-maintenance pavements are achieved. However, the installation cost for PCPs has decreased significantly, from about \$900/yd^2 in 2001 to about \$400/yd^2 in 2010. • Some general observations pertaining to PCPs include : ➢ PCP systems are used in highway corridors with high traffic volumes and where lane closures are a challenge. For production use, PCP work is performed at night, typically between 8:00 p.m. and 6:00 a.m. ➢ Once installed, PCP systems behave similarly to conventional, cast-in-place (CIP) concrete pavements. ➢ The success of PCP systems rests on the successful integration of all components of the system. Installation quality is critical to long-term performance of PCP systems. ➢ All requirements related to concrete quality, load transfer at joints, and support condition for cast-in-place concrete pavements are also applicable to PCP systems. ➢ Overall installation productivity should not be an excuse to sacrifice design requirements and performance expectations. • A more favorable competitive environment is needed in the highway construction process to allow for innovations by engineers, contractors, and precasters to improve the technology that will lead to more efficient designs and installations.
Product Description(s)	(1) Final Report (*Precast Concrete Pavement Technology*, SHRP 2 Report S2-R05-RR-1). Documents the state-of-the-practice use of PCP system technologies in the United States and abroad (as identified through a comprehensive literature review and interviews/surveys with highway agencies and industry) and the results of a field testing program carried out in 2009 and 2010 on the following 14 projects (installation year given in parentheses): • PPCP projects: Georgetown, Texas frontage road (2001), Missouri I-57 (2005), Delaware Route 856 (2009), and Virginia I-66 (2009). • Continuous JPrCP projects—New York Tappan Zee Toll Plaza (2001/02), Minnesota TH-62 (2005), Virginia I-66 ramp (2009), California I-15 (2010), Illinois Tollway I-88 ramps (2008) and I-294 (2007), and New Jersey NJ-130 (2010). • Intermittent repair projects—New Jersey I-295 (2007/08), New Jersey I-280 (2008/09), Michigan I-675 (2003), and New York Route 27 (2009). The report covers all aspects of PCPs, from materials and design to fabrication and installation, with special consideration given to many technical and other factors, such as proprietary components (FMC Super-Slab System, Kwik-Slab), jointing and joint load transfer, load transfer design, support conditions, prestressing (selected systems), surface characteristics, application type (continuous vs. intermittent), and maintenance of traffic. It includes chapters containing guidance on the following items (some of which are presented as products below): • Design of PCP systems. • Fabrication of PCP panels. • Installation of PCP panels. • Maintenance, repair, and rehabilitation of PCP systems. • Decision-making process for PCP systems (project suitability/selection). • PCP system approval and trial installation (establishing processes for evaluating and approving new PCP systems or components within an agency). The final report includes an appendix containing a PCP Technology Implementation Plan. (2) Design Guidelines (Chapters 4-8 of Final Report) contains detailed guidance (recommendations and requirements) for designing the various components of PCP systems (JPrCP for intermittent applications, JPrCP and PPCP for continuous applications), including concrete properties, panel reinforcement, load transfer assembly, prestressing, posttensioning, panel lifting/transport, panel

	thickness (structural design analysis), and joint layout/design. (3) Panel Fabrication Guidelines (Chapter 9 of Final Report) contains detailed guidance for producing PCP panels at the plant, including formwork assembly and disassembly, steel hardware installation, blockout and grout port provisions, panel undersealing, concrete placement, concrete finishing and curing, and QC/QA. (4) Panel Installation Guidelines (Chapters 10-12 of Final Report) contains detailed guidance for the installation of PCP panels for intermittent repairs (JPrCP) (Chapter 10), continuous jointed PCP applications (JPrCP and ICPCP) (Chapter 11), and continuous prestressed applications (PPCP) (Chapter 12). (5) PCP System Decision Process (Chapter 15 of the Final Report) contains detailed guidance in evaluating the suitability of PCP/modular pavement for a project, based on variety of agency considerations (current practices, attitude toward new technologies, costs, safety, design responsibility, constructability), project-specific factors (traffic, lane-closure requirements, site access for heavy construction equipment), and resource factors (experienced local contractors, proximity of precast plants, available equipment). (6) Model Specifications (*Model Specifications for Precast Concrete Pavement Systems*) includes model specifications for fabricating and installing jointed precast concrete pavement systems for intermittent and continuous applications and for fabricating and installing precast prestressed concrete pavement systems. The model specifications cover materials, panel fabrication, panel installation, panel acceptance testing, as well as method of measurement and basis for payment. The specifications were formulated from specifications developed by the AASHTO Technology Implementation Group (TIG) and from more recent specifications developed by California DOT, New York State Department of Transportation (DOT), New Jersey Department of Transportation (DOT), Illinois Tollway Authority, and Ontario Ministry of Transportation. (7) Webinar (Precast Pavement Technology-Current and Future Directions) conducted on July 28, 2010, this 95-minute web briefing explored the use of PCP as a way to provide faster repairs using durable, longer-lasting pavements. (8) Webinar (Modular Pavement Technology): a 1.5-hour webinar covering the results of SHRP 2 R05, including a review of available PCP systems, a summary of PCP applications, guidelines for design, fabrication, installation, and selection of PCP systems, and tools for cost/benefit assessment.
Product Status	(1) Final Report (*Precast Concrete Pavement Technology*, SHRP 2 Report S2-R05-RR-1). Available online at www.trb.org/Main/Blurbs/167788.aspx. (2) Design Guidelines (Chapters 4-8 of Final Report). Available online at www.trb.org/Main/Blurbs/167788.aspx. (3) Panel Fabrication Guidelines (Chapter 9 of Final Report). Available online at www.trb.org/Main/Blurbs/167788.aspx. (4) Panel Installation Guidelines (Chapters 10-12 of Final Report). Available online at www.trb.org/Main/Blurbs/167788.aspx. (5) PCP System Decision Process (Chapter 15 of the Final Report). Available online at www.trb.org/Main/Blurbs/167788.aspx. (6) Model Specifications (*Model Specifications for Precast Concrete Pavement Systems*). Available online at www.trb.org/Main/Blurbs/167788.aspx. (7) Webinar (Precast Pavement Technology-Current and Future Directions). Summary available online at www.trb.org/Pavements/Blurbs/163684.aspx. (8) Webinar (Modular Pavement Technology). Planned for 9/24/13. Registration at www.trb.org/StrategicHighwayResearchProgram2SHRP2/Blurbs/169376.aspx.

Target Audience	• Highway Agency
	  ➢ Highway administrators.
	  ➢ Engineering staff (pavement design, construction, materials).
	• Other Stakeholders: Contractors, precast manufacturers, industry trade associations, consultants (engineering and testing), academia.

Pertinent Applications in the Highway Life	• Program Development: Planning, scoping, programming.

Cycle (Impacted Project Phases)	• Project Development: Engineering and safety studies, design, PS&E. • Contracting and Construction: Bidding, preconstruction, construction. • Management, Maintenance, and Operations: Asset management, system maintenance and preservation.
Pertinent Technical Areas	• Pavement management. • Project planning/programming. • PCP project and system-type selection. ➢ Pavement design (PCP system) (preservation/rehab design per intermittent/localized full-depth repairs or full panel replacement applications) (rehab/reconstruction design per continuous applications). • PCP panel fabrication. • PCP panel installation. • PCP maintenance, repair, and rehabilitation.

Implementations	• Implementations Performed as part of R05 Project
	  ➢ Project Level: 2011 demonstration project on I-90/Beverly Road ramp (narrow-mouth slots). (Field testing of 14 previously installed, in-service PCP system projects in 2009 and 2010).
	  ➢ Program Level: Workshop in April 2013. Webinar in September 2013. (Recommendations provided in report include forming a PCP expert task group (ETG), giving presentations at meetings, developing NHI training materials, organizing and conducting workshops and a national conference, developing a video).
	• Post R05 Project Implementations
	  ➢ Project Level: The Illinois Tollway has used PCP for intermittent full-depth repair for several years. One of its projects (I-90/Beverly Road ramp, 2011) was demonstrated and highlighted in R05, and some of the technology developed in R05 may have been incorporated by the Tollway and used in subsequent PCP projects, such as I-294 Tri-State Tollway in 2012 (20 mi of intermittent PCP and CIP repairs) and 2013 plans for I-55/I-294 ramp, I-294/I-80 ramp, I-88 at Highland Ave, and I-88 at Spring Road.
	  ➢ Program Level: None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Concrete pavement on a high-volume roadway with heavy trucks has been in service a few years and is starting to develop localized slab failures; lane closures to repair the slabs need to be minimal. Need to determine if the pavement is a suitable candidate for PCP and, if so, what particular system type would be most appropriate. • Existing pavement at a toll plaza on a high-volume roadway is greatly deteriorated and in need of reconstruction, especially in the manual toll lanes. A continuous PCP application has been determined to be the preferred alternative. Need to develop the design details and specifications for the PCP system. <u>Project Characteristics</u> • Project Type: Greenfield, Reconstruction, Rehabilitation, Preservation/Maintenance • Asset Type/Renewal Product Category: Pavement • Geographic Location: Any setting; Any climate • Geometrics: Any • Conflicting Features: Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any speed; High-volume; Any vehicle composition • Highway System: Interstates/freeways, other primary routes • Functional Class: Interstates, freeways/expressways, other principal arterials
Administrative/Program Level Implementation Paths (Ways that an	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Existing agency practice of using CIP concrete repair throughout network is creating user cost

upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	issues in urban areas. Need to investigate if PCP system technology would be a viable alternative to current practice. • PCP system technology has been tried by an agency on a couple projects and exhibited good success; greater use is desired. Need to develop agency standards regarding applications, design details, and fabrication/installation testing and acceptance.
Barriers/Challenges and Ways to Overcome Them	• Resistance to change within the agency regarding practices of slab repair/replacement and/or design and construction of small-area roads. Educate and demonstrate PCP success in other places, gain buy-in by soliciting input on situations within the agency network where the technology would have the greatest potential for success, establish trial projects that can help validate the technology. • Resistance from PCC paving industry: Same as above, but also provide justification (cost-effectiveness, user cost and other considerations) for use in certain circumstances. • Lack of locally qualified precast manufacturers and/or panel installation contractors. Engage PCP industry in market potential evaluation.
Project Key Words	Precast concrete pavement (PCP), prestressed concrete pavement, accelerated construction, design, construction, maintenance, rehabilitation, feasibility, long-term performance, decision criteria, model specification, implementation.

Project Cost: $1,000,000

Expanded Summary for Renewal Project R06 (*A Plan for Developing High-Speed, Nondestructive Testing Procedures for both Design Evaluation and Construction Inspection*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	Texas Transportation Institute (TTI): Andrew Wimsatt
Project Status and Time Frame	Completed March 2007 through July 2008
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Pavements • Structures (bridges) • Structures (tunnels) • Earthworks • Retaining walls
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Limited or reduced traffic disruption on existing facilities during preliminary engineering investigations. ➢ More rapid and reliable information on as-built conditions. ➢ Facilitated/more timely reopening of roadways and structures during reconstruction.
Project Objectives	• To review existing and emerging NDT technologies, evaluate the existing inspection requirements, and develop a research and development (R&D) plan to address those requirements. The R&D plan was subsequently used by the SHRP 2 Technical Coordinating Committee for Renewal to program additional funds concerning NDT for design evaluation and construction inspection of renewal projects.
Summary of Findings	The R06 study emphasized the need for in situ testing technologies/techniques that provide approximately 100 percent coverage of infrastructure and that can produce results in real time or at least within 48 hours. Key findings of the research included the following: • Based on survey responses from 21 state highway agencies (SHAs), NDT technologies/techniques are used to varying degrees for a variety of purposes. Among the more common applications are falling weight deflectometer (FWD) testing for pavement structural response, inertial profiling and profilograph testing for pavement smoothness assessment, nuclear density testing for pavement and earthwork compaction, crosshole sonic logging for drill shaft integrity testing, ultrasonic testing (UT) and magnetic particle testing for bridge components, rebound hammer testing for hardened concrete, and ground-penetrating radar (GPR) for infrastructure assets. • Successful implementation of any NDT technology involves upper-management support within the SHAs, continuous communication between NDT developers and users, and extensive training and technology transfer. SHAs that are involved in implementing NDT technologies had at least one employee dedicated to the technology or technologies. • In many instances, NDT implementation is more challenging than the original development of the technology. Implementation may require a different set of skills than the science and engineering required to develop and prototype equipment. Implementation involves working within organizations, establishing specifications, providing training, setting goals, documenting benefits, and establishing good overall communication channels within the agency and externally with contractors and trade organizations. These considerations must be addressed effectively if any NDT is to be implemented successfully.
Product Description	(1) Final Report (*A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection*, SHRP 2 Report S2-R06-RW). Documents the entire

	research effort, which included a literature review on NDT applications, a questionnaire survey on SHA practices, discussions with NDT experts, and vetting through an international symposium on NDT. Presents the study results and recommendations, which included identification of existing and emerging NDT technologies, identification of 29 specific areas of need for NDT (in bridges, pavements, tunnels, earthworks, and retaining walls), and recommendations for funding additional SHRP 2 research to address the following priority needs: • Automated methods of accurately profiling bridges. • Changes in profiles of tunnel linings over time. • Identification of bridge deck deterioration, including its cause. • Continuous deflection device at the highest possible speed for pavements. • New NDT quality assurance tools for ensuring quality construction. • Measurement of interlayer bonding between hot-mix asphalt (HMA) layers for pavements. The final report also includes research problem statements for a variety of specific needs designated as Priority 1.
Product Status	(1) Final Report (*A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection*, SHRP 2 Report S2-R06-RW). Available online at http://www.trb.org/Publications/Blurbs/162261.aspx.

Target Audience	• Highway Agency
	  ➢ Design engineers.
	  ➢ Construction engineers.
	  ➢ Asset management engineers.
	• Other Stakeholders: Consultants, equipment vendors, contractors

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Design: Evaluation of strength and/or integrity of existing infrastructure assets (bridges, pavements, tunnels, etc.). • Contracting and Construction: Construction inspection and quality control (QC)/quality assurance (QA) testing. • Asset Management: Asset performance monitoring and management.
Pertinent Technical Areas	• Pavement construction quality testing. • Bridge construction quality testing. • Roadway features quality testing (paint striping, paint and epoxy compounds on miscellaneous steel structures, concrete for miscellaneous structures, etc.). • Pavement evaluation/testing. • Bridge evaluation/testing. • Tunnel evaluation/testing. • Pavement maintenance. • Bridge maintenance. • Asset management.

Implementations	• Implementations Performed as part of R06 Project
	  ➢ Project Level: None.
	  ➢ Program Level: None.
	• Post R06 Project Implementations: This project spawned seven follow-on studies (R06A through R06G).

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the	<u>Problems/Issues/Constraints; Corresponding Needs</u> • Not applicable. The project identified additional research needed in the area of NDT. <u>Project Characteristics</u> • Project Type: Reconstruction, Rehabilitation, Maintenance/Preservation. • Asset Type/Renewal Product Category: Pavements, Bridges and Other Structures, General Roadway. • Geographic Location (Setting and Climate): Any setting; Any climate.

product(s) as part of an actual highway project)	• Geometrics: Any. • Conflicting Features: Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any. • Highway System: Any. • Functional Class: Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints; Corresponding Needs • Not applicable. The project identified additional research needed in the area of NDT.
Barriers/Challenges and Ways to Overcome Them	• Not applicable. The project identified additional research needed in the area of NDT.
Project Key Words	Nondestructive testing (NDT), falling weight deflectometer (FWD), rolling weight deflectometer (RWD), ground-penetrating radar (GPR), nuclear density testing, high-speed inertial profilers, infrared testing, ultrasonic testing (UT), sonic echo/impulse response, spectral analysis of surface waves (SASW), pavements, bridges, tunnels, earthworks.

Project Cost: $350,000

Expanded Summary for Renewal Project R06A (*Nondestructive Testing to Identify Concrete Bridge Deck Deterioration*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	Rutgers University, Center for Advanced Infrastructure and Transportation (CAIT): Dr. Nenad Gucunski
Project Status and Time Frame	Ongoing: March 2009 through December 2014 (original work complete and the developed web tool is now being expanded to be a repository for all of R06 series projects)
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Structures (bridges)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Improved long-term deck assessment for lower repair/maintenance/replacement life-cycle costs. ➢ Improved maintenance and repair of concrete deck delaminations by NDT detection. ➢ Improved estimating of deck repair quantities for bids.
Project Objectives	• To identify and characterize rapid NDT technologies for concrete deck deterioration. • To evaluate the strengths and limitations of applicable NDT technologies from the perspective of speed, accuracy, precision, and ease of use. • To validate the promising technologies. • To recommend test procedures and protocols for the most effective application of the bridge deck NDT methods evaluated. • To develop a repository for practitioners.
Summary of Findings	• For each of the main deterioration types, there are technologies that have demonstrated fair to good ability of detection. However, there is not a single technology that has shown the capability to detect and characterize all deterioration types. • Four technologies were identified as having fair to good potential for delamination detection: impact echo, chain drag/hammer sounding, infrared thermography, and ground-penetrating radar (GPR). • Four technologies were identified as having fair to good potential for corrosion detection and/or characterization of corrosive environment: half-cell potential, electrical resistivity, galvanostatic pulse measurement, and GPR. • Only one technology—ultrasonic surface wave testing—was validated as a fair technology for characterization of vertical cracks. • Three technologies were identified as capable to detect and characterize concrete quality/deterioration: ultrasonic surface waves, impact echo, and GPR. • The overall value and ranking were to some extent influenced by the selected performance measures, and by the applied weights and significance factors in the grading process.
Product Description	(1) Online Library of Nondestructive Technologies for Infrastructure Systems (NDToolbox). Electronic repository (tool box) of NDT technologies for bridges, pavements, and tunnels, which can be incorporated into transportation agencies' inspection manuals and/or management systems. The repository includes documentation for test procedures, protocols, photos, sample data output, equipment features (cost, availability, specifications, etc.), advantages, and limitations. (2) Final Report (Nondestructive Testing to Identify Concrete Bridge Deck Deterioration, SHRP 2 Report S2-R06A-RR-1). Documents the entire research effort, including field validation testing of 10 NDT technologies on Route 15 bridge over I-66 in Haymarket, Virginia in fall 2010. The report catalogues each of the technologies in terms of descriptions, physical principles, applications, and limitations. Also, it includes suggestions on equipment modifications and/or future research needed to

	develop promising technologies that could meet any gaps found on the current technologies. (3) Equipment Validation Test Videos. Web-based videos of various NDT devices being field tested on Route 15/I-66 overpass bridge in Haymarket, Virginia. The devices include GPR (NDT Corporation, IDS of Italy, 3D-RADAR of Norway, Olson Engineering and IDS, Rutgers), half-cell potential (Rutgers), infrared thermography (FHWA, U. of Texas at El Paso), impact echo (Germann Instruments, U. of Illinois, NDT Corporation, Rutgers), galvanostatic pulse measurement (Olson Engineering), electrical resistivity (Rutgers), impact echo and ultrasonic surface waves (U. of Texas at Austin, Olson Engineering), impulse response (Germann Instruments), ultrasonic pulse echo (U. of Texas at El Paso), and ultrasonic surface waves/portable seismic pavement analyzer (PSPA) (Rutgers).
Product Status	(1) Online Library of Nondestructive Technologies for Infrastructure Systems (*NDToolbox*). Web tool developed originally for bridge deck assessment technologies, but expanded to be a repository for all of R06 series projects (categorized by bridges, pavements, and tunnels). Available online at www.ndtoolbox.org. (2) Final Report (*Nondestructive Testing to Identify Concrete Bridge Deck Deterioration*, SHRP 2 Report S2-R06A-RR-1). Available online at http://www.trb.org/Main/Blurbs/167278.aspx. (3) Equipment Validation Test Videos. Available online at www.trb.org/Main/Blurbs/167278.aspx or at: http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Video-FieldValidationTestingofNondestructiveTestingTechnologiesonaConcreteBridgeDeck_511.aspx.

Target Audience	• Highway Agency
	  ➢ Bridge maintenance/preservation engineers.
	  ➢ Bridge management engineers.
	  ➢ Bridge construction engineers and deck repair bid estimators.
	• Other Stakeholders—Consultants, contractors

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development: Scoping, scheduling, and budgeting. • Project Development: Plans, specifications, and estimates (PS&E). • Contracting and Construction: Project advertising, bidding, and award. • Management, Maintenance, and Operations: Asset performance monitoring and management, system maintenance and preservation, and improved asset performance/quality.
Pertinent Technical Areas	• Bridge evaluation/testing. • Bridge maintenance. • Bridge management.

Implementations	• Implementations Performed as part of R06A Project
	  ➢ Project Level: field validation testing of 10 different bridge deck NDT devices on Rt. 15/I-66 overpass bridge in Haymarket, Virginia in fall 2010.
	  ➢ Program Level: Videos of Haymarket, Virginia equipment validation testing produced and put online.
	• Post R06A Project Implementations: None?

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints; Corresponding Needs</u> • The deck on an interstate overpass bridge has begun to show signs of distress, including cracking, spalling, and staining; not sure what to do—Need to identify evaluation techniques/tools that can be used to pinpoint the exact problems and determine the degree and extent of the problems. <u>Project Characteristics</u> • Project Type: Rehabilitation, Maintenance/Preservation. • Asset Type/Renewal Product Category: Bridges. • Geographic Location (Setting and Climate): Any setting; any climate. • Geometrics: Any. • Conflicting Features: Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition): Any. • Highway System: Any.

	• Functional Class: Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints; Corresponding Needs • Current techniques/tools being used by the agency to detect and characterize distresses in concrete bridge decks are not considered effective/successful. Need toolbox information and video demonstrations covering the applications, principles of operation, and performance of NDT technologies for condition assessment and quality assurance of concrete bridge decks.
Barriers/Challenges and Ways to Overcome Them	• The various NDT devices have varying limitations in terms of ability to detect and characterize all of the common bridge deck distresses. Hence, the reliability of getting comprehensive information from one device is lacking. ➢ Need to identify situations where bridge deck distresses are consistently limited to one (or possibly two) specific types that can be reliably detected/characterize by a given device, and use that device for those situations.
Project Key Words	Bridges, concrete, decks, delamination, cracking, maintenance, nondestructive testing (NDT), ground-penetrating radar (GPR), corrosion, infrared, thermography, impact echo, spectral analysis of surface waves, half-cell, galvanostatic pulse, electrical resistivity.

Project Cost: $750,000

Expanded Summary for Renewal Project R06B (*Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	University of Connecticut—Dr. Maria Chrysochoou
Project Status and Time Frame	Active—February 2009 through April 2014 (original work complete and contract modification executed authorizing contractor to pilot and refine specifications through work with DOTs)
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Structures (bridges) • Pavements • Roadway Features (traffic markings)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Reduced construction inspection time, leading to reduced construction delay, shorter lane closures, and increased safety. ➢ Improved quality assessment of materials, leading to more durable and longer-lasting construction and reduced life-cycle costs.
Project Objectives	• To identify the most practical applications of portable spectroscopic equipment for a wide range of materials commonly used in transportation infrastructure. • To identify and evaluate practical hand-held, point-and-shoot equipment that will offer promise to state highway agencies (SHAs) in verifying basic chemical "fingerprint signatures" of transportation construction materials. Specific applications might include: ➢ Verification of chemical composition and presence of solvents/diluents in structural coatings and pavement markings. ➢ Verification of chemical composition and quality/uniformity of epoxy adhesives. ➢ Verification of presence of chemical admixtures in fresh/cured PCC mix. ➢ Verification of chemical composition and quality/uniformity of PCC curing compounds. ➢ Verification of type, class, and quantity of polymer in polymer-modified asphalt binders, emulsions, and mixtures. ➢ Verification of presence, type, and quantity of anti-strip agents in asphalt concrete. ➢ Verification of presence of reclaimed asphalt pavement (RAP) in hot-mix asphalt (HMA) and determination of RAP content in HMA. • To develop relatively simple spectroscopic testing procedures and protocols that inspectors and front-line personnel could use in the field to ensure quality construction.
Summary of Findings	The spectroscopic techniques evaluated in the laboratory included Fourier Transform Infrared (FTIR) spectroscopy, X-ray Florescence (XRF), Raman Spectroscopy (RS), Size-Exclusion Chromatography (SEC), Nuclear Magnetic Resonance (NMR), and X-Ray Diffraction (XRD). The materials list included epoxy coatings and adhesives, traffic paints, portland cement concrete (PCC) with chemical admixtures and curing compounds, and asphalt binders, emulsions, and mixes with polymer additives. The laboratory testing phase (Phase II) indicated that three methods were most promising for field application: FTIR, XRF, and RS. A compact FTIR spectrometer working in the Attenuated Total Reflectance (ATR) mode was the most successful device to fingerprint pure chemical compounds (i.e. epoxies, waterborne paints, polymers, and chemical admixtures) and to detect additives or contaminants in complex mixtures (i.e., PCC, asphalt binders, emulsions, and mixes). Portable XRF was determined to be suitable for QA/QC of paints and epoxies on the basis of their metal content (Ti or Zn). The main factor affecting the accuracy of the XRF method is the calibration method used for analysis, especially for lighter elements (P, S and Ca), as well as drying of the paint when exposed to

	the atmosphere. Finally, fingerprinting of paints, curing compounds and chemical admixtures to Portland Cement Concrete (PCC) was found to be feasible using a portable Raman analyzer developed by Real Time Analyzers Inc. (RTA), a member of the research team. Field tests under Phase III confirmed the applicability of most methods and produced results similar to the laboratory phase. Specifically, the compact ATR-FTIR spectrometer, hand-held XRF instrument, and RTA's Raman analyzer were employed successfully to analyze the composition of both simple and complex inorganic and organic compounds such as epoxy coatings and adhesives, concrete curing compounds, and waterborne traffic paints. Furthermore, ATR allowed for the identification of chemical admixtures in freshly mixed PCC samples and provided their concentrations when they were higher than 0.5 wt%. Verification of polymer presence in asphalt binders and emulsions was also possible using the ATR FT-IR spectrometer. While the identification of polymer in HMA presented a challenge, a fast binder extraction procedure in the field with using DCM solvent appeared to be a feasible alternative for the direct evaluation of polymer-modified HMA.

Product Description	Currently available products include:
	(1) Final Report (*Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials*, SHRP 2 Report S2-R06B-RR-1)—Documents the entire research effort and results, and includes several appendixes containing supporting information (testing protocols and procedures, literature review, survey results, workshop results, field verification results) and products (spectral library, provisional AASHTO standards, field operation manuals). A summary of the research performed by phase is as follows:
	
	• Phase I: Identification (through SHA surveys and a workshop with SHA and industry experts) of QA/QC needs for spectroscopic testing, determination of which spectroscopic techniques can address those needs, and development of appropriate feasibility criteria.
	• Phase II: Identification of most promising methods for field application through laboratory testing and confirmation (through SHA surveys) of the relevance of the recommended material/method combinations to the needs of material testing professionals.
	• Phase III: Verification of the feasibility of field QA/QC procedures for three chosen material/method combinations—ATR FTIR spectrometer (Bruker® ALPHA spectrometer with a single-reflection diamond ATR accessory), hand-held XRF instrument (Innov-X® Alpha™ XRF analyzer), and RTA's Raman analyzer (RTA Fourier Transform Raman spectrometer). Verification entailed field testing at eight locations of different material samples, including scraped dried (solid) paint and fresh (solid) paint on steel structures and on HMA pavements; dried (solid) and fresh (liquid) epoxy compounds on metal; fresh PCC paste and fresh admixture used in precast PCC slab castings; before (liquid) and after (dry) curing compound on precast wall block casting; fresh mix and extracted binder from polymer-modified HMA paving, Nova chip seal paving, and rubberized chip seal paving; and anti-strip agent. The field tests included:
	  ➢ Mansfield Depot, CT: Verification of chemical composition of epoxy coatings and adhesives (fresh and dried) on metal.
	  ➢ East Hartford, CT: Quantification of elemental composition of white and yellow traffic paint markings (on HMA pavement).
	  ➢ Buckland Street, Manchester, CT: Verification of presence and chemical composition of admixtures in PCC (pavement slabs).
	  ➢ Oldcastle Precast Plant, Avon, CT: Verification of presence of curing compound on PCC surface (wall block castings).
	  ➢ I-84 Eastbound, Middletown/Farmington, CT: Verification of polymer presence and quantification in polymer-modified HMA mix and polymer-modified emulsion tack coat (HMA paving).
	  ➢ Route 160, Rocky Hill, CT: Verification of polymer presence in polymer-modified emulsions (Novachip seal paving).
	  ➢ Route 89, Mansfield Center, CT: Verification of polymer presence in polymer-modified binders (rubberized chip seal paving).
	  ➢ Gateway Terminal, New Haven, CT: Verification of presence and chemical composition of

	antistripping agent (from tank and from antistripping-modified binder). (2) Proposed AASHTO Standards (Appendix C of Final Report)—Generic testing procedures were expanded to proposed AASHTO standard specifications as follows: • Standard Practice for Identification of Water Reducing, Accelerating, and Retarding Chemical Admixtures in Fresh Portland Cement Concrete by Attenuated Total Reflectance (ATR) Infrared Spectrometer. • Standard Method of Test for Determination of Titanium Content in Traffic Paints by Field-Portable X-Ray Fluorescence (XRF) Spectroscopy. (3) Field Operation Manuals (Appendix D of Final Report)—Targeted to SHA technical personnel responsible for spectroscopic testing using the field-portable ATR-FTIR and field-portable XRF instruments. The manuals will help the testing personnel to undertake correct steps during spectroscopic testing and will provide more concise instructions as opposed to typical generic manuals provided by the manufacturers. Anticipated, but not currently available products include: (4) Electronic Spectral Library—Library/database of spectra for pure materials, which can be used for the identification of those materials in the field.
Product Status	(1) Final Report (*Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials*, SHRP 2 Report S2-R06B-RR-1)—Available online at www.trb.org/Main/Blurbs/167279.aspx. (2) Proposed AASHTO Standards (Appendix C of Final Report)—Available online at www.trb.org/Main/Blurbs/167279.aspx. (3) Field Operation Manuals (Appendix D of Final Report)—Available online at www.trb.org/Main/Blurbs/167279.aspx. (4) Electronic Spectral Library—Expected to be made available as online application (Note: Final Report states that the electronic copy of the spectral library is located at www.trb.org/Main/Blurbs/167279.aspx, however, no such copy is currently available).

Target Audience	• Highway Agency
	  ➢ Materials engineers.
	  ➢ Construction engineers and technicians.
	• Other Stakeholders—Contractors, Testing Consultants

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Contracting and Construction—Construction QA/QC of new and/or existing materials used in transportation. • Management, Maintenance, and Operations—Asset performance monitoring and management, system maintenance and preservation.
Pertinent Technical Areas	• Pavement construction quality testing. • Bridge construction quality testing. • Roadway features quality testing (paint striping, paint and epoxy compounds on miscellaneous steel structures, concrete for miscellaneous structures, etc.).

Implementations	• Implementations Performed as part of R06B Project
	  ➢ Project Level—Validation Testing of different material/method combinations at eight different locations in CT (Mansfield Depot, East Hartford, Manchester, Avon, Middletown/Farmington, Rocky Hill, Mansfield Center, and New Haven).
	  ➢ Program Level—None.
	• Post R06B Project Implementations—None?

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level	Problems/Issues/Constraints—Corresponding Needs • A contractor on a highway project plans to use chemical admixtures to improve concrete mix workability and durability. However, lab testing to verify the presence and content of the admixtures will not be immediately available; not sure what to do—Need to identify an appropriate NDT device that can be used on-site to at least verify the presence of the admixtures.

manager can implement or further test the product(s) as part of an actual highway project)	Project Characteristics • Project Type—Reconstruction, Rehabilitation, Maintenance/Preservation. • Asset Type/Renewal Product Category—Pavements, Bridges and Other Structures, General Roadway. • Geographic Location (Setting and Climate)—Any setting; Any climate. • Geometrics—Any. • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • To streamline the construction process and reduce the burden placed on its testing labs, an agency is seeking to adopt NDT tools and standards that can be used in the field to ensure material quality—Need toolbox information covering the applications, principles of operation, and performance of appropriate NDT technologies, as well as accompanying testing standards.
Barriers/Challenges and Ways to Overcome Them	• ? ➢ ?
Project Key Words	X-ray Florescence (XRF), Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy (RS), epoxy coatings, adhesives, traffic paints, Portland cement, concrete chemical admixtures, curing compounds, asphalt binders, emulsions, polymer additives.

Project Cost: $399,792

Expanded Summary for Renewal Project R06C (*Using both Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	Texas Transportation Institute (Texas A&M University)—Tom Scullion
Project Status and Time Frame	Active—March 2009 through December 2013
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Pavements (Asphalt)

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Improved construction quality, longer pavement life, and reduced life-cycle costs due to more complete assessment of asphalt pavement quality parameters during paving.
	  ➢ Real-time identification of defects so construction operations can be modified to produce a more uniform, longer-lasting pavement.
	  ➢ Minimal disruption to traffic during testing/data collection process.
	• Saves Lives
	  ➢ Improved worker safety during testing/data collection process.

Project Objectives	• To demonstrate infrared (IR) and ground-penetrating radar (GPR) technologies as NDT techniques to assess hot-mix asphalt (HMA) or warm-mix asphalt (WMA) density uniformity and to minimize the risk of segregation problems, and to make recommendations for how these technologies can be incorporated into existing state highway agency (SHA) specifications for construction quality assurance (QA). The IR and GPR technologies under investigation should provide near 100 percent coverage of the constructed surface area.
Summary of Findings	• IR technology can be used during asphalt paving operations to identify localized cold spots (these are often impossible to adequately compact leading to high void areas which let moisture enter the pavement's lower layers, thereby accelerating the occurrence of pavement distress and shortening pavement life). This study demonstrated that the dielectric constant as measured by GPR is highly correlated to asphalt layer density. These measurements can be made both during and after compaction. To convert the measured dielectrics to density, a limited number of field cores are taken and tested in the laboratory. • Numerous IR techniques exist for collecting thermal profiles of HMA/WMA construction; the most promising techniques for full-coverage testing include process control IR cameras, IR linescanners, and IR sensor bars. Only the IR sensor bar system includes commercially available software for creating distance-based thermal profiles. • GPR systems are commercially available for collecting full-coverage uniformity data. However, the use of GPR in the U.S. is complicated by restrictions put on it by the Federal Communications Commission (FCC). Other limitations include the level of expertise required and the lack of data-processing automation. • The IR sensor bar system demonstrated in this study worked well, installing easily and providing real-time output for review. In terms of level of testing coverage and amount of operator attendance and effort required, the demonstrations showed that the IR bar system is clearly superior to the localized thermal profiling methods currently in some SHA test procedures. The thermal data correlated well with in-place mat density, and final air voids in the mat were found to be a function of both placement temperature and mix properties. The Pave-IR system demonstrated in this study

	is now commercially available. • The GPR systems demonstrated in this study performed well for data collection and generated full-coverage density maps of the constructed surface area. The two GPR systems used correlated well with each other and, after calibration to field cores, provided nearly identical results. • GPR has the advantage over IR in that it is directly correlated with the parameter of main interest to pavement engineers—mat density. Current work is aimed at developing a robust GPR system which can readily be implemented by SHA and paving contractors.
Product Description	Currently available products include: (1) Final Report (*Using Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers*, SHRP 2 Report S2-R06C-RR-1)—Documents the first two phases of the research project, including a literature review to identify the most promising IR (paver-mounted IR bar system by Moba Corporation) and GPR (GSSI's 2.2 GHz system, and TTI's 1 GHz system as a default) technologies for the HMA density application, the evaluation of equipment specifications and test procedures for developing field testing protocols, and the demonstration/showcasing of IR and GPR equipment at construction projects in each of four American Association of State Highway and Transportation Officials (AASHTO) regions, as follows. ➢ AASHTO Region 1, I-295 near Freeport, ME (Aug 2011)—Moba Pave-IR and hand-held spot radiometer used to collect thermal profile data on SuperPave SP-12.5 surface mix placed using material transfer device and paver. TTI's 1-GHz system and GSSI's 2.2-GHz system used for GPR data collection. ➢ AASHTO Region 2: Lake Underhill Drive near Orlando, FL (Jun 2010)—Moba Pave-IR and hand-held spot radiometer used to collect thermal profile data on SuperPave SP-12.5 surface mix placed using tarped bobtail trucks and paver. TTI's 1-GHz system and GSSI's 2.2-GHz system used for GPR data collection. ➢ AASHTO Region 3: TH 60 east of Worthington, MN (Sep 2010)—Moba Pave-IR used to collect thermal profile data on SuperPave SP-12.5 surface mix placed using windrow elevator equipment and paver. TTI's 1-GHz system and GSSI's 2.2-GHz system used for GPR data collection. ➢ AASHTO Region 4: US 190 near Woodville, TX (Sep 2009)—Moba Pave-IR and hand-held spot radiometer used to collect thermal profile data on stone matrix asphalt (SMA) surface mix using windrow elevator equipment and paver. TTI's 1-GHz system used for GPR data collection. The report also provides recommendations for helping expedite implementation of IR systems—activities such as additional demonstration projects, webinars and conference presentations, and site visits to SHAs to explain the technology and provide information on implementation options. Appendixes A-E of the report contain the following test/equipment specifications as reference/supporting information: ➢ Thermal camera testing method (Swedish National Road Administration Method for Defining Temperature Variation During Paving of Hot-Mix Asphalt). ➢ GPR equipment (GPR Hardware Specifications for Systems Used in TxDOT). ➢ GPR testing method (Finnish PANK Method for Air Void Content of Asphalt Pavement with GPR). ➢ Pave-IR thermal profile testing method (TxDOT Method TEX-244-F for Thermal Profile of Hot-Mix Asphalt). ➢ GPR testing method (Method for Detecting Segregation with GPR). (2) Research Article (*TTI Turns Up the Heat on Asphalt Cold Spots*, Texas Transportation Researcher) and accompanying Interview Video—Describes the use and benefits of Pave-IR and GPR technologies in HMA paving. (3) Equipment Demonstration Video—2-minute video that shows a demonstration of an infrared bar being used for quality control and measurement of new HMA layers during paving operations. Anticipated, but not currently available products include:

	(4) Model Specifications—Model quality control (QC) and/or quality assurance (QA) specifications for the Pave-IR and GPR technologies. (5) Pilot Studies—Two DOTs to pilot the model specifications, including Vermont which pilot-tested them in conjunction with FHWA's Every Day Counts initiative. (6) Training Material?
Product Status	(1) Final Report (*Using Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers*, SHRP 2 Report S2-R06C-RR-1)—Available online at www.trb.org/Main/Blurbs/167280.aspx. (2) Research Article (*TTI Turns Up the Heat on Asphalt Cold Spots*, Texas Transportation Researcher) and accompanying Interview Video—Available online at www.trb.org/Main/Blurbs/167280.aspx. (3) Equipment Demonstration Video—Available online at www.trb.org/Main/Blurbs/162606.aspx. (4) Model Specifications—Under development. Once completed, will be published as an addendum to Final Report. (5) Pilot Studies—Ongoing. Once completed, results will be published as an addendum to Final Report. (6) Training Material?

Target Audience	• Highway Agency
	  ➢ Materials engineers (HMA).
	  ➢ Construction engineers and technicians.
	• Other Stakeholders—HMA paving contractors.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Contracting and Construction—Construction QA/QC of new HMA or WMA pavements. • Management, Maintenance, and Operations—Asset performance monitoring and management, system maintenance and preservation.
Pertinent Technical Areas	• Pavement construction quality testing. • Specifications writing.

Implementations	• Implementations Performed as part of R06C Project
	  ➢ Project Level—4 Field Demonstrations of GPR and IR technologies conducted in AASHTO Region 1 (ME), Region 2 (FL), Region 3 (MN), and Region 4 (TX) as part of HMA Overlay Projects between Sep 2009 and Aug 2011. Model specification pilot testing in Vermont. 2 additional Field Demonstrations planned for Spring 2013 in VA and PA.
	  ➢ Program Level—None???
	• Post R06C Project Implementations—Several states are considering drafting or have already drafted specs that incorporate the IR technology (TX being the leader).

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • A stretch of highway scheduled to receive a structural HMA overlay is located in an area in which several factors (e.g., long distance from plant, many intersections, etc.) will make it difficult to achieve uniformity in mix placement—Need to identify an appropriate NDT device for measuring and monitoring the quality of the paving mat. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation, Maintenance/Preservation. • Asset Type/Renewal Product Category—Pavements. • Geographic Location (Setting and Climate)—Any setting; Any climate. • Geometrics—Any. • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program	<u>Problems/Issues/Constraints—Corresponding Needs</u>

Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	• An agency has had recurring problems with HMA deterioration stemming from segregation during construction—Need toolbox information covering the applications, principles of operation, and performance of appropriate NDT technologies for HMA construction quality, as well as accompanying model specifications.
Barriers/Challenges and Ways to Overcome Them	• The various NDT devices have varying limitations in terms of ability to detect and characterize all of the common bridge deck distresses. Hence, the reliability of getting comprehensive information from one device is lacking. ➢ Need to identify situations where bridge deck distresses are consistently limited to one (or possibly two) specific types that can be reliably detected/characterize by a given device, and use that device for those situations.
Project Key Words	Asphalt, hot-mix asphalt (HMA), warm-mix asphalt (WMA), segregation, quality assurance (QA), quality control (QC), infrared (IR), infrared thermography, infrared imaging, temperature, density, uniformity, ground-penetrating radar (GPR), air voids, cores, dielectric, correlation.

Project Cost: $250,000

Expanded Summary for Renewal Project R06D (*Nondestructive Testing to Identify Delamination Between HMA Layers*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	Auburn University, National Center for Asphalt Technology (NCAT)—Dr. Michael Heitzman
Project Status and Time Frame	Ongoing—February 2009 through March 2013 (expected completion) (original work complete and contract modification executed for pilot projects)
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Pavements

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Improved long-term pavement performance and reduced pavement life-cycle costs.
	  ➢ Improved maintenance and repair of hot-mix asphalt (HMA) delaminations by NDT detection.
	• Saves Lives
	  ➢ Safer and smoother roads for traveling public.

Project Objectives	• To identify and develop nondestructive testing (NDT) techniques that are capable of identifying and determining the extent and depth of delaminations and discontinuities in HMA pavements. • To determine key indicators that may be used to identify potential areas of delamination, including lack of bond, stripping, and other causes. The NDT techniques developed under this project should provide rapid results with near 100 percent continuous coverage of the pavement area.
Summary of Findings	Various NDT methods were initially demonstrated by companies with promising NDT technologies for detection of HMA delaminations (i.e., debonding between pavement lifts caused by loss of bond and/or stripping) on an "initial blind" basis on simulated delaminations constructed in laboratory HMA slabs and on an HMA test section at the NCAT test track. After the NDT participants predicted the locations and depths of HMA delamination conditions ranging from shallow (2 in.) to deeper (5 in.), comparisons were made between the predicted conditions and the actual as-built conditions. Following refinements and additional testing, two of the most promising NDT technologies were selected for further development and evaluation—(1) low-speed (1 to 2 mph) mechanical wave impact echo (IE)/spectral analysis of surface waves (SASW) scanning by Olson Engineering, Inc. and (2) higher-speed (up to 40 mph) ground-penetrating radar (GPR) by 3D Radar. Full-scale pilot test programs were conducted on actual HMA pavements with a few cooperating DOTs by the research team and both NDT companies. Current findings (research is ongoing) include the following: • GPR, SASW, and IE all demonstrated the ability to detect delamination to varying degrees and depths. • Although it is likely that the results of this project will not lend themselves to full and immediate implementation of the NDT techniques developed, it should be noted that 3D-Radar technology is commercially available and can be implemented (the cost of the technology will determine the pace of implementation). • Although both NDT technologies were demonstrated successfully (software development is the key to easier data analysis), further research and development (R&D), as well as validation testing, will be required after the completion of this project. • Technology commercialization will be needed, along with the possible development of standard testing procedures (Note: because NDT settings will need to change with varying pavement

	conditions, standard procedures may not be viable).
Product Description	Currently available products include: (1) Final Report (*Nondestructive Testing to Identify Delaminations Between HMA Layers*)—Five-volume report covering the first two phases of the study. Volumes II through V are web-only. ➢ Volume I (*Summary*, SHRP 2 Report S2-R06D-RR-1)—Provides a comprehensive summary of the study, including the research approach, the controlled and uncontrolled evaluations of the NDT equipment/techniques, and the conclusions and recommendations. Appendices A, B, and C include Technical Briefs summarizing the technologies/techniques (GPR by 3D-Radar, SASW by Olson Engineering, and mechanical wave IE by Olson Engineering) developed in the study, including test procedures, protocols, photos, sample data output, equipment features (cost, availability, specifications, etc.), advantages, and limitations. ➢ Volume II (*Theoretical Models*, SHRP 2 Report S2-R06D-RW-2)—Describes the theoretical models used in the development of GPR, infrared thermography, and mechanical wave (IE, impulse response, and ultrasonic surface waves) techniques capable of detecting and quantifying delaminations in HMA pavements. ➢ Volume III (*Controlled Evaluation Reports*, SHRP 2 Report S2-R06D-RW-3)—Describes the controlled evaluations performed on the NDT equipment, both in the lab and at the NCAT test track. The equipment evaluated included GPR, infrared thermography, mechanical wave (portable seismic pavement analyzer [PSPA], scanning IE, multiple impact surface waves), lightweight deflectometer, and falling weight deflectometer [FWD]). ➢ Volume IV (*Uncontrolled Evaluation Reports*, SHRP 2 Report S2-R06D-RW-4)—Describes the Phase II uncontrolled evaluations of the GPR (by 3-D Radar) and improved IE/SASW (by Olson Engineering) equipment undertaken on HMA overlaid pavements on I-75 (NB/SB, MP 409-413) near Gainesville, Florida and on US 400 (WB, MP 412-425.5) near Pittsburgh, Kansas in winter 2010/spring 2011. ➢ Volume V (*Field Core Verification*, SHRP 2 Report S2-R06D-RW-5)—Describes the field core verification results for the GPR and IE/SASW equipment at the Gainesville, Florida and Pittsburgh, Kansas test sites. Anticipated, but not currently available products include: (2) Guidelines Document ("Guidelines for Using NDT Methods to Identify Delamination in Asphalt Pavements")—Guidance in conducting GPR and IE/SASW testing.
Product Status	(1) Final Report (*Nondestructive Testing to Identify Delaminations Between HMA Layers*: Volumes I-VI, SHRP 2 Reports S2-R06D-RR-1, S2-R06D-RW-2, S2-R06D-RW-3, S2-R06D-RW-4, and S2-R06D-RW-5)—Available online at www.trb.org/Main/Blurbs/167281.aspx. (2) Guidelines Document ("Guidelines for Using NDT Methods to Identify Delamination in Asphalt Pavements")—Under development. Once completed, will be published as an addendum to the Final Report.
Target Audience	• Highway Agency ➢ Pavement maintenance/preservation engineers. ➢ Pavement designers. ➢ Pavement management engineers. • Other Stakeholders—Pavement management consultants.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Design. • Management, Maintenance, and Operations—Asset performance monitoring and management, system maintenance and preservation, and system operations.
Pertinent Technical Areas	•

Implementations	• Implementations Performed as part of R06D Project
	  ➢ Project Level
	  ▪ Two Uncontrolled Field Evaluations of improved versions of GPR and IE/SASW NDT equipment for detecting HMA layer delaminations (FL I-75 and KS US-400 in winter 2010/spring 2011).
	  ➢ Program Level—None.
	• Post R06D Project Implementations—None (from R06D Team Product Summary—Project results will not lend themselves to full and immediate implementation of the two NDT techniques developed; further R&D and validation testing is needed.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints—Corresponding Needs • Not applicable currently. Project results do not lend themselves to full and immediate implementation of the two NDT techniques developed; further R&D and validation testing is needed.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • Not applicable currently. Project results do not lend themselves to full and immediate implementation of the two NDT techniques developed; further R&D and validation testing is needed.
Barriers/Challenges and Ways to Overcome Them	• Not applicable currently. Project results do not lend themselves to full and immediate implementation of the two NDT techniques developed; further R&D and validation testing is needed.
Project Key Words	Roadway, pavement, hot-mix asphalt (HMA), delamination, stripping, preservation, maintenance, nondestructive testing (NDT), ground-penetrating radar (GPR), impact echo (IE), spectral analysis of surface waves (SASW).

Project Cost: $799,937

Expanded Summary for Renewal Project R06E (*Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	The Transtec Group—Dr. Robert O. Rasmussen
Project Status and Time Frame	Completed—February 2009 through November 2011
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Pavements (Concrete)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Improved long-term pavement performance and reduced pavement life-cycle maintenance and repair costs. ➢ Improved QC of new pavements by paving contractors. ➢ Reduced vehicle operating costs. • Saves Lives ➢ Safer and smoother roads for traveling public.
Project Objectives	• To enable real-time control of concrete pavement smoothness during construction by providing proven technologies for measuring smoothness in real time and model specifications and guidelines for transportation agencies. Specifically, to: ➢ Evaluate and demonstrate real-time smoothness measuring technologies for concrete paving. ➢ Develop both model specifications and construction guidance that are capable of working with the identified technology in such a way as to further rapid implementation by State Highway Agencies (SHAs). (Note: Real-time smoothness refers to measuring and evaluating the concrete pavement surface profile during construction, somewhere along the paving train while the concrete surface is still wet (plastic). These measurements are then used to check for objectionable profile characteristics; things that are known to happen in projects that can affect pavement smoothness. With this information, paving operations can be adjusted on the fly. Ideally, deviations are detected in real time and corrections made such that the final hardened concrete surface can avoid being ground to achieve the smoothness requirements.)
Summary of Findings	This project evaluated and demonstrated both emerging and proven technologies. Seven potential measurement devices were identified and studied, of which two were found to warrant subsequent evaluation and demonstration—the ultrasonic GOMACO Smoothness Indicator (GSI) (a non-contact sensing system that can be paver-mounted or equipped on a separate stand-alone modular frame that straddles the pavement width) and the laser-based Ames Engineering Real Time Profiler (RTP) (a non-contact sensing system that is paver-mounted). The devices were evaluated as part of concrete paving projects in Arkansas, Georgia, Michigan, New York, and Texas, and observations were made about the potential of these devices, and the technology as a whole, to improve the quality of pavement construction through improved smoothness. From this project, model specifications and construction guidance were developed to expedite the implementation of these technologies. Both real-time profilers demonstrated adequate performance as tools for construction quality control (QC). However, the technologies were not found to be suitable for quality assurance (QA) devices and/or for calculation of pay adjustments for smoothness. Hence, it was recommended that the technologies not be a replacement for conventional profiling for QA (acceptance) or for better practices for constructing smoother pavements. Furthermore, it is envisioned that the real value of the

	work conducted under this effort consists of providing (a) validation of innovative tools for evaluating concrete pavement smoothness in real time, (b) tools that can be used for quality control (QC), (c) tools that can reduce must-grinds and thus reduce project delays and claims, and (d) improved understanding about what construction artifacts can affect smoothness (e.g., stringline effects, concrete loading/delivery effects, dowel baskets and transverse reinforcement effects, finishing effects, localized roughness). Finally, recommendations were presented to continue implementation of these technologies (e.g., training and outreach materials), along with development of a "real-time smoothness knowledge-based system" to enhance the current technology software capabilities.
Product Description	(1) Final Report (*Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction*, SHRP 2 Report S2-R06E-RR-1)—Documents the research activities and presents the findings and recommendations of the work carried out in three distinct but connected phases: • Phase I: Identified and reviewed all potential real-time smoothness measuring technologies, including GOMACO GSI, Ames RTP, Texas DOT Sliding Profiler, Surface Systems & Instruments (SSI) Dynamic Surface Profiler, APR Consultants Auto Rod & Level, and Virginia Tech Vehicle Terrain Measurement System (VTMS). Subsequently recommended three for further evaluation; only two of which were available to participate in Phases II and II of the study—GOMACO GSI and Ames RTP. • Phase II Field Evaluation: Conducted thorough field evaluation of GOMACO GSI and Ames RTP, by working with the two technology vendors, an experienced paving contractor, and the host agency (Georgia DOT). The field evaluation took place in May 2010 on I-75 near Adel, Georgia. The project consisted of widening and reconstructing 9.85 mi of roadway using 12-in. continuously reinforced concrete pavement (CRCP). • Phase III Field Technology Demonstrations: Corroboration of Phase II findings through a series of additional field demonstrations of the GOMACO GSI and Ames RTP. Demonstration locations and dates included: ➢ Vilonia Bypass near Vilonia, Arkansas (May 2011, GSI only)—10.142 mi of new construction with JPC. ➢ I-94 in Jackson County, Michigan (July 2011, GSI and RTP)—multi-miles of reconstruction with JPC. ➢ I-90 Thruway interchange 39-40 near Weedsport, New York (August 2011, RTP only)—15.2 mi of reconstruction with jointed reinforced concrete pavement (JPCP). ➢ SH 114/SH 121 near Dallas/Ft. Worth, Texas (June 2011, RTP only)—8.4 mi of widening and reconstruction with CRC. The report includes a generic set of better practices to improve smoothness and a draft model specification for conducting real-time smoothness measurements on PCC pavement, as described below. (2) Construction Guidelines (Chapter 3 of Final Report)—A generic set of better practices to improve smoothness in real time. The practices are presented in table form in terms of objectionable profile characteristics and better practice guidelines to prevent them. The guidelines are intended to facilitate evaluation and implementation of real-time smoothness measuring technologies. (3) Model Specification (Appendix H of Final Report)—The model specification, entitled "Recommended Practice for Real-Time Smoothness Measurements on Concrete Pavements During Construction," is intended to facilitate evaluation and implementation of real-time smoothness measuring technologies. It is not intended as a replacement for existing smoothness testing and acceptance requirements, but rather as a supplement to QC testing and process control. Its most logical application is as part of a quality management plan (QMP).
Product Status	(1) Final Report (*Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction*, SHRP 2 Report S2-R06E-RR-1)—Available online at www.trb.org/Main/Blurbs/167282.aspx. (2) Construction Guidelines (Chapter 3 of Final Report)—Available online at

	www.trb.org/Main/Blurbs/167282.aspx. (3) Model Specification (Appendix H of Final Report)—Available online at www.trb.org/Main/Blurbs/167282.aspx.

Target Audience	• Highway Agency
	  ➢ Pavements and materials engineers.
	  ➢ PS&E engineers.
	  ➢ Construction engineers and technicians.
	• Other Stakeholders—Concrete paving contractors, paving equipment vendors.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Contracting and Construction—Construction specifications and QC testing • Management, Maintenance, and Operations—System maintenance and preservation (concrete overlays)
Pertinent Technical Areas	• Pavement Specifications (testing equipment and construction smoothness testing/monitoring) • Pavement Construction Smoothness Testing and Monitoring (QC and process control)

Implementations	• Implementations Performed as part of R06E Project
	  ➢ Project Level
	  ▪ One (1) Field Evaluation of GOMACO GSI and Ames RTP in May 2010 on I-75 in Adel, Georgia.
	  ▪ Four (4) subsequent Field Demonstrations of GOMACO GSI and Ames RTP performed between May and August 2011 on Vilonia Bypass near Vilonia, Arkansas, I-94 in Jackson County, Michigan, I-90 Thruway near Weedsport, New York, and SH 114/SH 121 near Dallas/Ft. Worth, Texas.
	  ➢ Program Level—None.
	• Post R06E Project Implementations
	  ➢ Project Level—None.
	  ➢ Program Level—None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Existing 6-mi long, 4-lane interstate highway with moderate traffic has been determined to be in need of reconstruction, and the pavement type selected for the reconstruction is 9-in. doweled jointed plain concrete (JPC). Recent PCC paving projects have experienced some difficulties in attaining the required levels of smoothness—Need a process put in place that gives more timely and intuitive information about the as-constructed smoothness in order to avoid difficulties in achieving smoothness. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation (PCC overlay) • Asset Type/Renewal Product Category—Pavements • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—None • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training,	<u>Problems/Issues/Constraints—Corresponding Needs</u> • The agency's pavement smoothness specification has been called into question because, while contractors are generally achieving the required smoothness level, the constructed pavements seem to ride rough—Need to evaluate the adequacy of the specification, particularly the testing and reporting procedure. • PCC paving contractors are experiencing problems constructing pavements that meet agency specifications without having to perform substantial must-grinds—Need to implement new technologies that can improve contractor process control.

policy development meetings, procedural manual updates])	
Barriers/Challenges and Ways to Overcome Them	• Lack of knowledge of more complex smoothness testing equipment, both on the part of agency field personnel and contractor personnel. ➢ Need to provide training on the equipment through workshops and/or demonstrations. • Resistance from agency field personnel and/or contractor personnel due to lack of resources/manpower and/or perception of the technology as being a low priority. ➢ Need to get buy-in from upper management (through promotional events and materials) as to the importance of the technology in ensuring long-lasting smooth pavements.
Project Key Words	Roadway, pavement, concrete, paving, smoothness, international roughness index (IRI), profiling, quality control (QC), quality assurance (QA), testing.

Project Cost: $550,000

Expanded Summary for Renewal Project R06F
(*Development of Continuous Deflection Device*)

SHRP 2 Program Officer	Chuck Taylor
Contractor and PI Info	Virginia Tech Transportation Institute (Virginia Tech University)—Dr. Gerardo Flintsch
Project Status and Time Frame	Complete—April 2009 through May 2012
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Pavements

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Improved and more cost-effective pavement management through network-level pavement structural condition evaluation.
	  ➢ Minimal disruption to traffic.
	• Saves Lives
	  ➢ Improved worker and highway user safety.

Project Objectives	• To critically assess (1) the potential of existing continuous deflection devices as a practical and cost-effective tool for use in the development of optimum pavement rehabilitation strategies on rapid renewal projects, and (2) their capability for screening structural deficient sections and scoping their needs at the network level. The assessment examined:
	  ➢ The potential demand by and value to public agencies.
	  ➢ The technical capabilities (including accuracy and repeatability of test results and ability to provide meaningful data), limitations (field applications, equipment configuration, operating and safety characteristics), and other impediments to implementation of existing devices.
	  ➢ Further development of the technology including both hardware and software needed to make these tools practical for use.
	• Key research questions include the following:
	  ➢ Are the selected devices capable of providing the quality information needed to support the main pavement management business functions identified by potential users?
	  ➢ Can the devices be used for screening pavements at the network level and thus, identify weak (structurally deficient) sections, which can then be further investigated at the project-level (e.g., using falling weight deflectometer [FWD])?
	  ➢ Can the structural response information collected by the devices be used to differentiate sections that may be good candidates for preservation (good structural capacity) from those that would likely require a heavier treatment (showing structural deterioration/deficiencies)?

Summary of Findings	• There are many continuous deflection-measurement technologies available, including (a) laser-based devices that measure deflection below an actual moving truck load, (b) vibratory load devices, and (c) image analysis methods. Two devices were selected for detailed evaluation in this study, based on their potential for traffic speed measurements and potential application at a network level: the Rolling Weight Deflectometer (RWD) and the Traffic Speed Deflectometer (TSD). • The TSD can (a) provide adequate repeatability for network-level data collection, (b) collect deflection measurements and/or indices that are comparable to those collected by traditional measurement devices such as the FWD, and (c) provide measurements that can be used for supporting some of the most critical network-level applications identified by potential users. • Although the information collected in the study suggests that the RWD may be able to provide the same type of capabilities, this has not been confirmed because of the unavailability of the equipment for the detailed evaluation in the second phase of the project. Additional tests are

	needed to fully assess the repeatability and reproducibility of the RWD. • Continuous deflection-measurement technology is just now maturing and future research should be conducted to further assess the measurement capabilities of the devices, the usefulness of the collected data, and how to best interpret the measurements from devices.
Product Description	(1) Final Report (*Assessment of Continuous Pavement Deflection Measuring Technologies*, SHRP 2 Report S2-R06F-RW-1)—Summarizes the various activities completed during the research, including (a) a review of literature and case studies for assessing technology capabilities and operational limitations, (b) a survey of and follow-up interviews with state highway agencies (SHAs) to identify their needs for continuous deflection measurement, and (c) a detailed evaluation of candidate devices using actual data collected in the field, and (d) field testing/verification of the TSD at eight sites/sections in the United Kingdom (designated F1, F3, F5, and F6 for flexible pavements; C1, C2, and C3 for composite pavements; and R2 and R3 for rigid pavements) (Note: a similar evaluation of the RWD in the United States was planned but was not possible due to unavailability of the equipment). Presents the study findings, conclusions, and recommendations for implementation, and contains various implementation materials, such as a catalogue of existing technologies, case studies, and a dissemination and implementation plan, as described below. (2) Catalogue of Existing Technologies (Chapter 3 of Final Report)—Describes existing technologies and equipment for continuously measuring pavement deflections or equivalent, their development/ implementation status, capabilities and limitations, type and quality of data collected, and how this approach compares to traditional FWD testing and data. (3) Case Studies/Example Applications (Chapter 4 of Final Report)—Illustrations of the potential application of the technology for supporting various pavement management decision-making processes. Applications include using circular binary segmentation to identify uniform sections (UK sites F1 and C2 used), computing structural health indices (UK sites F1, F3, and F5 used), identifying weak sections (UK site F1 used), and discriminating between sections with good and poor structural capacity (all 8 UK sites used). (4) Dissemination and Implementation Plan (Chapter 5 of Final Report)—Recommendations for moving the technology forward. (5) Research Problem Statements (Appendix A of Final Report)—Contains more complete descriptions of four follow-on research projects recommended to facilitate the implementation of the technology. These include: ➢ Side-by-Side Comparison of Continuous Deflection Measuring Devices. ➢ Integrating Continuous Deflection Measurements into Pavement Management Business Functions. ➢ Pavement Structural Assessment Methods Using Continuous Deflection Measurements. ➢ Evaluation of the Absolute Accuracy of Continuous Deflection Measuring Devices on Instrumented Road Sections.
Product Status	(1) Final Report (*Assessment of Continuous Pavement Deflection Measuring Technologies*, SHRP 2 Report S2-R06F-RW-1)—Available online at www.trb.org/Main/Blurbs/167283.aspx. (2) Catalogue of Existing Technologies (Chapter 3 of Final Report)—Available online at www.trb.org/Main/Blurbs/167283.aspx. (3) Case Studies/Example Applications (Chapter 4 of Final Report)—Available online at www.trb.org/Main/Blurbs/167283.aspx. (4) Dissemination and Implementation Plan (Chapter 5 of Final Report)—Available online at www.trb.org/Main/Blurbs/167283.aspx. (5) Research Problem Statements (Appendix A of Final Report)—Available online at www.trb.org/Main/Blurbs/167283.aspx.
Target Audience	• Highway Agency ➢ Highway administrators. ➢ Pavement management engineers. ➢ Pavement maintenance and preservation engineers. ➢ Pavement evaluation and design engineers.

	• Other Stakeholders—FHWA, AASHTO, toll road operators and concessionaires, pavement design and management consultants, paving contractors, equipment manufacturers.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Pavement evaluation, rehabilitation design. • Management, Maintenance, and Operations—Asset performance monitoring and management, system maintenance and preservation. • Contracting and Construction—Construction quality control/quality assurance (QA/QC).
Pertinent Technical Areas	• Pavement Condition Monitoring (network level) • Pavement Management (screening for rehab candidates [i.e., road sections that need to be investigated further at the project level], development of a "structural health index" for the network) • Pavement Preservation (differentiating sections that may be good candidates for preservation versus those that likely require a structural treatment)
Implementations	• Implementations Performed as part of R06F Project ➢ Project Level—Field Testing/Verification of one candidate NDT device; TSD in the UK. (Note: a similar evaluation of a second candidate device [RWD] was planned, but not possible due to equipment unavailability). ➢ Program Level—None (Note: a mini-workshop on continuous deflection measurement was conducted at Pavement Evaluation 2010 Conference). • Post R06F Project Implementations ➢ Project Level—None. ➢ Program Level—None.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • A long stretch of moderately aged (say, 6 to 8 years old) highway pavement is exhibiting some environmental- and load-related distresses, including raveling/weathering, thermal cracking, and wheelpath cracking—Need a process/technology to help determine if the pavement is a good candidate for preservation or rehabilitation, and, if so, whether there are certain sections that are more suitable for one treatment or the other. <u>Project Characteristics</u> • Project Type—Reconstruction, Rehabilitation, Preservation/Maintenance • Asset Type/Renewal Product Category—Pavements • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—None • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • An agency's process of programming roads for treatment based on condition survey data is unreliable and/or untimely—Need to implement a quicker and more informative (structural response) method of evaluating conditions and identifying candidate roads for preservation and rehabilitation. • An agency's project-level pavement evaluation methodology is based on limited sampling of the roadway surface condition and discrete locations of FWD testing, which don't provide adequate information about the uniformity of the structural condition of the pavement—Need to implement a program that includes continuous deflection measurements for identifying particularly weak or strong areas of the road that will result in a more targeted treatment.
Barriers/Challenges and Ways to Overcome	• Resistance from upper management due to the financial aspects of the technology and the staffing and training requirements.

Them	➢ Need to get buy-in from upper management (through promotional events and materials, training and workshops) as to the importance of the technology and its cost-effectiveness in the pavement management process.
Project Key Words	Rolling Wheel Deflectometer (RWD), Traffic Speed Deflectometer (TSD), continuous deflection, pavement, flexible, rigid, composite, deflection bowl, network, pavement management, structural condition index (SCI), base damage index (BDI)

Project Cost: $250,000

Expanded Summary for Renewal Project R06G (*High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings*)

SHRP 2 Program Officer	Monica A. Starnes
Contractor and PI Info	Texas Transportation Institute (Texas A&M University)—Andrew Wimsatt
Project Status and Time Frame	Complete—September 2009 through January 2013
SHRP 2 Renewal Product Category	• Nondestructive Testing (NDT)
Highway Asset Area	• Structures (tunnels)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Minimized tunnel closures and disruption to traffic. ➢ Improved scheduling of tunnel maintenance and/or rehabilitation activities. • Saves Lives ➢ Increased worker and highway user safety.
Project Objectives	• To identify NDT technologies for evaluating the condition (e.g., moisture, voids, and corrosion) of various types of tunnel linings (e.g., unreinforced concrete, reinforced concrete, shotcrete, and steel) and tunnel lining finishes (e.g., tile). The techniques must be capable of analyzing conditions within the tunnel lining and the surrounding substrate. • To evaluate the applicability, accuracy, precision, repeatability, ease of use, capacity to minimize disruption to vehicular traffic, and implementation and production costs of the identified technologies. • To conduct the required development in hardware or software for those techniques that show potential for technological improvement within the time limitations of this project. • To prove the validity of the selected technologies/techniques to detect flaws within or verify conditions of the targeted tunnel components. • To recommend test procedures and protocols to successfully implement these techniques. Evaluation, in the context of this project, is defined as both a rapid screening of the testing area and as an in-depth, although slower, assessment of an area deemed problematic during screening. In both cases, and based on SHRP 2 priorities, dependable NDT techniques that minimize disruption to traffic are sought under this project.
Summary of Findings	• To minimize traffic disruption, it is necessary to use NDT techniques for high-speed testing of tunnel linings. • Based on lab and field evaluation/validation results, the techniques below were found to be able to detect defects with minimum surface areas of 1 ft^2 and depths up to 4 in. They appear to provide useful information for evaluating tunnel linings and should be considered for implementation. ➢ Air-Coupled Ground-Penetrating Radar (ACGPR). ➢ Ground-Coupled Ground-Penetrating Radar (GCGPR). ➢ Thermal camera/thermography. ➢ SPACETEC Laser Scanner. ➢ Ultrasonic Tomography (UST). ➢ Ultrasonic echo. ➢ Combined Ultrasonic Surface Wave (USW) and Impact Echo (IE) (Portable Seismic Property Analyzer [PSPA]). • A comprehensive sequence for NDT testing of tunnels is as follows:

	➢ Perform rapid scanning of tunnel lining: Collect thermal images and air-coupled GPR data. ➢ Analyze rapid scanning data: Identify "areas of concern" for in-depth testing based on thermal images, GPR results, and observed surface distresses. ➢ Conduct in-depth testing: Collect data at "areas of concern" using ground-coupled GPR and either ultrasonic tomography, ultrasonic echo, or portable seismic property analyzer (PSPA) device. ➢ Evaluate in-depth test results. • With consistent advancement of NDT, current methods will continue to improve and new methods will continue to be developed to aid in tunnel inspections.
Product Description	<u>Currently available products include</u>: (1) Final Report ("High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings" Pre-Publication Draft, December 2012)—Documents the work conducted under Phase II of the project (provided below) and presents the main conclusions and recommendations (including implementation actions). Appendixes A-X contain testing criteria for the various NDT devices tested, as well as data and image analysis results for the various lab and field evaluation/verification activities. ➢ Laboratory evaluation of fabricated concrete/shotcrete/metal specimens at TTI. ▪ Ultrasonic Tomography (UST)/ultrasonic linear array (ACS A1040 MIRA). ▪ ACGPR (TTI 1-GHz system). ▪ GCGPR (GSSI 1.5-GHz system). ▪ Thermal camera/thermography (FLIR T-300 system). ▪ Combined Ultrasonic Surface Wave (USW) and Impact Echo (IE) (UTEP Portable Seismic Property Analyzer [PSPA]). ➢ Field validation testing in April 2011 at Chesapeake Bay Channel Tunnel on US 13 near Norfolk, VA. ▪ Laser Scanner (SPACETEC TS-3) for infrared surface imaging to identify "areas of concern" (including tile debonding). ➢ Field validation testing in June 2010, October 2010, February 2011, and June 2011 at two Helsinki, Finland tunnels (Hakamaentie Tunnel with concrete lining; Vuosaari Tunnel with shotcrete lining). ▪ ACGPR for detecting structural defects (areas with high moisture content, corrosion risk, voids). ▪ Thermal camera/thermography for detecting anomalies (moisture, voids, cracks). ▪ Laser scanner for quantifying tunnel lining condition. ➢ Field validation testing in October 2011 at five U.S. tunnels (Eisenhower Memorial Tunnel on I-70 near Dillon, CO; Hanging Lake Tunnel on I-70 near Glenwood Springs, CO; No Name Tunnel on I-70 in Garfield County, CO; and Washburn Tunnel on Federal Road near Houston, TX; Chesapeake Bay Channel Tunnel on US-13 near Norfolk, VA). ▪ ACGPR (TTI 1-GHz system) (all tunnels). ▪ Thermal camera/thermography (FLIR T-300 hand-held system) (3 tunnels). ▪ Thermal camera/thermography (FLIR A-325 vehicle-mounted system) (all tunnels). ▪ UST (ACS A1040 MIRA) (4 tunnels). ▪ Combined USW and IE (PSPA) (3 tunnels). ▪ GCGPR (GSSI 1.5-GHz system) (3 tunnels). ▪ Ultrasonic echo (German BAM and ACS A1220 Monolith (3 tunnels). ▪ Impact echo (3 tunnels). ▪ Acoustic sounding (1 tunnel). ➢ Field investigation in October 2011 for detecting loose tiles and moisture underneath tiles at two U.S. tunnels (Chesapeake Bay Channel Tunnel on US-13 near Norfolk, VA; Hanging Lake Tunnel on I-70 near Glenwood Springs, CO) ▪ UST (ACS A1040 MIRA). ▪ Impact echo. <u>Anticipated, but not currently available products include</u>:

	(2) Software (TUNNELCHECK)—Supports integration of GPR and video-collected data to identify problem areas in the tunnel more quickly. (3) User Manual—Provides guidance in selecting NDT technologies that can more effectively and quickly detect defects behind or within tunnel linings.
Product Status	(1) Final Report ("High-Speed Nondestructive Testing Methods for Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings" Pre-Publication Draft, December 2012)—Available online at www.trb.org/Main/Blurbs/168768.aspx. (2) Software (TUNNELCHECK)—Not currently available. (3) User Manual—Not currently available.

Target Audience	• Highway Agency
	  ➢ Maintenance engineers and technicians.
	  ➢ Asset managers.
	• Other stakeholders—Tunnel evaluation consultants, tunnel construction contractors, equipment manufacturers.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Contracting and Construction—Quality assurance/quality control (QA/QC) of new tunnel construction. • Management, Maintenance, and Operations—Asset management, tunnel maintenance and repair.
Pertinent Technical Areas	• Tunnel evaluation/testing. • Asset management.

Implementations	• Implementations Performed as part of R06G Project
	  ➢ Project Level
	  ▪ Field validation testing at Chesapeake Bay Channel Tunnel near Norfolk, VA (2011), Hakamaentie and Vuosaari Tunnels in Helsinki, Finland (2010 and 2011), Eisenhower Memorial Tunnel near Dillon, CO (2011), Hanging Lake Tunnel near Glenwood Springs, CO (2011), No Name Tunnel in Garfield County, CO (2011), Washburn Tunnel near Houston, TX (2011), and Chesapeake Bay Channel Tunnel near Norfolk, VA (2011).
	  ➢ Program Level—None
	• Post R06G Project Implementations—None?

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • A tunnel through a mountain in Virginia is beginning to show signs of distress in the form of cracks and spalls in the concrete, and displaced tiles—Need to identify NDT equipment to further ascertain the nature and extent of the distressed areas. <u>Project Characteristics</u> • Project Type—Reconstruction, Rehabilitation, Maintenance/Preservation. • Asset Type/Renewal Product Category—Pavements, Bridges and Other Structures, General Roadway. • Geographic Location (Setting and Climate)—Any setting; Any climate. • Geometrics—Any. • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement	<u>Problems/Issues/Constraints—Corresponding Needs</u> • A highway agency is spending too much time and creating too much disruption in its efforts to evaluate and monitor tunnel conditions—Need information on NDT technologies and protocols that can make the evaluations quicker and more efficient.

the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	
Barriers/Challenges and Ways to Overcome Them	• Lack of knowledge in the operation of the equipment and the processing, analysis, and interpretation of collected data. ➢ Need to establish and conduct classroom and hands-on training for all field personnel, as well as maintenance and asset management staff.
Project Key Words	Laser scanning, thermal imaging, ground-penetrating radar (GPR), tunnels, concrete, tiles, lining, void, moisture, flaws, bonding, ultrasonic surface waves (USW), impact echo (IE), impulse response (IR).

Project Cost: $1,650,000

Expanded Summary for Renewal Project R07
(*Performance Specifications for Rapid Renewal*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Trauner Consulting Services, Inc.—Sid Scott (now currently with Hill International)
Project Status and Time Frame	Ongoing—February 2007 through May 2013
SHRP 2 Renewal Product Category	• Pavements • Bridges
Highway Asset Area	• Pavements (geotechnical) • Structures (bridges-geotechnical)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Effective performance specifications result in improved quality and long-term durability of product for owner and more efficient delivery of product by contractor. ➢ Accelerated construction resulting in minimized highway user impacts. ➢ Reduced quality assurance (QA) burden on owner during construction. ➢ Performance risk placed on the party best able to manage it.
Project Objectives	• To develop different specifications that can be used effectively in various contracting scenarios (design-bid-build, design-build, warranties, etc.) and an implementation plan for the transition to these specifications. • To encourage further innovation by reducing mandatory method requirements and defining the end product performance. • To identify the relative risks of performance specifying among project owners, contractors/subcontractors, and suppliers, and to identify strategies to equitably allocate and manage risk to all parties. • To promote improved performance.
Summary of Findings	• Performance specifications for rapid renewal can: ➢ Promote innovation by reducing mandatory method requirements. ➢ Motivate contractors to be more responsible for performance and to invest in new processes/technology that will improve product performance. ➢ Help agencies achieve high-level performance-based management initiatives and meet key project performance indicators. ➢ Improve likelihood of meeting project-specific performance goals. • Measurement strategies that provide a better indication of quality and performance can be used to relate design assumptions to as-constructed conditions and performance. • Cultural changes and training may be necessary to support performance specifications.
Product Description(s)	(1) Final Report (*Performance Specifications for Rapid Highway Renewal*, Pre-Publication Draft, March 2013)—Documents the entire research effort and presents results and recommendations. Includes brief descriptions of three demonstration projects (MoDOT Route 141 Roadway Improvement Project in Chesterfield [fall 2010/spring 2011, pavement foundation QA/QC testing application], VDOT Rt. 208 Lake Anna Bridge Rehabilitation Project [November 2011, bridge performance shadow spec application], LADOTD US-90 Frontage Roads in Iberia Parish [October 2012, pavement structure roller-integrated compaction monitoring application]) performed to validate the proposed performance requirements. Other agencies with potential interest in specification demonstration projects were identified as follows: (a) Utah DOT Work Zone Traffic performance specification, (b) Iowa DOT Precast Modular Bridge or Pavement specifications, (c) Mn/DOT and/or IDOT Geotechnical performance specifications (roadway ground improvement or in-place pavements), (d) DelDOT PCC pavement specification, and (e) FLDOT HMA warranty specification.

	(2) Guide Specifications Document (*Guide Performance Specifications*)—Guide performance specifications to be used by engineers and specifiers as a template from which to develop project-specific performance specifications. The specifications are provided in the following areas: • HMA pavement (design-bid-build [DBB], design-build [DB], and warranty contracts). • PCC pavement (DBB, DB, and warranty contracts). • Precast/modular concrete pavement (DBB contract). • Pavement foundation (Roller-Integrated Compaction Monitoring [RICM] on embankment fill, subgrade, and/or subbase). • Ground improvement (under development). • Pavement (design-build-operate-maintain [DBOM] contract). • PCC bridge deck (DBB or DB contracts). • Work zone traffic control. • Quality management plans (QMP). Each specification has been developed with a specific delivery approach in mind; that is, the recommended performance parameters and materials and construction requirements are intrinsically linked to the roles and responsibilities and risk allocation deemed appropriate for a particular delivery approach (design-bid-build, design-build, warranty, and maintenance contracting). Guidance has been built into the specifications to help users select performance parameters and performance measurement strategies (test method, sampling plan, target value, pay adjustment mechanism) that will align with the project's goals and the capabilities of the agency and industry. To the extent possible, the specifications follow the AASHTO five-part format, deviating when necessary to address the design and post-construction requirements inherent to design-build and warranty/maintenance contracting. (3) Implementation Guidelines Document (*Volume I–Strategies for Implementing Performance Specifications: A Guide for Executives and Project Managers* and *Volume II–Developing and Drafting Effective Performance Specifications: A Guide for Specification Writers*, Pre-Publication Drafts)—To accompany the guide specifications, a two-volume set of implementation guidelines has been prepared to provide a broader, more philosophical overview of the benefits and challenges associated with implementing performance specifications. Volume I is a procedural manual designed to provide Executives and Project Managers with a broad overview of the benefits and challenges associated with implementing performance specifications. Recommendations are provided regarding project selection criteria, procurement and project delivery options, industry and legal considerations, and the various cultural and organizational changes needed to support the implementation of performance specifications. Volume II presents a flexible framework that specification writers can use to assess whether performance specifying represents a viable option for a particular project or project element, and if so, how performance specifications can then be developed and used to achieve project-specific goals and satisfy user needs. The guidance is intended to be accessible to both experienced and novice members of a project team, as well as adaptable to any project element and delivery method. In addition to providing a step-by-step "how-to" guide for developing performance specifications, this document also contains additional guidance on application areas (e.g., pavements, bridge deck, earthworks, and work zone) found to have the greatest need or potential for performance specifying. (4) Webinar (*Performance Specifications for Rapid Renewal [SHRP 2 R07]*)—1.5-hour webinar consisting of four parts: (1) brief overview of SHRP 2, (2) technical presentation focused on research outcomes and products (including how to develop and implement performance specifications), (3) validation projects used to validate the use of performance specifications, and (4) product implementation plans, actions, and opportunities.
Product Status	(1) Final Report (*Performance Specifications for Rapid Highway Renewal*)—Pre-Publication Draft, March 2013. (2) Guide Specifications Document (*Guide Performance Specifications*)—Pre-Publication Draft, October 2012. (3) Implementation Guidelines Document (*Volume I–Strategies for Implementing Performance Specifications: A Guide for Executives and Project Managers* and *Volume II–Developing and*

	Drafting Effective Performance Specifications: A Guide for Specification Writers)—Pre-Publication Draft, September 2012. (4) Webinar (*Performance Specifications for Rapid Renewal [SHRP 2 R07]*)—Conducted June 11, 2013. Available online at http://www.trb.org/ElectronicSessions/Blurbs/168927.aspx

Target Audience	• Highway Agency
	  ➢ Administrators/executives (upper-level management).
	  ➢ Project managers.
	  ➢ Construction management engineers.
	  ➢ Field construction engineers and inspectors/technicians.
	  ➢ Designers (pavements, structural, geotechnical, traffic).
	  ➢ PS&E Engineers.
	• Other Stakeholders—Consultants, Contractors, Design-Bid Consortiums

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Engineering studies, design, PS&E. • Contracting and Construction—Project advertising, bidding, and award, construction. • Management, Maintenance, and Operations—Maintenance and operations.

Pertinent Technical Areas	• Evaluation of suitability of user performance specifications.
	• Performance specification development/writing for:
	  ➢ HMA pavement (DBB, DB, or warranty contracts).
	  ➢ PCC pavement (DBB, DB, or warranty contracts).
	  ➢ Precast/modular concrete pavement (DBB contract).
	  ➢ Pavement (DBOM contract).
	  ➢ Pavement foundation.
	  ➢ Ground improvement.
	  ➢ PCC bridge deck (DBB or DB contracts).
	  ➢ Work zone traffic control.
	  ➢ Quality management plan (QMP).

Implementations	• Implementations Performed as part of R07 Project
	  ➢ Project Level—3 Field Demonstration projects conducted as part of study to showcase the performance specs:
	  ▪ Rt. 141 Chesterfield, MO (fall 2010/spring 2011)—Geotechnical performance specification.
	  ▪ Rt. 208 Lake Anna Bridge in Virginia (Nov 2011)—Concrete bridge deck performance specification (bridge deck replacement).
	  ▪ US-90 Frontage Road in Ibernia Parish, LA (Oct 2012)—Roller-integrated compaction monitoring technology and mechanistic QA/QC testing for HMA pavement.
	  ➢ Program Level—Webinar conducted June 11, 2013.
	• Post R07 Project Implementations
	  ➢ AASHTO/FHWA/SHRP 2 R07 Implementation Assistance Program—Announced in 7/24/13 web conference. Application process runs from 8/2/13 through 9/6/13. Announcement of recipients in October 2013.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Project involves a bridge or structure that poses a challenge for developing performance specifications—Need to work toward a hybrid specification that combines performance-oriented parameters with prescriptive methods. • Existing test methods and sampling plans are challenging to implement in a rapid renewal context; not sure what performance measurement strategies to adopt—Need to consider the use of new and emerging nondestructive testing (NDT) techniques that would facilitate rapid renewal. • Rapid renewal project calls for a specific delivery approach (design-bid-build, design-build, warranty, or design-build-operate-maintain)—Need to use the guide specification tailored to that

	delivery approach. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Risks and gaps in performance measurement are difficult to quantify given the current level of understanding—Need to qualitatively decide whether performance specifications are appropriate and how to allocate risk among project participants. • Contractor is not motivated to provide more than the required minimum under traditional specifications—Need to consider performance specifications to empower contractor to save time, minimize disruption, and/or enhance safety and quality. • Resistance to change from agency staff accustomed to traditional specifications and reluctant to assume new responsibilities—Need to address how the decision to use performance specifications could affect an agency's traditional project delivery phases, from project planning and preliminary engineering through to construction completion and possibly beyond to maintenance and asset management. • Difficult industry transition from more traditional contracts and specifications—Need to address cultural and organizational issues that create a learning curve for contractors to progress to a new business model. • Inadequate flow of information regarding performance provisions to subcontractors—Need to promote collaboration, early contractor involvement, and integrated services.
Barriers/Challenges and Ways to Overcome Them	• Roles and responsibilities of the contractor and agency can become blurred. ➢ Need to define responsibilities clearly in the specifications or contract documents. • The agency can exert less control over the work. ➢ Need to ensure that performance specifications incorporate appropriate incentives, which can provide a more rational mechanism for adjusting payment based on quality or performance. • Risk associated with newer or less proven methods, varying contractor performance. ➢ Need to identify parameters critical to performance and establish related thresholds.
Project Key Words	Roadway, pavement, bridge, rapid renewal, work zone traffic control, risk, performance, performance-related method, alternative project delivery, performance specification selection tool, contract delivery selection tool, specification, warranty, maintenance.

Project Cost: $2,999,984

Expanded Summary for Renewal Project R09
(*Guide for the Process of Managing Risk on Rapid Renewal Projects*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Golder Associates, Inc.—Dr. William J. Roberds
Project Status and Time Frame	Completed—Dec 2007 through Jan 2011
SHRP 2 Renewal Product Category	• Project Delivery/Construction
Highway Asset Area	• Pavements • Structures (bridges) • Roadway Features
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Improved project performance (i.e., reduced costs, reduced construction time and traffic disruption during construction, increased time to replacement after construction, and increased safety) by better anticipating and planning for potential problems/opportunities (risks). ➢ Practical and compatible process for an agency.
Project Objectives	• To address the general lack of understanding of risk, especially associated with innovative rapid renewal projects (including different project delivery approaches and rapid construction techniques) that can lead to poor project performance. • To develop practical guidance/tools for the application of risk management methods to the project development process (including but not limited to rapid renewal projects) in a manner consistent with the business practices and skills of highway agencies.
Summary of Findings	• Risks are potential problems, as well as potential opportunities (negative risks), that can significantly affect project performance. They are events characterized by their probability of occurrence and the specific performance impacts if they occur. • A simple application of risk assessment involves the identification, assessment, evaluation, and ranking of all significant project risks and opportunities, whereas a more complex risk analysis also includes quantifying the uncertainties in project performance. • A simple application of risk management involves the identification, evaluation, planning and eventual implementation of cost-effective risk reduction actions, whereas a more complex effort also includes quantifying the uncertainties in mitigated project performance and thereby determination of appropriate project contingencies (schedule as well as cost). • After training, simple applications can be done efficiently in-house by an agency in a two-day workshop, whereas complex applications can be done by qualified third parties supervised by agency staff.
Product Description(s)	<u>Currently available products include:</u> (1) Guide Document (*Guide for the Process of Managing Risk on Rapid Renewal Projects*, Pre-Publication Draft, February 2013)—Presents a formal risk management process to better understand and to actually optimize project performance specifically for rapid renewal projects, especially by anticipating and planning for potential problems (risks) and potential improvements (opportunities). Provides an overview of the steps in the process and detailed guidance for each step, with a risk checklist. A complete hypothetical rapid renewal case study is included in Appendix F of the Guide. Appendix G of the Guide presents materials for a course designed to train DOT staff to successfully implement the risk management process described in the Guide. (2) Example/Hypothetical Application (Appendix F of Guide Document)—Provides a complete hypothetical rapid renewal case study performed by QDOT. The example involves the planning to reconstruct and expand segments of two existing (intersecting) highways, US-555 and SH-111,

	through a rapidly-developing suburban area. QDOT wants to minimize cost, schedule, and disruption through construction, and maximize longevity after construction. To help achieve these objectives, QDOT will use design/build project delivery and encourage accelerated construction methods. (3) Workshop/Training Course Materials (Appendix G of Guide Document)—A 2-day workshop (entitled Simplified Risk Management Training) for simple applications of the risk management process was developed and piloted in North Carolina. The workshop materials provide an overview of risk management (for executives and participants) and the Excel template leads the trained in-house risk manager through the steps of the process (i.e., project structuring, risk identification/assessment/evaluation/ranking, and development of risk reduction plans). The training is focused on DOT facilitators to help them (a) implement the risk management process directly on relatively simple rapid renewal (as well as non-rapid renewal) projects, and (b) supervise the evaluation of more complex projects and/or quantitative risk analysis. (4) Risk Management Planning Tool—Electronic tool for conducting simplified risk management planning for rapid renewal projects. Includes (a) Microsoft Excel workbook template, (b) hypothetical QDOT project (US-555 and SH-111) using the risk management planning template, and (c) a user's guide to facilitate use of the risk management planning tool. (5) Webinar—On August 20, 2013, TRB conducted a 90-minute webinar entitled Managing Risk in Rapid Renewal Contracts. This webinar explored a formal risk management process that will help optimize performance for accelerated reconstruction projects, offering practical methods for identifying, assessing, mitigating, allocating, and monitoring risk. <u>Anticipated, but not currently available products, include:</u> (6) Final Report—Provides background and documentation for the development of the Guide Document, including a "gap analysis." It presents the results of the two pilot training workshops and recommendations for implementation.
Product Status	(1) Guide Document (*Guide for the Process of Managing Risk on Rapid Renewal Projects*, Pre-Publication Draft, February 2013)—Available online at http://www.trb.org/Main/Blurbs/168369.aspx. (2) Example Application (Appendix F of Guide Document)—Available online at http://www.trb.org/Main/Blurbs/168369.aspx. (3) Workshop/Training Course Materials (Appendix G of Guide Document)—Available online at http://www.trb.org/Main/Blurbs/168369.aspx. (4) Risk Management Planning Tool—Available online at http://www.trb.org/Main/Blurbs/168369.aspx. (5) Webinar—A link for obtaining the webinar recording exists at http://www.trb.org/Highways1/Blurbs/169261.aspx. (6) Final Report—Available at a later date.

Target Audience	• Highway Agency (primary)
	  ➢ Designated agency risk managers at HQ, program, or project level.
	• Highway Agency (secondary)
	  ➢ Agency executives at HQ, program, or project level (to understand value of risk management).
	  ➢ Project staff (project manager, design engineer, project engineer and construction engineer) who will participate in workshops.
	• Other Stakeholders—Consultants, Contractors

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—System planning; scoping, scheduling and budgeting; and programming. • Project Development—Preliminary and final design.
Pertinent Technical Areas	• Project planning/programming. • Preliminary engineering studies. • Project design reviews.

Implementations	• Implementations Performed as part of R09 Project
	  ➢ Project Level—None.
	  ➢ Program Level—None.
	• Post R09 Project Implementations
	  ➢ AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 1)—R09 Implementation Assistance Program announced in 2/7/13 web conference. Application process runs from 2/15/13 thru 3/15/13. Announcement of recipients in April 2013. Two agency awards made include:
	  ▪ Florida DOT: Proof of Concept assistance on Gateway Express project.
	  ▪ Georgia DOT: Proof of Concept assistance on SR 96 Corridor project.
	  ➢ AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 2)—R09 Implementation Assistance Program announced in 7/26/13 web conference. Application process runs from 8/2/13 thru 9/6/13. Applicants include Colorado DOT, Florida DOT, Georgia DOT, Minnesota DOT, Oregon DOT, Pennsylvania DOT, Utah DOT, and Vermont DOT. Announcement of recipients in October 2013.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Accelerated schedule for rapid renewal project means that base project scenario is defined but risk assessment is lacking—Need to brainstorm a comprehensive set of risks and opportunities, checking against lists of common risk factors, and document these in a project risk register. • Complex project involves many different risk factors whose severity changes over time—Need to implement risk management including monitoring milestones and risk reduction activities to determine the status of contingencies when risks are avoided or reduced. • Project has limited budget flexibility remaining and requires risk management planning—Need to identify and evaluate possible actions to reduce risk based on cost-effectiveness, considering both changes in base project costs and the reduction in probability of risk events. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints and Corresponding Needs</u> • Underestimating project budgets and schedules leads to additional disruption and is detrimental to the agency's credibility—Need to broaden project scenarios beyond a deterministic approach using a single value to encompass assumptions and risk factors for multiple outcomes, with the goal of optimizing project performance. • Formal risk management processes are a new practice in the context of rapid renewal projects and challenging to implement because of the approaches involved—Need to emphasize an efficient and defensible approach to risk management in which risk factors are identified, assessed, and opportunities to manage risk are evaluated for cost-effectiveness. • Rapid renewal projects may involve innovative methods where risk is increased because there is little past experience to learn from—Need to ensure that a formal risk management process with well-defined steps allows the agency to anticipate and plan for risks in an iterative fashion.
Barriers/Challenges and Ways to Overcome Them	• Risk factors may be difficult to project in advance and risk severity may be challenging to measure accurately. ➢ Need to subjectively assess relevant risk factors, either qualitatively or quantitatively, and prioritize them on that basis in the project risk register. • Different risk factors might overlap or have the potential to combine and interact in ways that affect the overall project risk.

	➢ Need to analytically combine risk factors and probabilities of different scenarios occurring to determine impact on project performance measures, which can include quantifying the uncertainty in the risk analysis.
Project Key Words	Risk, risk management, risk identification, risk assessment, risk analysis, risk management implementation, risk checklist, risk register, rating risk, risk prioritization, risk reduction planning, risk mitigation, risk management plan, quantitative risk analysis, qualitative risk analysis, risk-based contingency, probability, probability distribution, confidence level.

Project Cost: $250,000

Expanded Summary for Renewal Project R10
(Project Management Strategies for Complex Projects)

SHRP 2 Program Officer	Jerry DiMaggio
Contractor and PI Info	Iowa State University—Jennifer Shane, Ph.D.
Project Status and Time Frame	Active—September 2009 through December 2013
SHRP 2 Renewal Product Category	• Project Delivery/Construction
Highway Asset Area	• Pavements • Structures (bridges)

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Better management of time and budget on the project.
	  ➢ On complex projects there will be:
	  ▪ Improved decision speed.
	  ▪ Reduced turnaround times on key deliverables.
	  ▪ Expedited approvals required by the government.

Project Objectives	• To provide transportation agencies with tools that can be used to develop innovative and effective project management strategies that will accelerate sound decision-making during rapid renewal projects. The tools will include:
	  ➢ A guidebook for innovative project management.
	  ➢ Example case studies of project management strategies for complex projects.
	  ➢ Workshop and training packages to support adoption of these management strategies by all stakeholders.

Summary of Findings	• Fifteen projects in the United States (CA, OR-WA, CO, OK, TX, IL-MO, IN-KY, MI, FL, NC, VA, RI, DC) and three international projects (Canada, New Zealand, United Kingdom) were investigated through in-depth case studies to identify tools that aid project managers of complex projects to successfully deliver projects. These 18 projects represent a number of different project types (7 corridor projects, 4 bridge projects, 3 corridor and bridge projects, 2 tunnel and bridge or roadway projects, 2 transit projects), locations, project size, and phases of project development. The methods and tools identified from these projects fall into two different areas: Project Development and Project Execution.
	• The findings involve the use of 5 Dimensional Project Management (5DPM), which includes the 3D of technical, schedule and cost, along with financial and context. The five methods identified are:
	  ➢ Defining critical project success factors.
	  ➢ Selecting the contract based on project outcomes.
	  ➢ Assembling and owner driven project team.
	  ➢ Preparing early cost model and finance plan.
	  ➢ Defining political action plans.
	• The 13 tools that may be helpful on complex projects include:
	  ➢ Develop dispute resolution.
	  ➢ Identify critical permit issues.
	  ➢ Determine required level of ROW/Utilities involvement.
	  ➢ Design to budget.
	  ➢ Establish flexible design criteria.
	  ➢ Develop finance expenditure model.
	  ➢ Incentivize critical project outcomes.

	➢ Perform comprehensive risk analysis. ➢ Evaluate applications of off-site fabrication. ➢ Determine work sequence. ➢ Colocate team. ➢ Evaluate flexible financing. ➢ Establish public involvement plan.
Product Description(s)	Currently available products include: (1) Final Report (*Project Management Strategies for Complex Projects*, Pre-Publication Draft, July 2012)—Documents entire research effort and presents results and recommendations. Discusses the findings of a detailed literature review and analysis, intended to determine what makes projects complex and to identify some ways the complexity is being managed. Describes in detail the identification and development of project management tools and the development of the Guidebook, which entailed: ➢ 18 case study projects used to identify project management tools. ▪ Capital Beltway HOT Lanes (Virginia DOT) ▪ Detroit River International Crossing (Michigan DOT) ▪ San Francisco Doyle Drive/Route 101 (Caltrans) ▪ Green Street (City of Saskatoon, Saskatchewan, CA) ▪ Heathrow T5 (British Airports Authority) ▪ Hudson-Bergen Light Rail Minimum Operable Segment (New Jersey Transit) ▪ Oklahoma City I-40 Crosstown (Oklahoma DOT) ▪ I-95 New Haven Harbor Crossing Corridor Improvement (Connecticut DOT) ▪ Ft. Lauderdale I-595 Corridor Improvements (Florida DOT) ▪ Montgomery and Prince George's Counties InterCounty Connector (Maryland SHA, Maryland General Engineering Consultants) ▪ James River Bridge (Virginia DOT) ▪ Lewis and Clark Bridge (Washington State DOT) ▪ Louisville-Southern Indiana Ohio River Bridge Project (Community Transportation Solutions, Kentucky Transportation Cabinet) ▪ St. Louis New Mississippi River Bridge (Missouri DOT, Illinois DOT, FHWA, Horner and Shifrin Engineers) ▪ North Carolina Tollway (North Carolina Turnpike Authority) ▪ Northern Gateway Toll Road (New Zealand Transport Authority) ▪ Texas State Highway 161 (Texas DOT, KBR, Williams Brothers Construction Company) ▪ Denver I-25/I-225 Southeast Corridor T-REX (Colorado DOT, Parsons Brinkerhoff) ➢ 2 validation efforts of the 5DPM concept, project development methods, and project execution tools. ▪ I-15 South (Nevada DOT). ▪ I-74 Corridor (Iowa DOT). ➢ 2 two pilot workshops and six AASHTO Regional workshops conducted, resulting in modifications to the Guidebook. ▪ Pilot Workshops: Kansas City, MO (March 28, 2011) and Salt Lake City, UT (April 28, 2011). ▪ AASHTO Regional Workshops: Troy/Albany, NY (Nov 3-4, 2011), Columbus, OH (Sep 28-29, 2011), Ames, IA (Aug 16-17, 2011), Los Angeles, CA (Sep 21-22, 2011), Austin, TX (Sep 8-9, 2011), Orlando, FL (Oct 17-18, 2011). (2) Guidelines Document *(Guidebook: Project Management Strategies for Complex Projects*, Pre-Publication Draft, July 2012)—The guidebook is intended to facilitate utilization of effective strategies for managing complex projects. It focuses on the five practical methods and thirteen tools that can be immediately beneficial. It also includes the mapping for interactions. (3) Workshops/Training Courses—Two Pilot Workshops and six AASHTO Regional Workshops intended to introduce the 5DPM concept and the five methods. (4) Webinar—On May 7, 2013, TRB conducted a 90-minute webinar entitled New Strategies for Managing Complex Projects. This webinar explored the five-dimensional approach that was developed in the study.

	Anticipated, but not currently available products, include: (5) Training Course Materials—This is a 1.5-day training session/workshop that covers the 5DPM and the Project Development Methods. It covers the identification and prioritization of complexity factors. A course was delivered to the Colorado DOT on April 30 to May 1, 2012. Another course was conducted for Minnesota DOT on October 11-12, 2012. Final training materials are being developed. (6) Webinars—A series of 13 one-hour webinars are being developed for each of the execution tools. Examples include incentives for critical project outcomes, dispute resolution plan, comprehensive risk analysis, critical permit issues, design to budget and eight others.
Product Status	(1) Final Report (*Project Management Strategies for Complex Projects*, Pre-Publication Draft, July 2012)—Available online at http://www.trb.org/Main/Blurbs/167481.aspx. (2) Guidelines Document *(Guidebook: Project Management Strategies for Complex Projects*, Pre-Publication Draft, July 2012)—Available online at http://www.trb.org/Main/Blurbs/167482.aspx. (3) Workshops/Training Courses—Two Pilot Workshops delivered in Spring 2011 in MO and UT. Six AASHTO Regional Workshops delivered in fall 2011 in NY, OH, IA, CA, TX, and FL. (4) Webinar—A link for obtaining the webinar recording exists at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Blurbs/168714.aspx. (5) Training Course Materials—Available at a later date. Reference information to the Colorado and Minnesota courses is available at: http://www.intrans.iastate.edu/events/shrp2complexprojects/. (6) Webinars—Available at a later date.

Target Audience	• Highway Agency
	  ➢ Project managers.
	  ➢ Design engineers.
	  ➢ Construction engineers and inspectors.
	• Other Stakeholders—Consultants, Contractors

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Preliminary and final design and PS&E. • Contracting and Construction—Preconstruction and construction.
Pertinent Technical Areas	• Project Planning/Programming. • Project Management.

Implementations	• Implementations Performed as part of R10 Project
	  ➢ Project Level
	  ▪ 15 U.S. Case Study projects (VA, MI, CA, OK, FL, CT, MD, WA, KY, MO-IL, NC, TX, CO) and three International Case Study projects (CA, UK, NZ) used to identify project management tools/strategies.
	  ▪ Two Validation Studies (I-15 Las Vegas NM, I-74 IA).
	  ➢ Program Level
	  ▪ Two Pilot Workshops (MO and UT) and six Formal Workshops (NY, OH, IA, CA, TX, FL) in fall 2011 conducted during development of best practice strategies.
	  ▪ Two Training Courses (CO and MN) conducted in spring/fall 2011 covering the 5DPM concepts and strategies.
	• Post R10 Project Implementations
	  ➢ AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 1)—R10 Implementation Assistance Program announced in 2/7/13 web conference. Application process runs from 2/15/13 thru 3/15/13. Announcement of recipients in April 2013. Five agency awards made include:
	  ▪ Georgia DOT: Lead Adopter assistance on Northwest Corridor project.
	  ▪ Massachusetts DOT: Lead Adopter assistance on Route 20 project in Charlton/Oxford.
	  ▪ Michigan DOT: Lead Adopter assistance on I-75 and I-94 project.
	  ▪ Montana DOT/Federal Lands Highway: Lead Adopter assistance on Gardiner Gateway project.

	▪ New Mexico DOT: Lead Adopter assistance on NM 209 project.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints—Corresponding Needs • Highway renewal project presents added complexity because of bridges and overpasses that must be raised to meet clearance requirements, connections to arterial and collector streets, and large number of utilities crossing project limits—Need to establish early and consistent coordination from the beginning of the project to interface with existing systems and manage changes while maintaining traffic safety and mobility. • Formal risk analysis is required prior to agency obtaining funding necessary to move forward with a project—Need to apply five-dimensional project management, expanding on traditional cost/schedule/quality analysis to incorporate project context and financing. • Agency has adopted an alternative project delivery method that increases the complexity of the project—Need to conduct an analysis of project success factors and effective practices in order to identify interaction of contextual factors. Project Characteristics • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints and Corresponding Needs • Agency staff are unfamiliar with five-dimensional project management principles—Need to provide training on the methods and tools used to handle complex projects, so that managers develop the experience and intuition to make the necessary judgments. • Projects are narrowly conceptualized as products without regard to their organizational context or political environment—Need to focus on value creation using a multidisciplinary approach in which projects have multiple purposes in the context of social interactions and stakeholder relations. • Lack of accountability and coordination between departments and agencies responsible for various projects tasks—Need to train project managers to think of complex projects as integrated systems, particularly as rapid renewal timelines compress distinct project phases and make them harder to manage separately.
Barriers/Challenges and Ways to Overcome Them	• Project complexity is challenging to measure and define. ➢ Need to emphasize effective project management principles without requiring overly restrictive definitions, as being too exhaustive or precise may interfere with rapid renewal. • Project factors are discussed as discrete events that can create complexity independently. ➢ Need to consider dynamic interaction between multiple factors as another source of complexity. • Project management approach is treated as a linear function with defined start and end points. ➢ Need to think of projects as interactive processes to be approached from multiple viewpoints with multiple purposes.
Project Key Words	Complex projects, design and construction of complex projects, critical factors in complex projects, managing complex projects, selecting the contract, cost model and financial plan, political action plan, risk analysis, off-site fabrication, ROW/utilities involvement, dispute resolution, permit issues, colocate team, flexible financing.

Project Cost: $1,250,000

Expanded Summary for Renewal Project R11 (*Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process*)

SHRP 2 Program Officer	Monica Starnes
Contractor and PI Info	The Louis Berger Group—Dane Ismart
Project Status and Time Frame	Active—September 2009 through December 2013
SHRP 2 Renewal Product Category	• Project Delivery/Construction
Highway Asset Area	• Pavements • Structures (bridges)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Reduced traffic disruption and increased safety. ➢ Minimized, managed and mitigated road user impacts to the traveling public at the project, corridor and network levels.
Project Objectives	• To identify and document effective practices for executing highway renewal activities as they affect the corridor and network level by considering construction and scheduling alternatives, budget limitations, adjacent communities, and impact to the traveling public. • To provide guidance for selecting appropriate tools, techniques, performance measures, and practices during project development (i.e., from planning through construction). • To assess and develop training needs and materials and knowledge transfer methods for implementation.
Summary of Findings	• The literature review and interviews conducted determined that past studies have predominately focused on project and work zone congestion impacts. Efforts on this project have focused on macro-level analyses of the corridors and networks from planning, programming, design and construction. This is a bigger picture and more integrated approach than in the past. • The software is an integrated framework to allow for more holistic decisions to be made. • The software tool can import traffic networks, optimize by recommending efficient strategies, and evaluate impacts of route choice behavior.
Product Description(s)	<u>Currently available products include:</u> (1) Final Report (*Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process*, Pre-Publication Draft, October 2012)—Documents the project work activities and the products developed under the study, including the Workzone Impact and Strategy Estimator (WISE) software tool, workshops for testing the WISE tool, and training materials for instruction in the use of the WISE tool. Work activities included a literature review to investigate agency regulations, policies, and guidelines; interviews with DOT and metropolitan planning organization (MPO) representatives to identify management strategies and measures of success; analysis of the interview results to guide the development of the software tool and the training material; and evaluation of various project impact software tools and applications (e.g., STEAM, HERS, CA4PRS, AIMSUN, MITSUM, and various agency spreadsheet tools). (2) Software Tool (*Workzone Impact and Strategy Estimation [WISE]*, Version 2.5A)—WISE is a software tool to analyze the impacts of multiple, concurrent work zone across a network or complex corridor upon road user costs. It can be used to minimize, manage and mitigate road user costs from safety and operational perspectives. The tool was developed in two separate components: (1) Graphical User Interface and (2) Computational Interface. There are three major functions of the

	software: (1) the Planning Module, (2) the Operational Module, and (3) the "handshake" between the two. (3) User Guide (*Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process: WISE User Guide*, Pre-publication Draft, 2012)—Provides an introduction to the WISE Software Package Version 2.5A, as well as instruction and background detail on the workspace, planning module, operations module, and the "handshake" between the two. Also, contains detailed information on how to load and convert a network and how to load traffic data. (4) Workshops—Designed to test the basic concepts and design of the WISE software tool, and generate suggested improvements to the tool. The workshops included a dry run workshop in Baton Rouge, LA (Nov 30, 2011), a second workshop in Fairfax, VA (Dec 13-14, 2011), a third workshop in Houston, TX (Feb 28-29, 2012). (5) Training Materials—Provides how-to instruction on the use of the WISE software tool. The materials consist of a PowerPoint presentation, a participant workbook, and an instructor's guide. (6) Webinar—Outreach designed to further publicize the study and its products. <u>Anticipated, but not currently available products, include:</u> (7) WISE Model Verifications and Pilot Implementations—As part of Phase IV, verification applications of the WISE software are underway at the following locations: ➢ Phoenix, AZ (Arizona DOT and Maricopa Association of Governments)—Re-creation of the impacts of the recently completed renewal and expansion of the Phoenix freeway regional system. ➢ Des Moines, IA (Iowa DOT and Des Moines Area MPO)—Re-creation of the impacts of the I-235 corridor renewal. (8) WISE Model Business Case Applications—Anticipated applications in the New York City, NY metropolitan area and the Orlando, FL metropolitan area.
Product Status	(1) Final Report (*Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process*, Pre-Publication Draft, October 2012)—Available online at http://www.trb.org/Main/Blurbs/168143.aspx. (2) Software Tool (*Workzone Impact and Strategy Estimation [WISE]*, Version 2.5A)—Available online at http://www.trb.org/Main/Blurbs/168143.aspx. (3) User Guide (*Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process: WISE User Guide*, Pre-publication Draft, 2012)—Available online at http://www.trb.org/Main/Blurbs/168144.aspx. (4) Workshops—Described in final report (http://www.trb.org/Main/Blurbs/168143.aspx). (5) Training Materials—Available from SHRP 2. (6) Webinar—Described in final report (http://www.trb.org/Main/Blurbs/168143.aspx). (7) WISE Model Verifications and Pilot Implementations—Available at a later date. (8) WISE Model Business Case Applications—Available at a later date.
Target Audience	• Highway Agency ➢ Planners. ➢ Program managers. ➢ Project managers. ➢ Design engineers. ➢ Traffic engineers. ➢ Project engineers. ➢ Construction engineers. • Other Stakeholders—Consultants
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—System planning, programming. • Project Development—Preliminary and final design. • Management, Maintenance, and Operations—System operations.

Pertinent Technical Areas	• Project planning/programming. • Preliminary engineering studies. • Project delivery method determination.

Implementations	• Implementations Performed as part of R11 Project
	  ➢ Project Level
	  ▪ Two Selected Sites for WISE Verification and Pilot Application—Phoenix Regional Freeway System expansion/renewal, Des Moines I-235 Corridor renewal.
	  ▪ Two Proposed Sites for additional WISE Verification and Pilot Application—New York Metro Area, Orlando Metro Area.
	  ➢ Program Level
	  ▪ Three workshops completed (Baton Rouge, LA [Nov 30, 2011], Fairfax, VA [Dec 13-14, 2011], Houston, TX [Feb 28-29, 2012]).
	• Post R11 Project Implementations
	  ➢ Project Level—None.
	  ➢ Program Level—None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Project has been significantly delayed and will not be completed within schedule, leading to cascading impact on other project schedules—Need to identify subsequent projects for which completion is a required precedent, reevaluate sequence of projects, and determine estimated impact on program cost for the purpose of assessing liquidated damages. • Renewal project is in the design phase of development and engineering staff must apply project information to analyze traffic diversion—Need to develop maintenance of traffic (MOT) scenarios and use the WISE software to select an acceptable scenario and verify the sequence of the project within the renewal program. • Emergence of congestion issues in moderately urbanized area requires agency to expand its consideration of work zone impact mitigation—Need to quantitatively analyze impacts at the network level as part of project planning. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints and Corresponding Needs</u> • Agency has collected its universe of potential projects from existing systems and inputs and wants to develop a program of renewal projects—Need to develop an initial program sequence using the WISE software to provide a basic sketch that can inform the public process and decision-making for the program. • A set of renewal projects has been identified and preliminary scope determined, but information regarding fiscal year programming is incomplete—Need to identify instances of project precedence and use the WISE software to refine sequence, identifying cases where demand-based or duration-based strategies would be appropriate. • Tools related to maintenance of traffic in work zones and mitigating congestion and disruption exist primarily at the project level—Need to compare different sequencing scenarios in light of program objectives and assess their impacts using the WISE software.

Barriers/Challenges and Ways to Overcome Them	• Some agencies have developed their own tools but use very coarse estimation procedures.
	  ➢ Need to convert essential elements into templates that can be used in the development of the WISE process.
	• Wide variance in practices between agencies in developing renewal programs.
	  ➢ Need to establish a mandate for management of renewal activities and consideration of performance measures at the corridor or network level.
	• Contractor input and resources are rarely considered in planning to reduce work zone impacts.
	  ➢ Need to develop performance measures to evaluate past performance of contractors.

Project Key Words	Road user costs, multiple projects, network, corridor, route choice behavior, software.

Project Cost: $1,699,856

Expanded Summary for Renewal Project R15
(*Strategies for Utility and Transportation Agency Priorities in Highway Renewal Projects*)

SHRP 2 Program Officer	Monica Starnes
Contractor and PI Info	ICF International, Inc. and University of Florida—Co-PI: Marie Venner (ICF), Co-PI: Ralph D. Ellis, Jr. (UF)
Project Status and Time Frame	Completed—July 2007 through December 2009
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ The knowledge of the location and character/condition/attributes of existing utilities can allow timely decisions on design to accommodate or to move a utility. ➢ Avoiding unnecessary utility relocations decreases project timetables and costs. ➢ Timely and comprehensive identification of potential utility conflicts decreases project timetables. ➢ Effective coordination with affected utility agencies decreases project timetables and costs.
Project Objectives	• To investigate how to improve coordination between utility companies (UCs) and transportation agencies to reduce the negative impacts to both entities, and to the public.
Summary of Findings	Issues related to utilities are among the major causes of construction delays in highway construction projects. Because of the frequency with which utilities occupy existing highway rights-of-way, highway renewal projects are prone to setbacks related to mismanaged relocation of existing utilities. Lack of accurate information on the location of underground or overhead utility assets, inadequate estimation of the time and budget needed to conduct utility relocation activities, and insufficient coordination and cooperation between transportation agencies and utility companies are among key factors that contribute to construction delays. To improve performance, DOTs and UCs need to resolve the fundamental issues. The research identified strategies for management techniques, process structure, and application of technology. Successful implementation of the strategies require the following initiatives: • Operate as a team. DOTs and UCs need to operate as a team, interacting and cooperating in a partnership with a commitment to common goals, continuous communication, and organizational leadership. All other coordination improvement initiatives depend on this key improvement. • View utilities in highway ROWs as a DOT responsibility. DOTs need to redefine their role to include being custodians of corridors that transport vehicles, people, power, communications, and other essential service to the public. As a unit of government, DOTs have a greater obligation than UCs to protect and provide for the interests of all citizens. • Understand and learn the technology and business processes of the other half of the DOT and UC team. Utility systems are complex; the highway design and construction process is multilayered. DOTs and UCs need to be able to speak the other's language and know how they do business. • Improve location methods and mapping technologies. The current commonly used utilities location process is inaccurate and insufficient. Improvements in location precision and comprehensiveness, plus cost-efficient improvements, would significantly improve utility coordination. Complete and timely information is essential.
Product Description(s)	(1) Final Report (*Integrating the Priorities of Transportation Agencies and Utility Companies*, SHRP 2 Report S2-R15-RW)—Documents current practices, opportunities for improvement, and

	anticipated barriers for integrating utility and transportation agency priorities in highway renewal projects. The report also provides a plan for future research in this field. Thirteen best practices that span the whole project life cycle are documented in a toolbox format in Chapter 4 of the report. Each summary includes implementation requirements, potential obstacles/barriers, and benefits associated with the practice. The best practices include the following: ▪ Advance Relocation of Utility Work. ▪ Early Involvement of Utilities in Planning and Design Phase. ▪ Training of DOT Designers on Utility Relocation Process. ▪ Development of a Geographic Information System Database. ▪ Preconstruction and Progress Meetings. ▪ Incentive for Early Relocation. ▪ Development of Utility and ROW Management Systems. ▪ Inclusion of Utility Relocation Work in DOT Construction Contract. ▪ Subsurface Utility Engineering. ▪ SUE Rating Procedures. ▪ Utility Coordination Meeting Held During Design Phase. ▪ Work Site Utility Coordination Supervisor. ▪ Utility Impact Matrix. The information presented is derived from a detailed review of literature and 28 interviews with highway designers, utility relocation specialists, and utility owners; as well as a panel of industry experts. The research was divided into two distinctive, although not explicit, phases. The first phase of the project focused on data gathering to identify existing institutional issues and processes that contribute to delays in planning, designing, and constructing highway renewal projects, as well as identifying proven innovative practices, policies, and procedures to mitigate these delays. The second phase focused on data analysis and development of recommendations. (2) Webinar—On August 10, 2011, SHRP 2 conducted a webinar entitled "Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research," which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15.
Product Status	(1) Final Report (*Integrating the Priorities of Transportation Agencies and Utility Companies*, SHRP 2 Report S2-R15-RW)—Available online at http://onlinepubs.trb.org/onlinepubs/shrp2/shrp2_S2-R15-RW.pdf and at http://www.trb.org/Publications/Blurbs/161801.aspx. (2) *Webinar (*Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research)—*Available online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf.

Target Audience	• Highway Agency
	  ➢ Project planners.
	  ➢ Project designers (pavements, structures, roadway).
	  ➢ Utility coordinators.
	  ➢ ROW coordinators.
	  ➢ Construction managers and engineers.
	• Other Stakeholders—Utility owners, one-call utility notification centers, consultants, contractors.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning. • Project Development—Initial site conditions assessment, all phases of design. • Contracting and Construction—Construction. • Management, Maintenance, and Operations—Asset management.
Pertinent Technical Areas	• Utility Coordination and Planning (between highway agency, utility companies, and contractors). • Utility Relocation.

	• Utility and ROW Management. • Subsurface Utility Engineering (SUE).

Implementations	• Implementations Performed as part of R15 Project
	  ➢ Project Level—None.
	  ➢ Program Level—Webinar ("Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research") conducted August 2011 explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B.
	• Post R15 Project Implementations
	  ➢ Project Level—The implementation stage of one small aspect of this project is contained in a new SHRP 2 activity, R15(C). It is being implemented on a small trial basis with the Maryland SHA, which is only using the spreadsheet matrix, not the full-blown database.
	  ➢ Program Level—None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • No project-level implementation paths. Project R15 was a study only, with no real products to implement. The two follow-on studies, R15B and R15(C), will lead to products for implementation. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • No program-level implementation paths. Project R15 was a study only, with no real products to implement. The two follow-on studies, R15B and R15(C), will lead to products for implementation.

Barriers/Challenges and Ways to Overcome Them	• The main barrier to implementation is the internal DOT resistance to change. Most DOTs wait until later in the project to address utility conflicts, when it is too late to most effectively mitigate their effects.
	  ➢ Coordination works best when implemented at the beginning stages of a project.
	• DOTs continue to expect utility owners to know where their utilities are in the right-of-way and to keep permanent records. Also, DOTs find it easy to tell a utility owner to move their utility, especially if it is at their cost. This is not always in the best interest of the citizen (rate payer versus taxpayer issue).
	  ➢ The utility coordination process is a shared responsibility between utility owners and the DOT. Greater coordination, communication, and information sharing can help avoid conflicts.
	• Lack of educational and training opportunities in utility coordination is another barrier. Most DOT utility coordinators are not well trained in CADD.
	  ➢ ASCE and AASHTO are working on a solution to the training issue.

Project Key Words	Locating, surveys, one-call, geographic information systems (GIS), utility mapping, utilities, right-of-way (ROW), subsurface utility engineering (SUE), utility coordination, utility relocation, utility accommodation.

Project Cost: $250,000

Expanded Summary for Renewal Project R15B (*Identification of Utility Conflicts and Solutions*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Texas A&M Transportation Institute (TTI)—Cesar Quiroga
Project Status and Time Frame	Completed—March 4, 2009 through July 3, 2011
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Utilities
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Reduced project delays and work zone traffic impacts through: ▪ Comprehensive and quicker identification of utility conflicts (e.g., unexpected encounters of utility installation, unavailable or incorrect information about existing utility installations, damage to existing utility installations) ▪ Identification of effective resolutions and the overall management of conflicts. • Saves Lives ➢ Reduced lane closures minimize potential safety issues.
Project Objectives	• To provide tools and methodology for identifying and resolving utility conflicts that public agency and utility professionals can use to improve the project development process. Specific objectives include: ➢ Review trends around the country and identify best practices on the use of utility conflict matrices (UCMs). ➢ Develop a recommended UCM and document related processes. ➢ Develop training materials for implementing the UCM and related process.
Summary of Findings	Key findings of an initial online survey of state highway agencies (SHAs) (103 responses from 34 states) and a series of follow-up interviews with some of these SHAs (38 interviews with representatives from 23 states) were as follows: ➢ Tables/spreadsheets are common utility conflict management tools. ➢ There is a wide range of styles and contents used in tracking utilities and identifying utility conflicts. ➢ SHAs track a wide range of utility facility data items, the most common of which include class of utility facility, utility owner name and contact information, and basic utility facility details (e.g., utility diameter, material, and depth of cover). ➢ Project centerline and station is the most popular method for referencing utility conflicts along transportation project alignments. Other referencing methods used include route and mile point, control section and distance, and route markers and displacement. ➢ A variety of data management platforms are used by SHAs to manage utility conflict data, the most common being spreadsheets, word processors, and CAD. ➢ Various methods to track and update utility conflict locations on project drawings are used. The main preference is for traditional paper-based approaches (i.e., markups on printed drawings or maps); markups on CAD files and 2-D PDF files are increasingly accepted. ➢ Many SHAs follow the traditional approach for utility conflict management in which the

	agency sends a set of project plans to utility owners, the utility owners provide markups of their utility facilities (typically on hard copies), and the agency (or consultant) transcribe the markups onto design CAD drawings. ➢ The start of utility coordination varies. About 70 percent of SHAs frequently or always start utility conflict management during preliminary design or earlier. By the 60-percent design stage, roughly 85 percent of SHAs have frequently or always started utility conflict management. ➢ Some agencies prefer to begin utility relocations once the roadway design is complete and there is certainty the project will go forward as designed. Other agencies attempt to relocate all utility facilities in conflict by the time a project goes to letting. ➢ A review of 26 sample tables used by SHAs to manage utility conflicts indicated a wide range of styles and content used to develop and maintain UCMs. A total of 144 data items were identified and grouped into 12 categories: projects, project contacts, utility facilities, utility conflicts, right-of-way, utility investigations, utility relocation, utility coordination dates, agreements, costs, billings, and document tracking data. ➢ SHA recommendations regarding UCM development included the following: <u>Utility Conflict Matrix</u> ▪ Identify utility conflicts at the individual utility facility involved. ▪ Include control dates in UCMs to document progress within the project development process. ▪ Develop utility conflict sheets for individual utility owners. ▪ Keep UCMs simple. ▪ Maintain and update the UCM regularly. ▪ Use an 11×17-in. page size for utility conflict tables. ▪ Start assembling utility conflict tables during preliminary design. ▪ Include data from UCMs in PS&E assemblies. <u>Utility Conflict Management</u> ▪ Use document management systems to support the utility conflict management process. ▪ Conduct plan-in-hand field trips with utility owners. ▪ Use one-call services to identify utility owners and facilities early in the process. ▪ Use and document RFID tags for damage prevention during construction. ▪ Provide 3-D design details to utility owners early in the design phase. <u>Other</u> ▪ Involve stakeholders in the review of utility conflicts and solutions. ▪ Develop effective communications with utility owners regardless of reimbursement eligibility. ▪ Provide training to utility coordination stakeholders. Information and results of the SHA surveys and interviews provided the foundation for the development of the prototype stand-alone UCM and prototype UCM data model and database. Testing of the prototype data model was performed using a Microsoft Access® database implementation and data from sample utility conflict tables obtained from different SHAs. Work sessions held with the California, Georgia, and Texas DOTs resulted in minor modifications to the UCM and ideas and suggestions for training materials and implementation of research results. Following the development of training materials, two pilot workshops were conducted, leading to a revised and final set of training materials.
Product Description(s)	(1) Utility Tracking and Analysis Tools: Due to the wide variety of project and utility complexity, a tiered approach of tools was developed. These tools identify potential conflicts and analyze the best solution for each problem. Two of the prototype tools developed in the project are: a) *Utility Conflict Matrix (Prototype 1)*: This is a stand-alone Excel spreadsheet that includes a main utility conflict table and a supporting worksheet to analyze utility conflict resolution strategies. It was designed for simple projects and with the intent to satisfy the requirements of the majority of states. The UCM includes data items in two main sections: the UCM header

	(eight data items that include information about the project and control data items) and the UCM body (15 data items that include information about individual utility conflicts, such as conflict characteristics, data collection needs, and resolution status). b) *Utility Conflict Data Model and Database (Prototype 2)*: This is a robust, expandable UCM representation that enables the management of utility conflicts in a database environment. It includes a utility database (Microsoft Access®) and a data model (i.e., a visual interface system) in the form of an AllFusion Erwin Data Modeler that can be easily exported to databases such as Oracle and SQL Server. (2) Final Report (*Identification Of Utility Conflicts And Solutions*, SHRP 2 Report S2-R15B-RW)—Documents how a survey of state DOT practices regarding utility conflict identification was performed, the results of the survey, and follow-up interviews. Provides a sample utility conflict analysis and a merge of the sample with the survey results. Identifies the best practices employed by various state DOT entities. Documents the development of a stand-alone UCM prototype and how that prototype was designed and tested. Provides details on how the prototype was tested in three states (CA, GA, TX) and the feedback from the participants and the changes to the prototype that resulted from the feedback. Provides training materials, implementation strategies and guidelines, and study recommendations. (3) Training Course Materials (*UCM Seminar Materials*)—Includes a lesson plan and presentation materials (PowerPoint slides, presenter notes, participant handouts, and companion CD) to assist with dissemination of R15B findings. The 1-day UCM training course is divided into six lessons: ➢ Lesson 1: Introductions and seminar overview. ➢ Lesson 2: Utility conflict concepts and SHRP 2 Renewal Project R15B research findings. ➢ Lesson 3: Utility conflict identification and management. ➢ Lesson 4: Hands-on utility conflict management exercise. ➢ Lesson 5: Use of database approach to manage utility conflicts. ➢ Lesson 6: Wrap-up. (4) Pilot Training Course (*Pilot UCM Seminar*)—The first of two pilot courses was held in January 2011 at the Arkansas State Highway and Transportation Department (SHTD). A total of 20 participants from FHWA, the Arkansas SHTD, and county agencies involved in design, right-of-way, and utility coordination participated. (5) Pilot Training Course (*Pilot UCM Seminar*)—The second of two pilot courses was held in January 2011 at the South Dakota Department of Transportation (SDDOT). A total of 27 participants from SDDOT who work on project development, design, right-of-way, and utility coordination participated. (6) Webinar (*Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research*)—On August 10, 2011, SHRP 2 conducted this webinar, which explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B. Information on the problems addressed by the research, the research approach, and the research products (including how these products can be used and when they will be available) was presented, preceded by some background discussion of the derivative SHRP 2 Projects R01 and R15. (7) Webinar (*New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis*)—On February 15, 2012, SHRP 2 conducted this similar webinar, which explored new tools for underground utility location, data collection, and analysis. This webinar was again based on SHRP 2 Projects R01A, R01B, R01C, and R15B.
Product Status	(1) Utility Tracking and Analysis Tools a) *Utility Conflict Matrix (Prototype 1)*—Available online at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Training_Materials_for_Identification_of_Utility_Conflicts_and_Solutions_709.aspx. b) *Utility Conflict Data Model and Database (Prototype 2)*—Available online at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Training_Materials_for_Identification_of_Utility_Conflicts_and_Solutions_709.aspx. (2) Final Report (*Identification of Utility Conflicts and Solutions*, SHRP 2 Report S2-R15B-RW-1)—Available online at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2_S2-R15B-RW-1.pdf.

	(3) Training Course Materials (*UCM Seminar Materials*)—Available online at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Training_Materials_for_Identification_of_Utility_Conflicts_and_Solutions_709.aspx. (4) Pilot Training Course (*Pilot UCM Seminar*)— (5) Pilot Training Course (*Pilot UCM Seminar*)— (6) Webinar (*Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research*)—*Available online at* http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2011-08-10.pdf. (7) Webinar (*New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis*)—Available online at http://onlinepubs.trb.org/onlinepubs/shrp2/webinar_2012-02-15.pdf.

Target Audience	• Highway Agency
	  ➢ Project planners.
	  ➢ Environmental engineers.
	  ➢ Project designers.
	  ➢ Utility coordinators.
	  ➢ ROW coordinators.
	  ➢ PS&E Engineers.
	  ➢ Construction managers and engineers.
	• Other Stakeholders—Design consultants, contractors, utility owners, utility contractors, SUE consultants, FHWA, AASHTO.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning. • Project Development—Initial site conditions assessment, all phases of design. • Contracting and Construction—Construction. • Management, Maintenance, and Operations—Asset management, one-call responses.
Pertinent Technical Areas	• Utility Coordination and Planning (between highway agency, utility companies, and contractors). • Utility Relocation. • Utility and ROW Management. • Subsurface Utility Engineering (SUE).

Implementations	• Implementations Performed as part of R15B Project
	  ➢ Project Level—Tested and documented UCM Prototypes 1 and 2 using Utility Conflict Tables/Data from CA, GA, and TX.
	  ➢ Program Level
	  ▪ 2 Pilot Training Courses in AR and SD.
	  ▪ Webinar (“Advancing Technologies for Working with Underground Utilities: Current SHRP 2 Research”), conducted August 2011, explored four active SHRP 2 utility-related research projects: R01A, R01B, R01C, and R15B.
	  ▪ Webinar (“New SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis”) conducted Feb 2012.
	• Post R15B Project Implementations
	  ➢ Project Level—A follow-on project, R15(C), is underway with the Maryland SHA to do a trial small-scale implementation.
	  ➢ Program Level—None.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway	<u>Problems/Issues/Constraints—Corresponding Needs</u> • A major highway project has several utilities involved, with little margin of error in several locations—Need to enact a comprehensive design process with full interaction among agency designers and utility companies and leveraging of innovative solutions for avoiding the need for utility relocations. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation.

project)	• Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway. • Geographic Location (Setting and Climate)—Any setting (but usually urban or suburban); Any climate. • Geometrics—Any. • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • A highway agency is experiencing, on a recurring basis, delays in the construction schedule, in large part due to unexpected encounters with utilities—Need to establish a process and system for identifying, storing, and tracking utility location data.
Barriers/Challenges and Ways to Overcome Them	• The largest barrier to implementation is the reluctance of DOT utility coordinators to want to document utility conflicts and populate the matrix with data. They would rather prefer the utility owners do it. It is a change in the way they do business and they don't have the skills, the training, or the desire to do it. ➢ Establish and conduct workshops and training to demonstrate the benefits of UCM.
Project Key Words	Surveys, one-call, geographic information systems (GIS), utility mapping, utilities, right-of-way (ROW), subsurface utility engineering (SUE), utility coordination, utility relocation, utility accommodation, utility conflicts, utility conflicts matrix (UCM), utility conflict management.

Project Cost: $300,000

Expanded Summary for Renewal Project R16
(*Railroad-DOT Institutional Mitigation Strategies*)

SHRP 2 Program Officer	Monica Starnes
Contractor and PI Info	Gordon Proctor & Associates, Inc.—Gordon Proctor
Project Status and Time Frame	Completed—January 2008 through October 2009
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Railroads

Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money
	  ➢ Timely and reliable project reviews and better internal railroad coordination result in fewer project delays, less rework, and reduced project costs.
	• Saves Lives
	  ➢ Consistent/standardized design requirements deliver safer projects for railroad and highway users.
	  ➢ Standardized construction zone requirements result in safer work zones.

Project Objectives	• To identify strategies and institutional arrangements that can facilitate beneficial relationships between railroads and public agencies; investigate and develop innovative partnering techniques whereby railroads and the highway community are working cooperatively; develop draft model agreements and streamlined permitting processes; and identify barriers that impact effectiveness and propose remedies, including alternate project delivery techniques (such as design-build).
Summary of Findings	• Few metrics or widely recognized standards exist for performance in conducting railroad reviews, agreements, or approvals. • Highway agencies and railroads agree on best practices that expedite the review process. • Common problems include the inability to reimburse engineering review costs early in the project, the cost and availability of insurance, and right-of-way (ROW) appraisal processes. • Partnering to define successful outcomes, develop a level of service agreement, and maintain communications could be helpful to the agreement process.
Product Description(s)	(1) Final Report (*Strategies for Improving the Project Agreement Process between Highway Agencies and Railroads* [SHRP 2 Report S2-R16-RR-1])—Provides a comprehensive collection of recommended practices that promote cooperation between railroads and transportation agencies on highway projects that cross or lie alongside railways. The report presents standard processes and successful practices that can help both sides reduce the time and cost of project reviews. (2) Model Agreements (Appendix C of Final Report)—Contains composites incorporating provisions of model agreements collected from various highway agencies and railroads. These agreements provide a comprehensive list of provisions that, if adopted, would streamline the agreement process while protecting the rights and obligations of both the highway agencies and the railroads. These are offered as generic, basic structures that can be modified to meet the legal requirements and accepted contracting processes of individual agencies and railroads. Proposed model agreements include a partnering memorandum of understanding, master project agreement, preliminary engineering agreement, resurfacing agreements, highway overpass agreement, warning devices agreement, and pipe and wire agreement. (3) Webinar—On August 31, 2011, TRB conducted a webinar that explored the R16 Final Report. Panelists discussed model standard agreements, standard processes, and practices that will help public highway agencies and railroads reduce the time and cost of project reviews.

	(4) Webinar (*DOT and Railroad Collaborations: Best Practices for Expediting Agreements and Successfully Delivering Projects [SHRP 2 R16]*)—1.5-hour webinar consisting of seven parts: (1) brief overview of SHRP 2, (2) problems and perspectives of DOTs and Railroads, (3) examples of best practices and processes, (4) implementing the partnership process at project and program levels, (5) sustaining best practices and model processes, (6) benefits and impact on practice, and (7) implementation plans and opportunities.
Product Status	(1) Final Report (*Strategies for Improving the Project Agreement Process between Highway Agencies and Railroads* [SHRP 2 Report S2-R16-RR-1])—Available online at http://www.trb.org/Railroads/Blurbs/164283.aspx, as an e-book through Google, and as a hard copy through the TRB bookstore (http://books.trbbookstore.org/shrp2report.aspx). (2) Model Agreements (Appendix C of Final Report)—Available online at http://www.trb.org/Railroads/Blurbs/164283.aspx, as an e-book through Google, and as a hard copy through the TRB bookstore (http://books.trbbookstore.org/shrp2report.aspx). (3) Webinar—A recording of the webinar is available online at http://www.trb.org/ElectronicSessions/Blurbs/TRB_Webinar_Railroad_DOT_Institutional_Mitigation_165714.aspx. (4) Webinar (*DOT and Railroad Collaborations: Best Practices for Expediting Agreements and Successfully Delivering Projects [SHRP 2 R16]*)—Conducted July 9, 2013. Available online at http://www.trb.org/Law/Blurbs/169188.aspx.

Target Audience	• Highway Agency
	  ➢ Railroad liaison engineers/rail project coordinators.
	  ➢ Construction managers and engineers.
	  ➢ Project managers.
	  ➢ Utility engineers.
	  ➢ Project designers (geotechnical, pavements, structures).
	  ➢ ROW engineers.
	  ➢ Traffic engineers.
	  ➢ Environmental engineers.
	• Other Stakeholders—Contractors, Railroads, Utility Companies

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning, programming. • Project Development—Engineering, safety, and environmental studies, ROW and permitting, design. • Management, Maintenance, and Operations—System operations.
Pertinent Technical Areas	• Highway agency–railroad company agreements related to planning studies; preliminary engineering studies; project design reviews; construction; long-term maintenance; routine maintenance; safety projects; railroad crossing closures, openings and grade separations; right-of-entry; and utility repairs/improvements.

Implementations	• Implementations Performed as part of R16 Project
	  ➢ Project Level—None.
	  ➢ Program Level—Webinar conducted Aug 2011.
	• Post R16 Project Implementations
	  ➢ AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 2)—R16 Implementation Assistance Program announced in 7/18/13 web conference. Application process runs from 8/2/13 thru 9/6/13. Announcement of recipients in October 2013.

Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Highway project is being developed that will cross a railroad right-of-way; not sure how to manage coordination with railroad—Need to have a Memorandum of Understanding with the railroad as partner to drive shared vocabulary, performance expectations, and definition of success.

manager can implement or further test the product(s) as part of an actual highway project)	• Federally funded project involves resurfacing highway section at railroad crossing; requires a solution to deliver smooth transitions to adjacent pavement sections—Need to select appropriate resurfacing agreement that reflects common needs of public agencies and railroads, including railroad-specific issues. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation, Maintenance/Preservation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Railroad Interactions • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Inadequate coordination between agency and railroad leading to delays in development or construction—Need to use standard agreements to quickly authorize reviews of safety, engineering, and operational impacts. • Increased project costs due to delays while waiting for railroad reviews and agreements—Need to establish a Master Project Agreement that is legally binding on both parties, including laying out funding responsibilities and compensation for required reviews and related activities. • Conflict over recurring issues in the agreement process between the agency and the railroad—Need to adopt a continuous improvement framework so that both sides are tracking performance and regularly conferring on ways to improve it.
Barriers/Challenges and Ways to Overcome Them	• Lack of recognized standards and common baselines of performance ➢ Need to incorporate best practices into model agreements that take into account both railroad and agency perspectives. • Increased railroad traffic volumes on existing and finite corridors will make railroads less tolerant of delays or encroachments ➢ Need to manage project reviews efficiently to expedite negotiations.
Project Key Words	Roadway, pavement, highway, railroad, cooperation, freight, review, standard agreement, best practices, continuous improvement, streamlined permitting, right-of-way (ROW), design standards, lines of communication.

Project Cost: $400,000

Expanded Summary for Renewal Project R16A
(*Communicating Railroad–DOT Mitigation Strategies*)

SHRP 2 Program Officer	Monica Starnes
Contractor and PI Info	StarIsis Corporation—Shobna Varma
Project Status and Time Frame	Ongoing—November 2011 through November 2013
SHRP 2 Renewal Product Category	• Utilities/Railroads
Highway Asset Area	• Railroads • Bridges (over railroads) • Pavements (under railroads, abutting railroads, and at-grade crossings)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Timely and reliable project reviews. ➢ Better internal railroad coordination. ➢ Improved mechanisms for access to rights-of-way. ➢ Consistent design requirements. ➢ Improved insurance and indemnification processes. ➢ Streamline project delivery to minimize impact on neighboring communities and businesses. ➢ Management of administrative costs and overheads. ➢ Escalate issues to upper levels of both DOTs and railroads for faster resolution. ➢ Manage cost escalations due to delays in agreement processing. ➢ Minimize delays due to issues of contractor and employee safety. ➢ Adoption of partnering and other project management techniques to expedite resolution of issues that delay agreement processing and project delivery. ➢ Collaboration to extend productive life of crossings by using better materials.
Project Objectives	• To create, establish, and maintain a joint committee or community of interest to share best practices and distribute model processes. • To identify and recruit "champion-pairings" (at least one state DOT and one Class I/II railroad pairing) to apply and pilot test the results of SHRP 2 Project R16.
Summary of Findings	Not currently available (waiting on publication of Final Report).
Product Description(s)	<u>Currently available products include:</u> (1) Community of Interest—Selected group of stakeholders representing Class I and II railroads, federal highway agencies, SHAs, local governments, and other relevant entities. (2) Community of Interest Kickoff Meeting—Held April 11, 2012 in Kansas City, MO. Informational materials distributed at meeting, meeting minutes and meeting recordings made. <u>Anticipated, but not currently available products include:</u> (3) Community of Interest Follow-up Meetings and/or Webinars—Meeting/webinar materials and reports. (4) Champion Railroad–DOT Pairings—Established pairings of a Class I/II railroad and a DOT to serve as champions for implementing the results of SHRP 2 Project R16 via signing a Memorandum of Understanding (MOU) to implement master agreements for a major highway/rail project or program. (5) Case Report—Documents lessons learned from the Champion Pairings and specifies best practices used by the Champion Pairings. (6) Implementation Plan—Presents plan for long-term sustainability of the Community of Interest. (7) Final Report—Documents the research activities and presents the results and recommendations.

Product Status	(1) Community of Interest—Established prior to April 11, 2012 Kickoff Meeting. (2) Community of Interest Kickoff Meeting—Not officially available through SHRP 2, but information from the R16A Community of Interest Kickoff Meeting is available online at StarIsis website at http://starisis.com/R16_COI_meeting_page. (3) Community of Interest Follow-up Meetings and/or Webinars—Expected in future. (4) Champion Railroad–DOT Pairings—Expected in future. (5) Case Report—Expected in future. (6) Implementation Plan—Expected in future. (7) Final Report—Expected in future.
Target Audience	• Highway Agency ➢ Executives/administrators (Chief Executive Officers, Chief Engineers, and other senior DOT personnel [financial, audit, legal counsel, planning, real estate, etc.]). ➢ Contracting officers. ➢ Construction managers and engineers. ➢ Railroad liaison engineers/rail project coordinators. ➢ Project managers. ➢ Utility and ROW engineers. ➢ Project designers (geotechnical, pavements, structures). ➢ Traffic and safety engineers. ➢ Environmental engineers. • Other Stakeholders—Contractors, Railroads, Utility Companies
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning, programming. • Project Development—Engineering, safety, and environmental studies, ROW and permitting, design. • Contracting and Construction—Project Construction with emphasis on Design-Build. • Management, Maintenance, and Operations—System operations.
Pertinent Technical Areas	• Highway agency–railroad company agreements related to planning studies, preliminary engineering studies, project design reviews, construction, long-term maintenance, routine maintenance, safety projects, railroad crossing closures/openings and grade separations, right-of-entry, and utility repairs/improvements.
Implementations	• Implementations Performed as part of R16A Project ➢ Project Level—None. ➢ Program Level—None. • Post R16A Project Implementations—None
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Standard agreements for a DOT-railroad partnership are in place; not sure how to handle modifications and resolve technical issues—Need to establish a central point of contact that can help with any additional coordination, prioritize, and keep the project on schedule. • Highway project that involves interaction with railroads requires special design and project development expertise—Need to select a suitable engineering firm that can demonstrate experience with railroad requirements. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation, Maintenance/Preservation • Asset Type/Renewal Product Category—Pavements, Bridges/Structures, General Roadway • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Railroad Interactions • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program	<u>Problems/Issues/Constraints—Corresponding Needs</u>

Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	• Insufficient dissemination of innovations to support the adoption of streamlined processes between transportation agencies and railroads—Need to use peer testimony and example to drive adoption until it reaches a tipping point to spread to a larger population. • Fear of risk or the perception of a high cost of adoption in terms of money, time, and resources—Need to select practical and useful innovations that are ripe for adoption and acceptance by agencies.
Barriers/Challenges and Ways to Overcome Them	• Lack of understanding between agencies and railroads of each other's objectives and how to reach mutually acceptable agreements ➢ Need to create an ongoing forum for collaboration in developing model agreements and processes. • Lack of templates for later adopters of the process ➢ Need to create a readily accessible archive of case studies, agreements, model processes, and model projects.
Project Key Words	Roadway, pavement, highway, railroad, freight, cooperation, agreement processing, community of interest, standard agreement, best practices, continuous improvement, streamlined permitting, right-of-way (ROW), design standards, lines of communication.

Project Cost: $200,000

Expanded Summary for Renewal Project R19A (*Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems and Components*)

SHRP 2 Program Officer	Jerry DiMaggio
Contractor and PI Info	University of Nebraska, Lincoln—Dr. Atorod Azizinamini (now with Florida International University)
Project Status and Time Frame	Ongoing—December 2007 through December 2013
SHRP 2 Renewal Product Category	• Bridges
Highway Asset Area	• Structures (bridges)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Optimized system preservation through service life considerations being made in the design stage. ➢ Development of innovative subsystems, components, and elements that would provide higher levels of performance and result in reduced maintenance, work zones, and lane closures. • Saves Lives ➢ Improved safety through fewer lane closures and work zone restrictions brought about by longer bridge service life.
Project Objectives	• To improve existing systems, subsystems, and components that historically limited the service life of bridges. • To identify and provide promising concepts for alternative systems, subsystems and components. • To formalize consideration of service life-related issues at the design stage, similar to strength considerations.
Summary of Findings	• A significant portion of state DOT budgets are spent on maintenance issues resulting from a lack of comprehensive guidelines that address service life issues at the design stage in quantitative ways. Further, the design for service life is not approached in a comprehensive and systematic manner.
Product Description(s)	<u>Currently available products include the following:</u> (1) Guide Document (*Design Guide for Bridges for Service Life*, Pre-Publication Draft, 2013)—Summarizes in one document the entire range of knowledge needed by the bridge community to design both new and existing bridges for service life and durability. It presents a general framework for long-life design of bridges with spans of less than about 300 ft (although the framework can be adapted and customized for major and complex bridges with much longer spans), provides guidance in addressing the many design aspects (e.g., materials, bridge decks, corrosion of steel in reinforced concrete bridges, corrosion prevention in steel bridges, fatigue and fracture of steel structures, bridge joints, expansion devices, bridge bearings, pile fatigue and stability, and seamless bridge systems), and gives detailed example applications. It includes a fault tree flowchart that summarizes the factors that affect the service life of the bridge element or component under consideration. The Guide document consists of the 11 chapters listed below, covering the many different bridge elements and subsystems (e.g. piles, columns, girders, bridge bearings, deck joints) and components (i.e., substructure, superstructure, deck). For the most part, each chapter includes five categories of information pertaining to the bridge element/component under consideration: Descriptions, Factors that Affect Service Life, Mitigation Strategies, Optimum Selection Strategies, Examples and Tools. ➢ Chapter 1. Design for Service Life: General Framework—Presents the Guide approach to designing bridges for service life and summarizes the 12 steps for designing for service life for specific bridge elements, components, and subsystems:

	▪ Step 1. Identify the project requirements, particularly those that will influence the service life. ▪ Step 2. Identify feasible bridge systems capable of meeting the project demand. ▪ Step 3. Select each feasible bridge system one at a time and complete Steps 4 through 10. ▪ Step 4. Identify the factors that influence the service life of bridge elements, components, and subsystems, such as traffic and environmental factors. ▪ Step 5. Identify modes of failures and consequences. For instance, the corrosion of reinforcement causing corrosion-induced cracking and loss of strength. ▪ Step 6. Identify suitable approaches for mitigating the failure modes or assessing risk of damage, through life-cycle cost analysis (LCCA). For example, use of better performing materials for sliding surfaces in bearings or use of materials prone to deterioration at lower initial cost. ▪ Step 7. Modify the bridge element, component, or subsystem under consideration, using the selected strategy, and ensure compatibility of different strategies used for various bridge elements, components, or subsystems. This step may involve the need to develop several alternatives. ▪ Step 8. For each modified alternative, estimate the service life of the bridge element, component, or subsystem using Finite or Target Service Life Design approaches. ▪ Step 9. For each modified alternative, compare the service life of the bridge element, component, or subsystem to the service life of the bridge system and develop appropriate maintenance, retrofit, and/or replacement plan. ▪ Step 10. For each modified alternative, develop design, fabrication, construction, operation, maintenance, replacement, and management plans for achieving the specified design life for the bridge system. ▪ Step 11. For each modified alternative, conduct LCCA for each feasible bridge system meeting strength and service life requirements, and select the optimum bridge system. ▪ Step 12. When specified by the owner or in cases of major and complex bridges, document the entire design for service life processes in a document called the Owner's Manual. Conduct an independent review of the document and provide it to bridge owner at the time of opening the bridge to traffic. ➢ Chapter 2. Bridge System Selection—Describes the various bridge systems and factors that affect their service life. Provides a general strategy and rational procedure for selecting the optimum bridge system, subsystems, components, and elements, considering specific project limitations and requirements, such as climate, traffic, usage, and importance. ➢ Chapter 3. Materials—Provides general properties and durability characteristics of the two most commonly used materials in bridge systems—steel and concrete. For each material, discusses variables affecting the service life and mitigation strategies. ➢ Chapter 4. Bridge Decks—Describes various bridge deck types and essential information related to their service life, such as modes of deterioration and strategies to mitigate them. The focus is on cast-in-place and precast concrete bridge decks. ➢ Chapter 5. Corrosion Protection of Reinforced Concrete—Discusses basic mechanisms causing corrosion of reinforcement embedded in concrete and provides strategies for preventing corrosion of reinforcement in concrete bridges. ➢ Chapter 6. Corrosion Protection of Steel Bridges—Describes various coating systems using paint, galvanizing and metalizing, and describes corrosion resistant steel along with factors affecting service life. ➢ Chapter 7. Fatigue and Fracture—Provides basic information on fatigue and fracture and factors that cause fatigue and fracture in steel bridges. ➢ Chapter 8. Jointless Bridges—Discusses advantages, and disadvantages of various jointless bridge systems, and provides complete steps for design of jointless integral abutment bridges. Provides design procedures to extend the application of jointless integral bridges to curved girder bridges. ➢ Chapter 9. Bridge Expansion Devices—Describes various expansion joints used in practice, observed modes of failure for each, and potential mitigation strategies.

	➢ Chapter 10. Bridge Bearings—Describes various bearing types and lists the factors that affect service life of the various bearings with strategies to mitigate them. ➢ Chapter 11. Life-Cycle Cost Analysis—Provides essential information for incorporating LCCA in bridge system, subsystem, component, and element selection. Includes LCCA steps and elements. The Guide document provides a platform for developing customized manuals by individual state DOTs or for developing a customized and systematic approach for service life design of major and complex bridges. Anticipated, but not currently available products, include the following: (2) Final Report—Expected to document the entire research effort and presents results and recommendations. The final report will include descriptions of innovative subsystems, components, and elements developed through conduct of proof-of-concept tests. The innovative subsystem, component, and elements developed include: seamless bridge systems, self-stressing methods for bridge decks, higher performing sliding surfaces and new details for expanding application of jointless bridges to larger bridge lengths. (3) Webinar (Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems, and Components)—1.5-hour web presentation on R19A.
Product Status	(1) Guide Document (*Design Guide for Bridges for Service Life*, Pre-Publication Draft, 2013)—Available online at www.trb.org/Main/Blurbs/168760.aspx. (2) Final Report—Expected to be made available in late 2013. (3) Webinar (Bridges for Service Life Beyond 100 Years: Innovative Systems, Subsystems, and Components)—Scheduled for October 29, 2013. Details available at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/SHRP2Webinars.aspx.
Target Audience	• Highway Agency ➢ Bridge designers. ➢ Bridge engineers. ➢ Maintenance engineers. ➢ Materials engineers. • Other Stakeholders—Consultants, contractors.
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Engineering, preliminary and final design; PS&E. • Program Development—System planning; programming. • Management, Maintenance, and Operations—Bridge maintenance and preservation.
Pertinent Technical Areas	• Bridge design (decks, corrosion prevention, fatigue and fracture, bridge bearings, expansion devices, jointless bridges). • Bridge materials. • Bridge system selection. • Bridge rehabilitation, maintenance, and preservation. • Bridge life-cycle cost analysis. • Bridge construction techniques.
Implementations	• Implementations Performed as part of R19A Project ➢ Project Level—None. ➢ Program Level—Bridges for Service Life Beyond 100 Years Webinar (scheduled for October 29, 2013). • Post R19A Project Implementations ➢ Project Level—None. ➢ Program Level—None.
Functional/Technical Level Implementation	Problems/Issues/Constraints—Corresponding Needs • Bridge preservation helps extend the service life of a bridge—Need to use the guide and other

Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	resources to implement preservation activities for individual components of the bridges. • Regional collaboration is good for implementation of preservation activities—Need to attend regional and national conferences where preservation activities are discussed to develop a toolbox of useful activities for an agency. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation. • Asset Type/Renewal Product Category—Bridges. • Geographic Location (Setting and Climate)—Any setting; Any climate. • Geometrics—Limited to spans less than 300 ft • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Training is required to properly implement bridge preservation activities. ➢ Need to have maintenance and management personnel attend specific training for bridge preservation. • Life-cycle costs need to be considered when designing bridges. ➢ Need to implement a policy that looks at life-cycle costs of installation, maintenance, and repair to determine to most cost-effective components for bridges.
Barriers/Challenges and Ways to Overcome Them	• Changing the mindset form "worst first" to looking at taking rehabilitation/replacement dollars and implementing preservation activities. ➢ Need to establish training for all levels of bridge staff to demonstrate the benefits of a preservation-based approach. • The Guide is presented as an updatable document with room for improvements in key areas, including movement from forecasted deterioration models to actual models that are based on real field data, specific LCCA tools dedicated to bridges (with the ability to incorporate user costs), and more comprehensive design examples. ➢ Need to develop a plan of action for continued development of Guide, including strategies for developing appropriate mechanistic deterioration models and generating bridge condition/performance data, strategies for developing more robust LCCA tools, and strategies for developing more comprehensive and authentic designs. Case studies, demonstration projects, and/or accelerated test studies could be viable means for the strategies. The FHWA database may be a valuable resource, but it still requires several more years of data collection. • The Guide is a very lengthy document with a lot of detailed information that can be overwhelming to many users. ➢ Need to automate the use of the Guide by developing tools that would facilitate navigating through all of the detailed information.
Project Key Words	Service life, bridges, design, existing systems, subsystems, maintenance, proof-of-concept, conceptual development

Project Cost: $1,999,637

Expanded Summary for Renewal Project R19B (*Bridges for Service Life Beyond 100 Years: Service Limit State Design*)

SHRP 2 Program Officer	Jerry DiMaggio
Contractor and PI Info	Modjeski and Masters, Inc.—John Kulicki, PhD, PE
Project Status and Time Frame	Ongoing—September 2008 through December 2013 (expected)
SHRP 2 Renewal Product Category	• Bridges
Highway Asset Area	• Structures (bridges)
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Extending the service life of bridges will reduce the frequency and cost of rehabilitating and replacing them over time. • Saves Lives ➢ Enhanced bridge designs will reduce the frequency of work zones associated with bridge preservation, rehabilitation, and reconstruction activities, and therefore improve the safety of workers and users.
Project Objectives	• To develop new design codes that incorporate a rational approach based on service limit states (SLS) for durability and performance of bridge systems, subsystems, components and details that are critical to reaching the expected service life and assuring an actual life beyond 100 years. Special focus should be given to problematic systems, subsystems, components and details. The proposed SLS will include data sets related to durability, fatigue, fracture, and redundancy as integral issues of service life as reported in SHRP 2 Project R19-A. • To develop performance measures, incorporating predefined component classifications that will utilize full probability-based service life design criteria to maximize the actual life of the system. Consider material performance (including durability), structural performance of systems, subsystems, and components (optimum joints and bearings) and design practices leading to longer and more predictable service life. • To develop comprehensive design procedures, proposed specification changes, and implementation tools that include durability design in addition to structural design. In the conduct of this development, consider structural and material redundancy, and system, subsystem and component performance measures that will utilize service life design criteria to maximize the actual life of the system. The adjustments to SLS should not adversely affect ultimate limit state (ULS) and extreme event limit states.
Summary of Findings	• Many bridge components are designed and constructed based on proven ULS performance without regard for SLS. If bridge designers had a greater number of SLS design options for problematic bridge components, better decisions could be made and bridge systems could be designed to deliver a 100+ year service design life. However, to date, limited statistical effort has been dedicated to the development of new components, systems and approaches to better provide for a satisfactory performance using the SLS methodology.
Product Description(s)	<u>Anticipated, but not currently available products include:</u> (1) Final Report—Expected to document the entire research effort and present results and recommendations. (2) Framework for Specification Calibration—Incorporates nine steps: (a) Formulate limit state function and identify variables; (b) Identify representative structures and design cases; (c) Identify load and resistance parameters; (d) Develop statistical models for loads and resistances; (e) Develop reliability analysis procedures; (f) Calculate probability of failure for current designs and practices;

	(g) Select target probabilities; (h) Select potential load and resistance factors: (i) Calculate with new factors, revise as needed. (3) Calibrated SLS Load and Resistance Factors—Results to be transparent to LRFD users; Results captured in: LRFD Load Combinations Table, table of resistance factors, spec and commentary provisions. (4) Bridge Design Procedure and Proposed Specifications—Current service limit states will be calibrated and include: live load deflections, bearing movements, settlement of foundations and walls, permanent deformations and compact steel components, fatigue of structural steel and the steel reinforcement in concrete (through NCHRP 12-83), and slip-critical bolted connections. (5) Toolkit—Tools required for future service limit state improvements, including framework used for SLS calibration, databases (including a well-defined data format), software tools used in the SLS calibration, Monte Carlo spreadsheets, instructions for developing new or revised spreadsheets, set of resistance deterioration models, and brief users' manuals with examples. (6) Specification Design for Durability Product—Specification changes that include design for durability. (7) Implementation Framework—This modified framework would incorporate seven of the original nine steps outlined in the Framework Product and could form the basis of an administrative tool to be utilized by DOTs to track changes in the reliability index based on information from the field. The current serviceability would be determined based on the initial reliability indices, the terminal reliability indices, and the current reliability indices based on the current observed condition. This would form the basis of tracking the aging structure, utilizing the same basic probabilistic underpinning and data bases used for the calibration of the SLS. The terminal reliability index would be the safety level at which a bridge or component of a bridge would have to be taken out of service for either a major rehabilitation or replacement.
Product Status	(1) Final Report—Expected delivery by end of 2013. (2) Framework for Specification Calibration—Continual development through Phase 2; expected delivery to take place by end of 2013. (3) Calibrated SLS Load and Resistance Factors—Continual development through Phase 2. Expected delivery to take place by end of 2013. (4) Bridge Design Procedure and Proposed Specifications—Timeline calls for having some of the concrete service limit states available for consideration at the 2012 SCOBS Meeting (early July 2012), with the rest of the limit states available for the 2013 meeting. (5) Toolkit—Expected delivery of fall 2013, with possibility of extending to end of 2013. (6) Specification Design for Durability Product—Any durability-related design information that R19B might develop, other than that necessary to effectuate one of the limit states, will probably be turned over to the R19A group for inclusion in the *Guide for Bridges for Service Life*. Completion by 2014. (7) Implementation Framework—Work to start in late 2012 with lead states utilizing the system by about 2014.

Target Audience	• Highway Agency
	  ➢ Specification developers.
	  ➢ Bridge designers.
	  ➢ Bridge inspectors.
	  ➢ Program managers.
	  ➢ Bridge maintenance engineers.
	• Other Stakeholders—Consultants, contractors.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Project Development—Engineering, preliminary and final design; PS&E. • Program Development—System planning/programming, system operations. • Management, Maintenance, and Operations—Bridge performance monitoring and management, bridge maintenance and preservation.
Pertinent Technical Areas	• Bridge design (including design codes based on SLS). • Bridge specification development.
Implementations	• Implementations Performed as part of R19B Project

	➢ Project Level—None. ➢ Program Level—None. • Post R19B Project Implementations ➢ Project Level—None. ➢ Program Level—None.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints—Corresponding Needs • Designing structures that take into account a rational approach based on SLS for durability and performance—Need to adopt new codes once implemented. Project Characteristics • Project Type—Greenfield, Reconstruction, Rehabilitation. • Asset Type/Renewal Product Category—Bridges. • Geographic Location (Setting and Climate)—Any setting; Any climate. • Geometrics—Any. • Conflicting Features—Any. • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any. • Highway System—Any. • Functional Class—Any.
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • Accounting for durability and performance in the design of bridge components. ➢ Need to provide input to the development of AASHTO design specifications based on recommendations from Project R19B.
Barriers/Challenges and Ways to Overcome Them	• Adoption of these new specifications will require looking not at just the least initial cost, but life-cycle cost for the components of the bridge. ➢ Need to establish training for all levels of bridge staff to demonstrate the benefits of a preservation-based approach.
Project Key Words	Service limit, service limit states (SLS), design, specification, calibration, improvements, durability, reliability, rapid renewal, reliability theory

Project Cost: $1,000,000

Expanded Summary for Renewal Project R21
(*Composite Pavement Systems*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Applied Research Associates, Inc. (ARA)—Dr. Mike Darter
Project Status and Time Frame	Completed—September 2007 through June 2012
SHRP 2 Renewal Product Category	• Pavements
Highway Asset Area	• Pavements
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Increased performance of new composite pavements through improved design procedures and advanced construction practices, leading to: ▪ Reduced user delay and traffic disruptions (fewer and less frequent future maintenance/rehabilitation interventions and corresponding lane closures). ▪ Reduced life-cycle costs (thicker lower-cost bottom layer with recycled content, thinner high-quality surface layer that is renewable). ▪ Decreased risk of premature failure. ▪ Improved sustainability.
Project Objectives	• To investigate the design and construction of new composite pavement systems (not those resulting from the rehabilitation of existing pavements) for all levels of highway and urban streets. Specifically: ➢ To determine the behavior and identify critical material and performance parameters of composite pavement systems under many climate and traffic conditions. ➢ To evaluate, develop, and validate mechanistic-empirical performance models and design procedures consistent with the Mechanistic-Empirical Pavement Design Guide (MEPDG). ➢ To develop practical recommendations for construction specifications and techniques, life-cycle costing, and quality management procedures and guidelines. The research will focus on two promising applications of composite pavement systems: ➢ HMA/PCC—A thin, high-quality hot-mix asphalt (HMA) surface layer over a new, structural portland cement concrete (PCC) layer (e.g., jointed plain concrete [JPC], continuously reinforced concrete [CRC], jointed roller compacted concrete [RCC], lean concrete base [LCB], or cement-treated base [CTB]). ➢ Two-lift PCC/PCC—A thin, high-quality PCC surface layer over a thicker, structural PCC layer (e.g., JPC, CRC).
Summary of Findings	• The previous technology for the design and construction of new composite pavements was limited, with a major lack of understanding of the structural and functional performance of composite pavements and no developed mechanistic-empirical performance models for composite pavements. • European countries have been constructing HMA/PCC and PCC/PCC composite pavements for several decades and have substantial experience. • Composite pavements have been proven to provide long lives with excellent surface characteristics (low noise, good initial smoothness, and high friction), structural capacity, rapid renewal when needed, and to utilize recycled and lower-cost materials in the lower PCC layer Both HMA/PCC and 2-lift PCC/PCC pavements have strong technical, economical, and sustainability merits in fulfilling the key goals of the SHRP 2 program (i.e., long-lived, rapid renewal, and sustainable pavements). • Certain distress types that occur regularly in conventional HMA pavements and conventional PCC pavements can be avoided or greatly minimized with HMA/PCC pavements (e.g., bottom-up and top-down fatigue cracking, transverse low-temperature or shrinkage cracking in HMA). Moreover,

	because the HMA layer reduces temperature and moisture gradients in the underlying PCC slab, a reduction in load and related stresses occurs which dramatically increases the structural capacity of the PCC. • MEPDG and the new AASHTO DARWin-ME software can model HMA/PCC structural and functional performance reasonably well, although there are some limitations with respect to rutting, reflection cracking, and IRI (the reflection cracking model outlined in NCHRP Report 669 is recommended instead of the DARWin-ME model). New HMA/PCC pavement can be designed using the overlay design feature in DARWin-ME. • Certain distress types that occur regularly in conventional PCC pavements can be avoided or minimized with 2-lift PCC/PCC pavements (e.g., top-down fatigue cracking, polishing of surface friction). • New PCC/PCC pavement can be designed using MEPDG model version R21 1.300, which includes modifications to allowable PCC layer thickness, representative PCC layer properties, slab and base interaction properties, and PCC/PCC subgrade response modeling.
Product Description(s)	Currently available products include: (1) First Fruits Report (*2008 Survey of European Composite Pavements*, SHRP 2 Report S2-R21-RW1)—Documents a survey of in-service composite pavement sites in the Netherlands, Germany, and Austria that was conducted in May 2008 to assess the design, construction, and performance of composite pavement systems. These pavement systems were deliberately designed and constructed as composite pavements and had been in service under heavy vehicle loading for 10 to 20 years. The survey included field reviews of 16 composite pavement projects with various designs, including porous asphalt on CRC, stone matrix asphalt (SMA) on JPC, SMA on CRC, two-lift PCC on PCC and two-lift exposed aggregate concrete (EAC) on PCC. The report also discusses other issues that should be considered in the design and construction of new composite pavement systems. The information gathered for this report was used in the design and development of a plan to test composite pavements under SHRP 2 R21. (2) Final Report (*Composite Pavement Systems: Volume 1–HMA/PCC Composite Pavements*, SHRP 2 Report S2-R21-RR2; *Composite Pavement Systems: Volume 2–PCC/PCC Composite Pavements*, SHRP 2 Report S2-R21-RR3)—Presents the state-of-the-practice and corresponding guidelines for designing and constructing HMA/PCC and PCC/PCC composite pavements. The work effort consisted of a literature review; surveys of national and international highway agencies; evaluation of existing pavement design procedures and models (MEPDG/DARWin-ME, CalME, National Cooperative Highway Research Program (NCHRP) Report 669, NCHRP 9-30A); field surveys and data collection for 16 composite pavements located in three European countries (Netherlands [5], Germany [8], and Austria [4]) and 46 composite pavements (34 HMA/PCC and 12 PCC/PCC) located in the U.S. and Canada; construction and monitoring of composite pavement test sections at MnROAD, University of California Pavement Research Center (UCPRC), and Illinois Tollway; development of a composite pavement database; analysis of data; performance modeling and validation; and the development of design guidelines and procedures, construction specifications and guidelines, and life-cycle costing techniques. The final report contains several specific products, which are described in detail below. (3) Final Report Supplemental Materials ("Composite Pavement Systems: Final Report Appendices," Pre-Publication Draft)—Appendixes A-V covering history/background and distress mechanisms of composite pavements, construction and testing of MnROAD and UCPRC test sections, and various performance model refinements. (4) Design Guidelines (Chapter 4 in Final Report Volumes 1 and 2)—Contains guidelines and recommendations for designing HMA/PCC pavements using DARWin-ME software program (Volume 1) and guidelines and recommendations for designing PCC/PCC pavements using newly developed MEPDG version R21:1.300 (Volume 2). Also includes various suggested revisions to the MEPDG *Manual of Practice* that can be made in tandem with modifications to the DARWin-ME software program. (5) Example Applications/Illustrative Designs (Chapter 4 in Final Report Volumes 1 and 2)—Contains four illustrative HMA/PCC designs (Tucson AZ, Albertville MN, Columbus OH, San Antonio TX) (Volume 1) and one illustrative PCC/PCC design (Albertville MN) (Volume 2). (6) Life-Cycle Cost Analysis (LCCA) and Pavement Type Selection Guidelines (Chapter 4 in Final

	Report Volumes 1 and 2)—Contains guidelines for performing LCCA to compare costs of conventional HMA or PCC pavements with composite pavements using the FHWA RealCost program, as well as guidelines for selecting the preferred alternative via procedures outlined in NCHRP Report 703 (*Guide for Pavement Type Selection*). (7) Construction Guidelines and Procedures (Chapter 5 in Final Report Volumes 1 and 2)—Contains guidelines and step-by-step procedures for constructing (and quality monitoring) HMA/PCC and 2-lift wet-on-wet PCC/PCC pavements. Also contains general guidelines for material selection. (8) Test Sections—Three full-length, two-lane test sections (1 HMA/PCC [Cell 70] and 2 PCC/PCC [cells 71 and 72]) were constructed in April-June 2010 at MnROAD on I-94 near Albertville. These sections were monitored (instrumentation, field surveys, other field testing) for the first year and have been recommended for continued monitoring in the future. Also, twelve 45-ft long 1-lane wide HMA/PCC test sections were constructed at the University of California Pavement Research Center (UCPRC) in Davis in August/October 2009. These sections were monitored (with instrumentation) and tested with the Heavy Vehicle Simulator (HVS), and have been recommended for continued monitoring in the future. Finally, to emulate composite pavement construction best practices, two HMA/JPC pavement sections were constructed in October/November 2010 on the I-94 Illinois Tollway (Milwaukee Avenue WB on-ramp and Milwaukee Avenue EB off-ramp) near Gurnee, north of Chicago. Monitoring of the sections in the future has been recommended. (9) Project Database—Microsoft Excel database and MEPDG and DARWin-ME input files containing materials properties, performance, traffic, structure, location, and other data for 43 HMA/PCC and 15 PCC/PCC composite test sections surveyed and analyzed in the R21 study. The data may be of interest to agencies wishing to develop designs for new composite pavements. (10) Software Programs (MEPDG version R21:1.300 and revised AASHTO DARWin-ME)—Performance model revisions, Enhanced Integrated Climatic Model (EICM) model revisions, and various bug fixes made to the MEPDG, resulting in updated version of MEPDG (R21:1.300) for use in designing both HMA/PCC and PCC/PCC pavements. Performance model and other modifications incorporated into DARWin-ME for use in designing HMA/PCC pavements via the overlay design procedure. The revised software programs have been submitted to AASHTO for consideration/approval. (11) Training Materials—Presentations on design, construction, materials, performance, and examples of both types of composite pavements. (PowerPoint materials, design examples, and short video clips to promote the use and accelerate the adoption of new composite pavements?) <u>Anticipated, but not currently available products include</u>: (12) Construction Specifications (Appendix W in Final Report Appendices)—Sample specifications for HMA construction, PCC construction, PCC texturing, PCC curing, sawcutting, and sealing.
Product Status	(1) First Fruits Report (*2008 Survey of European Composite Pavements*, SHRP 2 Report S2-R21-RW1)—Available online at http://www.trb.org/Publications/Blurbs/163693.aspx. (2) Final Report (*Composite Pavement Systems: Volume 1–HMA/PCC Composite Pavements*, SHRP 2 Report S2-R21-RR2 and *Composite Pavement Systems: Volume 2–PCC/PCC Composite Pavements*, SHRP 2 Report S2-R21-RR3")—Available online at http://www.trb.org/Main/Blurbs/168145.aspx (Volume 1) and http://www.trb.org/Main/Blurbs/168533.aspx (Volume 2). (3) Final Report Supplemental Materials ("Composite Pavement Systems: Final Report Appendices," Pre-Publication Draft)—Available online at http://www.trb.org/Main/Blurbs/168145.aspx. (4) Design Guidelines (Chapter 4 in Final Report Volumes 1 and 2)—Available online at http://www.trb.org/Main/Blurbs/168145.aspx (Volume 1) and http://www.trb.org/Main/Blurbs/168533.aspx (Volume 2). (5) Example Applications/Illustrative Designs (Chapter 4 in Final Report Volumes 1 and 2)—Available online at http://www.trb.org/Main/Blurbs/168145.aspx (Volume 1) and http://www.trb.org/Main/Blurbs/168533.aspx (Volume 2). (6) Life-Cycle Cost Analysis (LCCA) and Pavement Type Selection Guidelines (Chapter 4 in Final Report Volumes 1 and 2)—Available online at http://www.trb.org/Main/Blurbs/168145.aspx (Volume 1) and http://www.trb.org/Main/Blurbs/168533.aspx (Volume 2).

	(7) Construction Guidelines and Procedures (Chapter 5 in Final Report Volumes 1 and 2)—Available online at http://www.trb.org/Main/Blurbs/168145.aspx (Volume 1) and http://www.trb.org/Main/Blurbs/168533.aspx (Volume 2). (8) Test Sections—In-place sections at MnRoad, UCPRC, and Illinois Tollway (I-94). (9) Project Database—Available from SHRP 2? (10) Software Programs (MEPDG version R21:1.300 and revised AASHTO DARWin-ME)—MEPDG version R21:1.300 available from SHRP 2 and AASHTO. Revised ASHTO DARWin-ME not yet available. (11) Training Materials—Available from SHRP 2? (12) Construction Specifications (Appendix W in Final Report Appendices)—Final Report Volumes 1 and 2 reference Appendix W, which is not currently available as part of the Final Report Appendices pre-publication draft.

Target Audience	• Highway Agency
	  ➢ Highway administrators.
	  ➢ Planners.
	  ➢ Pavement designers.
	  ➢ PS&E engineers.
	  ➢ Construction engineers.
	  ➢ Materials engineers.
	  ➢ Pavement management engineers.
	• Other Stakeholders—AASHTO, FHWA managers and engineers, pavement design and management consultants, research consultants/organizations, pavement industry groups.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning, scoping, programming. • Project Development—Pavement type selection, design, PS&E. • Contracting and Construction—Project bidding and award, construction.
Pertinent Technical Areas	• Pavement Type Selection (incl. life-cycle costing). • Pavement Design (Detailed) (new/reconstructed AC/PCC and PCC/PCC). • Pavement Mixture Design. • Pavement Specifications Development. • Pavement Construction Inspection and Testing. • Pavement Management.

Implementations	• Implementations Performed as part of R21 Project
	  ➢ Project Level
	  ▪ Test Sections constructed/monitored in three locations—MnROAD (3 test sections [1 HMA/PCC, 2 PCC/PCC] built in Apr-Jun 2010), UCPRC HVS Facility (12 test sections [HMA/PCC] constructed in Aug 2009, and Illinois I-94 Tollway near Gurnee (2 pavement sections [HMA/JPC] constructed in Oct/Nov 2010).
	  ➢ Program Level
	  ▪ Implementation roadmap presented in Final Report recommended continued monitoring of MnROAD composite pavement test sections, analysis of data to update/validate design models, and conduct of open houses at MnROAD to disseminate latest information on composite pavements.
	• Post R21 Project Implementations
	  ➢ Project Level—Illinois Tollway projects in 2012, including I-88 reconstruction/widening with 2-lift PCC/PCC and I-90/Rt. 47 interchange ramp construction using HMA/PCC.
	  ➢ Program Level—Presentation on design of composite pavements at the Illinois Tollway Open House on Sustainable Concrete Paving Practices (Aug 20-21, 2013).

Functional/Technical Level Implementation Paths (Ways that a mid-	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Existing interstate highway with high traffic volume identified as a good candidate for reconstruction; not sure what pavement type/design to utilize to achieve a long life (i.e., 40-50

level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	years)—Need to develop some preliminary pavement designs and perform an LCCA and pavement type selection to determine the preferred pavement type. • Moderately high-volume state highway has been approved for reconstruction and widening using a 2-lift PCC/PCC composite pavement; must move forward with project development and implementation—Need to perform detailed design using MEPDG version R21:1.300, develop material and construction specifications, and prepare construction plans. <u>Project Characteristics</u> • Project Type—Greenfield, Reconstruction, Rehabilitation • Asset Type/Renewal Product Category—Pavements • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—Any • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any speed, medium to high traffic and/or truck traffic • Highway System—Interstates/freeways, other primary routes • Functional Class—Any except minor collectors and local roads
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Agency has built few or no composite pavements, but is highly interested in long-life design concept—Need to evaluate the R21 information (test sections, past projects, construction guidelines) and explore the R21 design tools to determine if composite pavements have a place within the agency. • Some aspects of PCC/PCC construction are new to the agency and would require a change in practices or establishing new ones. Also, new equipment/materials may not be locally available—Need to develop a culture of long-life and renewable pavement within the agency using the various R21 products and other related information.
Barriers/Challenges and Ways to Overcome Them	• Initial cost of composite pavement is key issue in making the pavement type an alternative to be considered by the agency. ➢ Need to identify situations where it would be considered a viable alternative, compile available performance data (using local sections or sections from other locations with like conditions), and develop a cache of designs using the new design software programs (MEPDG version R21:1.300 and DARWin-ME) that would provide justifications for its use based on life-cycle costs and other key considerations. • Agency has no or little experience in mechanistic-empirical design using MEPDG/DARWin-ME and is content with existing design procedure. ➢ Need to show the benefits (quantifiable cost savings) that can be generated using MEPDG/DARWin-ME, and instruct/train designers in its use. Subsequently, instruct/design users on composite design using MEPDG version R21:1.300 and DARWin-ME.
Project Key Words	Composite pavement, hot-mix asphalt (HMA), portland cement concrete (PCC), HMA/PCC two-lift PCC/PCC, pavement design, pavement construction, specifications, life-cycle cost analysis (LCCA), MEPDG, performance models.

Project Cost: $4,000,000

Expanded Summary for Renewal Project R23
(*Using Existing Pavement In Place and Achieving Long Life*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Nichols Consulting Engineers—Newton Jackson
Project Status and Time Frame	Ongoing—February 2008 through December 2014
SHRP 2 Renewal Product Category	• Pavements
Highway Asset Area	• Pavements
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time, Money, and Lives ➢ Reduced costs due to improved design for long-life pavement renewal alternatives (both flexible and rigid pavements). ➢ Reduced costs and shorter construction timeline via reuse of existing pavement and increased construction productivity. ➢ Improved decision making (better and more timely decisions) as a result of user-friendly tools for initially assessing the scope of a project. ➢ Reduced traffic impacts and increased safety.
Project Objectives	• To identify approaches for using existing pavements in-place for rapid renewal projects that can achieve 50 years of service life. • To determine the advantages and disadvantages of each approach, develop detailed criteria on when an existing pavement can be used in-place, and identify practices and techniques to construct these types of pavements.
Summary of Findings	• A number of pavement renewal approaches were identified that could provide long-life pavements. • Existing pavement can be used to build long-life pavements and reduce construction time and costs as well as save valuable resources. • Design, construction, and maintenance processes and procedures all need to be considered to produce long-life pavements, particularly on rapid renewal projects. A full understanding of the design and construction processes required for long-life pavements is needed to build long-life pavements. • Realistic scoping assessments encourage pavement rehabilitation solutions using existing pavements that result in longer life and lower life-cycle costs. • An assessment of the existing pavement's subsurface drainage is important in making pavement renewal decisions. • Specification elements can be incorporated in pre-existing agency standard specifications to encourage improved construction processes for long-life pavements.
Product Description(s)	(1) Final Report (*Using Existing Pavement in Place and Achieving Long Life*, Pre-Publication Draft, February 2012)—Documents the activities and findings of the entire project, the scope of which included: ➢ Phase I—Identifying (through a literature review and a SHA survey) current renewal approaches in use by SHAs, analyzing the approaches to determine which factors are critical to success, developing criteria for when existing pavement can be used (with or without modification), and evaluating the advantages/disadvantages of renewal approaches. Detailed analysis of pavement performance (including analysis of Long-Term Pavement Performance (LTPP) data and design checks using MEPDG and PerRoad software) was used to confirm that the approaches could provide 50-year service life. ➢ Phase II—Developing practical design guides in consultation with seven SHAs (Illinois Tollway, Michigan DOT, Minnesota DOT, Missouri DOT, Texas DOT, Virginia DOT, and Washington State DOT). This consisted of (a) developing draft guidelines for renewal design

by working with the SHAs, (b) verifying the usability of the new design guides by designing an actual project in each state (except Illinois), (c) conducting three regional workshops (Missouri, Virginia, Washington) to compare designs between existing agency practice and the new process and to obtain input/feedback on the new process, and (d) revising the guidelines based on the input/feedback. The test/verification projects included I-75 in Cheboygan County, Michigan, I-35 in Chisago County, Minnesota, I-55 in Perry County, Missouri, US-75 from Loy Lake Road to Exit 64 in Texas, I-95 in Caroline County, Virginia, and in I-5 Skagit County, Washington (Joe Leary Slough to Nulle Road).

The report describes the development of the design guide process (i.e., guide for determining the feasibility of a variety of approaches [e.g., HMA overlay on existing HMA, HMA overlay over rubblized jointed plain concrete pavement (JPCP)/jointed reinforced concrete pavement (JRCP), unbonded concrete overlay on existing HMA] by describing how well each approach provides for a practical means of renewal in terms of its appropriateness relative to the expected traffic level, climatic conditions, expected length of service, and pavement condition). The design guide includes decision matrices for identifying when existing pavements can be used in-place and design tables that provide the methods necessary to incorporate the original material into the new pavement structure while achieving long life. It also covers information that should be considered to ensure that the user can produce a long-life pavement, as well as the selection of the optimum approach for any given site. Renewal options included in the design guide are:

- HMA over HMA renewal methods
  - HMA over existing HMA pavement
  - HMA over reclaimed/milled HMA (recycling)
  - Remove and replace (reconstruction, inlay) or lane addition (new construction)
- HMA over PCC renewal methods
  - HMA over existing HMA-surfaced composite pavements
  - HMA over crack and seated JPC pavements
  - HMA over saw, crack-and-seat JRC pavements
  - HMA over rubblized JPC/JRC pavements
  - HMA over existing CRC pavements
  - Remove and replace (reconstruction, inlay) or lane addition (new construction)
- PCC over HMA renewal methods
  - Unbonded PCC over existing HMA pavements
  - Remove and replace (reconstruction, inlay) or lane addition (new construction)
- PCC over PCC renewal methods
  - Unbonded PCC over existing PCC pavements (JPC, JRC, CRC)
  - Remove and replace (reconstruction, inlay) or lane addition (new construction)

Resource materials included as Appendix E of the report are (a) Pavement Assessment Manual, (b) Flexible Pavement Best Practices, (c) Rigid Pavement Best Practices, (d) Guide Specifications, (e) Life-Cycle Cost Analysis, and (f) Emerging Pavement Technologies.

(2) Scoping Tool (*Guidelines for Long Life Pavement Renewal*)—Web-based pavement design scoping tool that incorporates the treatment selection guidelines, a project assessment manual, best practices, model specifications, life-cycle cost analysis, and emerging technologies into an easy-to-use scoping tool that captures the critical inputs to aid in the pavement renewal decision-making process (accommodates design periods of 30-50 years). The scoping tool guides the user through the data gathering process and decision tables to identify a number of possible renewal approaches that will provide long life. It also provides access to pertinent information that should be considered by the engineer to design and construct long-life pavements. A knowledge base was assembled as a resource for users of the guidelines to facilitate the design and construction of long-life pavements. The scoping tool is unique in that it combines both pavement design and construction information in a single, easy-to-use knowledge base that supports the scoping and design process. Resource materials available within the scoping tool include the (a) Project Assessment Manual, (b) Flexible Best Practices, (c) Rigid Best Practices, (d) Guide Specifications, (e) Emerging Pavement Technologies, (f) Scoping Methodology, (g) Life-Cycle Cost Analysis, and (h) Pavement

	Considerations for Long-life Pavements.
Product Status	(1) Final Report (*Using Existing Pavement in Place and Achieving Long Life*, Pre-Publication Draft, February 2012)—Available online at http://onlinepubs.trb.org/onlinepubs/shrp2/SHRP2prepubR23Report.pdf. (2) Scoping Tool (*Guidelines for Long Life Pavement Renewal*)—Available online at www.pavementrenewal.org.
Target Audience	• Highway Agency ➢ Project designers (pavement and roadway). ➢ Construction engineers. ➢ Asset management engineers. ➢ Planners/programmers. • Other Stakeholders—Consultants, Contractors
Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning, scoping. • Project Development—Engineering studies, design, PS&E. • Contracting and Construction—Project bidding and award, construction. • Management, Maintenance, and Operations—Asset management, system maintenance and preservation.
Pertinent Technical Areas	• Pavement Rehabilitation Type Selection. • Pavement Rehabilitation Design (preliminary). • Project Planning/Programming.
Implementations	• Implementations Performed as part of R23 Project ➢ Project Level ▪ Work with seven SHAs to develop draft guidelines and use the guidelines on a project in each state (except Illinois) to verify usability of design guidelines. Test case projects included I-75 in Cheboygan County, Michigan, I-35 in Chisago County, Minnesota, I-55 in Perry County, Missouri, US-75 from Loy Lake Road to Exit 64 in Texas, I-95 in Caroline County, Virginia, and I-5 in Skagit County, Washington (Joe Leary Slough to Nulle Road). ➢ Program Level—One pilot workshop (Washington) and two regional workshops (Virginia and Missouri) with agencies and other stakeholders (industry, contractors) to compare new design guidelines with existing state procedures and determine refinements needed. • Post R23 Project Implementations ➢ Project Level ▪ AASHTO/FHWA/SHRP 2 Implementation Assistance Program—R23 scheduled for implementation in future rounds of the program. Application process arriving soon.
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	<u>Problems/Issues/Constraints—Corresponding Needs</u> • Existing 4-lane interstate highway with moderate traffic, vertical constraints (overhead structures), and PCC slabs with significant amounts of fatigue cracking and D-cracking; not sure what to do—Need to identify the best options available for rehabilitating the pavement to achieve a 50-year design life. • Existing 2-lane rural highway with moderately distressed asphalt pavement is scheduled to undergo widening to 4 lanes to accommodate increased traffic; not sure what to do—Need to identify the best options available for widening and improving the road to satisfy a 30-year design life. • Highway pavement has been in service for several years and design thickness was based on prevailing traffic volumes at the time; not sure what design is appropriate—Need to use design tables based on analytical tools to scope approximate range of thicknesses for long-life pavement designs. <u>Project Characteristics</u> • Project Type—Reconstruction, Rehabilitation

	• Asset Type/Renewal Product Category—Pavements • Geographic Location (Setting and Climate)—Any setting; Any climate • Geometrics—Any • Conflicting Features—None • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—Any • Highway System—Any • Functional Class—Any
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • Uncertainty about which highway renewal alternatives to select that use the existing pavement in-place—Need to use decision matrices developed for identification of renewal strategies for the existing pavement type. • Limited information about in-service performance on heavy-duty pavements for different types of pavement structures (asphalt, concrete, asphalt over concrete, concrete over concrete, or concrete over asphalt)—Need to identify when existing pavement can be used in place and understand the state of the art in rapid renewal approaches for high-volume roadways. • Inconsistency between pavements renewed for long-life and adjacent pavements and structures—Need to determine optimal methods for integrating the design of the renewed pavement.
Barriers/Challenges and Ways to Overcome Them	• Level of detail required to select, design, and construct an optimal renewal alternative that will achieve long-life performance ➢ Need to use project tool and resource documentation specifically devoted to addressing details critical to achieving long life. • Transition from existing design practices to long-life pavement design ➢ Need to validate results generated by decision support tool against agency knowledge about performance of existing pavements.
Project Key Words	Roadway, pavement, productivity, preservation, traffic impact, treatment, condition, life cycle, design, assessment, performance, construction, decision support matrix, cost-effectiveness, specifications, renewal, best practices, life-cycle costs.

Project Cost: $1,000,000

Expanded Summary for Renewal Project R26
(*Preservation Approaches for High-Traffic-Volume Roadways*)

SHRP 2 Program Officer	James Bryant
Contractor and PI Info	Applied Pavement Technology, Inc. (APTech)—David Peshkin
Project Status and Time Frame	Completed—April 2008 through Feb 2010
SHRP 2 Renewal Product Category	• Pavements
Highway Asset Area	• Pavements
Impact on Agency's Ability to Consistently Apply Rapid Renewal	• Saves Time and Money ➢ Improved long-term pavement performance and reduced pavement life-cycle costs. ➢ Minimized disruption to traffic and reduced user costs. ➢ Optimized system preservation through improved pavement programming. • Saves Lives ➢ Safer and smoother roads for traveling public.
Project Objectives	• To develop guidelines on pavement preservation strategies for high-traffic-volume roadways that can be used by transportation agencies. • To identify promising preservation strategies for application on high-traffic-volume roadways that may not commonly be used and make recommendations for further research opportunities.
Summary of Findings	• There are preservation treatments that are currently being extensively used or have been documented as successfully used on high-traffic-volume roadways. • Successful selection of projects and preservation treatments for high-traffic-volume roadways requires that: ➢ Treatment functions are properly matched to pavement conditions. ➢ Potential effects of traffic level and climatic conditions on expected treatment performance are properly assessed. ➢ Project construction constraints are carefully examined in relation to the limitations of the treatments. ➢ Treatment cost-effectiveness and other factors are properly and methodically considered.
Product Description(s)	(1) Final Report (*Preservation Approaches for High-Traffic-Volume Roadways*, SHRP 2 Report S2-R26-RR-1)—Documents the state of the practice of preservation treatments on asphalt and concrete pavements, focusing on treatments that are suitable for application on high-volume roadways. The information presented is derived from a detailed survey of transportation agencies and a review of national and international literature. The report also provides a general framework for how best practices are identified and it describes the process used to develop guidelines on the application of preservation treatments on high-volume roadways. (2) Guide Document (*Guidelines for the Preservation of High-Traffic-Volume Roadways*, SHRP 2 Report S2-R26-RR-2)—Provides guidance for suitable treatments for high-traffic-volume roads. Discusses key factors that affect the selection of a pavement preservation project and treatment, including traffic level, existing pavement condition, climatic condition, available work hours, and treatment performance and cost. Presents the project selection and treatment selection process, beginning with the determination of whether a project is a good candidate for preservation, proceeding to the identification of candidate treatments for the project, and ending with the treatment selection based on various economic (including cost-effectiveness) and noneconomic factors (e.g., constructability, safety, agency policies/preferences). The Guide includes two appendices—the first one containing one- to two-page technical summaries for the various preservation treatments and the second one providing two example exercises intended to illustrate

	certain portions of the treatment selection process. The guidelines are generic, and agencies should determine how these can be customized for their specific conditions. (3) Project Brief—This four-page project summary highlights a new tool to help highway agency managers and engineers preserve high-traffic-volume roadways in serviceable condition for longer periods of time, at a lower cost, in a safer manner, and with limited disruption to the traveling public. It describes the two key products of the R26 study, the Final Report and the Guide Document. (4) Webinar—On September 8, 2010, TRB conducted a 90-minute webinar entitled *Pavement Preservation for High-Traffic-Volume Roadways*. This webinar explored ways to evaluate pavement preservation strategies for high-traffic-volume roadways.
Product Status	(1) Final Report (*Preservation Approaches for High-Traffic-Volume Roadways*, SHRP 2 Report S2-R26-RR-1)—Available online at http://www.trb.org/Publications/Blurbs/165280.aspx and as a hard copy through the TRB bookstore (http://books.trbbookstore.org/shrp2report.aspx). (2) Guide Document (*Guidelines for the Preservation of High-Traffic-Volume Roadways*, SHRP 2 Report S2-R26-RR-2)—Available online at http://www.trb.org/Publications/Blurbs/164965.aspx and as a hard copy through the TRB bookstore (http://books.trbbookstore.org/shrp2report.aspx). (3) Project Brief—Available online at TRB website (www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Pavements_490.aspx). (4) Webinar—A link for obtaining the webinar recording exists at http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/RenewalWebinars.aspx.

Target Audience	• Highway Agency
	  ➢ Maintenance/preservation engineers.
	  ➢ Pavement management engineers.
	  ➢ Pavement designers.
	• Other Stakeholders—FHWA managers and engineers, pavement design and management consultants, research consultants/organizations, pavement industry groups.

Pertinent Applications in the Highway Life Cycle (Impacted Project Phases)	• Program Development—Planning, programming. • Project Development—Engineering and safety studies, design, PS&E. • Management, Maintenance, and Operations—Asset management, system maintenance and preservation.
Pertinent Technical Areas	• Pavement Testing and Evaluation • Pavement Preservation Project and Treatment Selection • Pavement Preservation Treatment Application/Construction • Pavement Management

Implementations	• Implementations Performed as part of R26 Project
	  ➢ Project Level—None
	  ➢ Program Level—None.
	• Post R26 Project Implementations
	  ➢ Project Level—AASHTO/FHWA/SHRP 2 Implementation Assistance Program (Round 1). The R26 Implementation Assistance Program was announced in 2/7/13 web conference. The application process ran from 2/15/13 thru 3/15/13. Announcement of recipients was held in April 2013. A total of 14 agency awards were made consisting of:
	  ▪ Arizona DOT: Lead Adopter assistance on four projects.
	  ▪ Delaware DOT: Lead Adopter assistance on two projects.
	  ▪ DC DOT: Lead Adopter assistance on four projects.
	  ▪ Georgia DOT: Lead Adopter assistance on three projects.
	  ▪ Kentucky DOT: Lead Adopter assistance on four projects.
	  ▪ Maine DOT: User Incentive assistance on three projects.
	  ▪ Massachusetts DOT: Lead Adopter assistance on four projects.
	  ▪ Minnesota DOT/MNRoad: Lead Adopter assistance on one project.

	▪ Missouri DOT: Lead Adopter assistance on four projects. ▪ Pennsylvania DOT: Lead Adopter assistance on three projects. ▪ Rhode Island DOT: Lead Adopter assistance on four projects. ▪ Tennessee DOT: User Incentive assistance on four projects. ▪ Washington State DOT: Lead Adopter assistance on four projects. ▪ Wisconsin DOT: User Incentive assistance on four projects. ➢ Program Level ▪ Webinar on R26 (Sep 8, 2010). ▪ Presentation on R26 and R26 Implementation Assistance Program at 2013 AASHTO Research Advisory Committee (RAC) Meeting (Jul 2013).
Functional/Technical Level Implementation Paths (Ways that a mid-level manager or possibly upper-level manager can implement or further test the product(s) as part of an actual highway project)	Problems/Issues/Constraints—Corresponding Needs • Pavement on a high-volume roadway has been in service a few years and is starting to show certain types of distress; not sure what to do—Need to determine if the pavement is a suitable candidate for preservation. • Pavement on a high-volume roadway has been in service a few years and is a good candidate for preservation; not sure what type of treatment is appropriate—Need to determine what type of treatments are suitable and which one is the preferred alternative based on expected performance and costs and other considerations. Project Characteristics • Project Type—Maintenance/Preservation, Rehabilitation • Asset Type/Renewal Product Category—Pavement • Geographic Location—Any setting; Any climate • Geometrics—Any • Conflicting Features—Minimal to none • Traffic Characteristics (Speed, Volume/ADT, and Vehicle Composition)—High-speed; High-volume; Any vehicle composition • Highway System—Interstates/freeways, other primary routes • Functional Class—Interstates, freeways/expressways, other principal arterials
Administrative/Program Level Implementation Paths (Ways that an upper-level manager or possibly mid-level manager can implement the product(s) into agency practice [e.g., training, policy development meetings, procedural manual updates])	Problems/Issues/Constraints—Corresponding Needs • Inadequate pavement structural performance on high-volume roads, resulting in earlier than anticipated rehabilitation—Need to identify strategy(s) to slow rate of development of some load-related distresses and thereby extend structural life. • Inadequate functional performance (comfort-related) on high-volume roads, resulting in earlier than anticipated rehabilitation—Need to identify strategy(s) to improve smoothness/profile (immediately and long-term) and thereby extend functional life. • Inadequate functional performance (safety-related) on high-volume roads, resulting in increased safety risk and/or earlier than anticipated rehabilitation—Need to identify strategy(s) to improve pavement surface friction (immediately and long-term) and reduce risk of crashes. • Unacceptably high pavement life-cycle costs (agency/direct costs only) due to earlier than anticipated rehabilitation—Need to identify strategy(s) to extend pavement life and thereby reduce life-cycle cost. • Unacceptably high level of traffic congestion (and corresponding user/indirect costs) associated with construction (rehabilitation) work zones—Need to identify strategy(s) that addresses performance issues but involves less disruption to traffic (and lower user/indirect costs). • Inadequate performance of a particular preservation treatment on high-volume roads—Need to identify treatments that better address the conditions of the existing pavement and are capable of performing well under high traffic and in the subject climate/environment. Need to identify proper timing of the treatment with respect to existing pavement condition.
Barriers/Challenges and Ways to Overcome	• Resistance to allowing use of some preservation treatments on high-traffic-volume (HTV) roads

Them	(i.e., use of the preservation treatment guidelines may be premature due to lack of reliable performance/durability information for those treatments). ➢ Skepticism must be overcome by showing the successes of those treatments in other agencies with similar conditions and by instituting field studies that demonstrate/validate successful application by the agency. • Ability of highway agency to persuade government officials and the traveling public of the net positive benefits of applying preservation treatments to HTV roads. ➢ Develop and clearly explain the benefit-cost value of preservation treatments applied early in the life of the pavement, as compared to more costly major repairs later. Make the case for performance/durability in a high-traffic setting not being impacted enough to diminish the benefit-cost value. • Potential for marketplace pressures coming to bear from affected industry groups ➢ Generate and document performance and cost information that can help justify or support a change in treatment policy(s).
Project Key Words	Roadway, pavement, pavement preservation, preservation treatment, traffic volume, rural, urban, pavement condition, climate, performance, construction, decision support matrix, cost-effectiveness, treatment function.

Project Cost: $250,000

APPENDIX B
Integration Tool Development Plan

Introduction

The development of the Project Builder Application (PBA), the integration tool discussed in Chapter 4, needs to follow a well-designed plan in order to implement the framework and deliver a successful product. Since the framework calls for the tool to run as a web-based application, the development approach should follow established methods for designing and building robust software tools.

This section outlines a plan for how the actual tool could be developed in collaboration with highway agencies and other stakeholders. The development scenario could involve an agency developing the software internally or working with an outside software developer. In addition, a software developer could work with a consortium of agencies, for example if multiple agencies wanted to share the development costs.

Software Development Process

The existing PBA framework is effectively ready for implementation using standard software development processes. Some of the key steps included in this process are

- Validating requirements
- Specification
- Architecture and design
- Implementation
- Software testing
- Deployment
- Maintenance

The steps of the development process are sequential in nature, in the sense that each activity builds on the work of the previous step. However, there is likely to be some overlap in activities during the transition from one step to the next.

Validating Requirements

The step of validating requirements involves determining the comprehensive list of requirements for the software. These will include user requirements (agency needs for the software to address), functional requirements (methods for the software to collect input and interact with users), and technical requirements (capabilities for storing, retrieving, and computing information). The completed list of requirements will drive the design parameters of the software system.

In traditional software development, the initial phase would more likely be described as requirements gathering, since it is assumed that little effort has previously gone into identifying the requirements for the software. Development of the PBA can build on the existing framework developed in Phase I and outlined in Chapter 4, which has already identified and incorporated

many of these requirements. In this context, the first step of the development process works a bit differently. The PBA developer can appropriately work from the existing requirements rather than reinventing the wheel. However, the requirements should be reviewed by the agencies supporting the development before further steps are undertaken. This allows stakeholders to validate that the requirements defined are sufficiently comprehensive and still applicable to their needs. To the extent that additions or modifications are necessary, the requirements can be adjusted accordingly.

Specification

The specification process involves creating a document that describes the requested behavior of the software. It will outline the core functionality of the software, list required features, and provide a high-level overview of the anticipated software architecture. This document should be agreed upon by the PBA developer and the agency or consortium. It will serve as the reference point when decisions about software design need to be made during subsequent steps.

Architecture and Design

In order to create the architecture and design of the system, the developer will need to plan a software solution that meets the criteria described in the specification. This includes defining the structure of the product and the underlying technical design of the system. Related activities include planning the design of interfaces, which should incorporate user experience design concepts to ensure the usability of the resulting tool.

Some key results of the architecture and design step will involve committing to particular options and configurations, such as deciding which programming languages to use, or selecting the software solution stack on which to build the application. It should also include analysis and evaluation of how the design will satisfy the requirements as originally defined. The architecture will need to be thoroughly documented in order to support potential future development and expansion of the software.

Implementation

The implementation step refers to the activity of programming the software tool based on the prescribed architecture and design. It may include selecting appropriate libraries and toolkits for integration into the program, in addition to creating the actual source code of the software. Initial debugging will be performed to ensure that the software is functional and contains the appropriate features. Verification and documentation activities should be included to track that the software fully implements specification requirements and to document the software codebase.

Software Testing

Software testing is the process of comprehensively checking that the software program behaves as intended, including all components and interfaces along with system performance. This step employs a combination of white-box testing (applying test cases to evaluate the internal functioning of individual units of code) and black-box testing (verifying the external

functionality of the overall program based on possible inputs and outputs). As part of the testing phase, a trial group of agency end users should be included to verify that the software meets stakeholder needs and collect feedback.

As errors and other defects are identified during the testing process, it will need to be accompanied by software modifications to remedy these problems. Testing and debugging activity continues in an iterative fashion until the program is ready for deployment.

Deployment

Deployment is the step in which the software is released for general use, at which point the agency or consortium can make it available to internal users, or to the wider public as appropriate. It involves deploying the complete software system for use, either on agency servers or in a hosted environment. Since the PBA tool framework is conceptualized as a secure web-based application, it has the flexibility to accommodate a full range of deployment options; it can be delivered to any user with Internet access, while also allowing the possibility of restricting access to the application, or certain parts of it, based on security principles and defined user roles.

Maintenance

Ongoing maintenance is required to keep the software fully operational. This includes maintenance of both the software program itself along with the deployment environment. The level of effort and responsibility for various maintenance activities should be agreed between the PBA developer and the agency or consortium.

In addition to maintaining operations and correcting any new defects, the maintenance step may encompass further modifications after the software has been released. This could include feature updates, performance improvements, or changes to adapt the product to a modified environment. For example, this phase might involve ongoing development to make the PBA tool available on mobile devices, as discussed in Chapter 4.

Development Timeline

The PBA developer and the agency or consortium will want to determine a suitable time frame in which to complete the development process. The length of the process will depend on the resources committed to the project, as well as the number and complexity of features the agency or consortium elects to include. The timing of the individual steps in the process should be included as part of the plan (see Figure B.1 for an example).

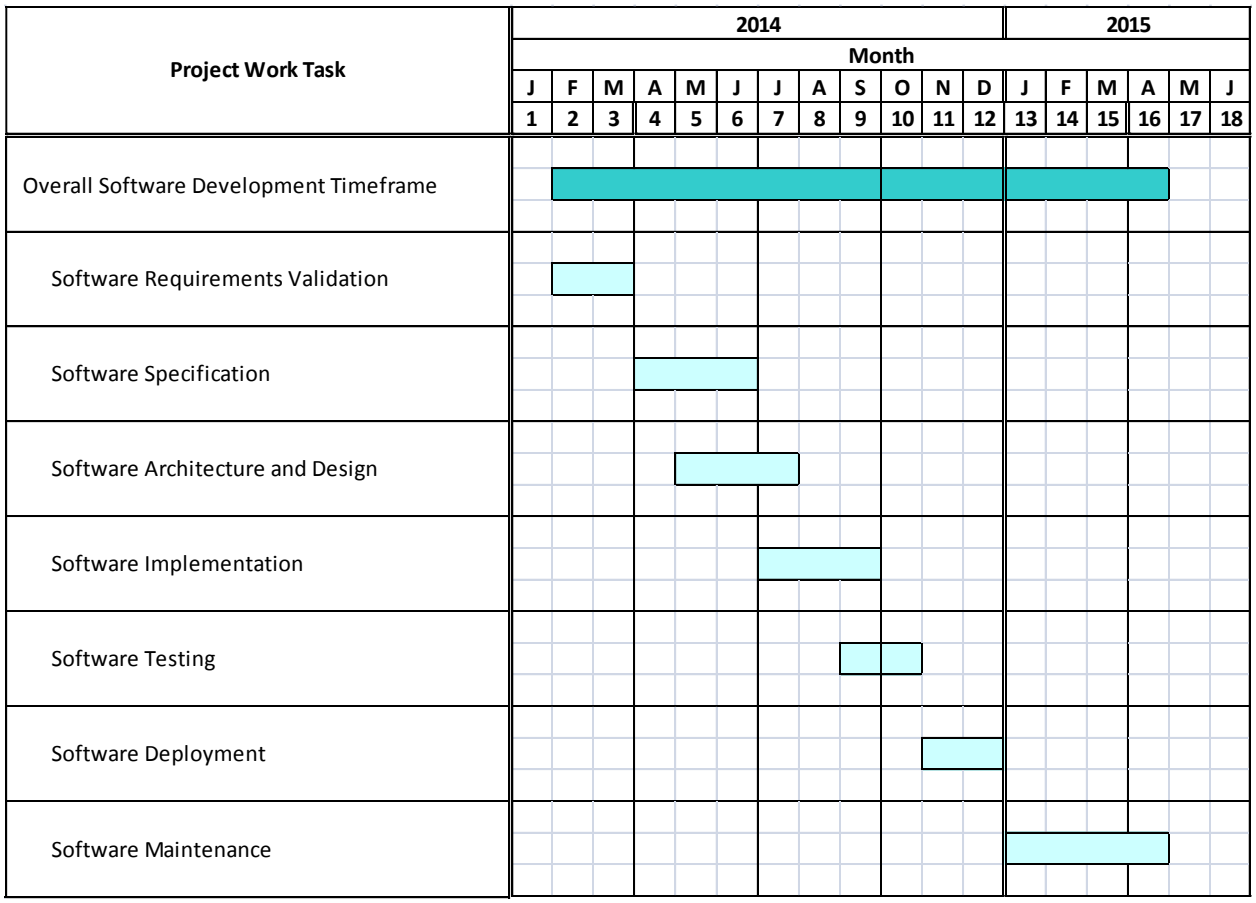

Figure B.1. Illustration of a representative work plan timeline for software tool development.