F-SHRP RENEWAL

PROVIDING OUTSTANDING CUSTOMER SERVICE

NCHRP Project 20-58(1) Renewal

DETAILED PLANNING FOR RESEARCH ON ACCELERATING THE RENEWAL OF AMERICA'S HIGHWAYS

FINAL REPORT

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
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April 2003

Center for Transportation Research and Education at Iowa State University
TDC Partners, Ltd. **Purdue University**

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LIST OF ABBREVIATIONS AND ACRONYMS

AASHTO ....American Association of State Highway and Transportation Officials
BMS .....bridge management system
CAD .....computer-aided design
CRC.....continuously reinforced concrete
DOT .....department of transportation
FHWA.....Federal Highway Administration
F-SHRP .....Future Strategic Highway Research Program
GIS .....geographic information system
GPS ..... global positioning system
HMA .....hot mix asphalt
IPDS.....intelligent project delivery system
IT..... information technologies
ITS.....intelligent transportation system
LTPP Program ..... Long-Term Pavement Performance Program
mph ..... miles per hour
NCHRP ..... National Cooperative Highway Research Program
NDE ..... nondestructive evaluation
NHS.....national highway system
QC/QA ..... quality control/quality assurance
RC .....reinforced concrete
RRR.....rehabilitation, repair, and replacement
SHRP..... Strategic Highway Research Program
TEA-21 ..... Transportation Equity Act for the 21st Century
TRB.....Transportation Research Board
VMT..... vehicle-miles traveled

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SECTION A. SUMMARY

Providing Outstanding Customer Service for the 21st Century: Research Plan for the Rapid Renewal of the Nation's Highway Infrastructure

Background

America's economy relies on highways. According to the U.S. Bureau of Transportation Statistics, as reported in Transportation Research Board (TRB) *Special Report 260: Strategic Highway Research* (2001), highways carry 90 percent of passenger trips and 69 percent of freight value. They also provide passenger and freight links to all other modes of transportation. The highway network is made up of 3.9 million miles of highways and local roads. This network is largely built but does not last forever. It must be periodically renewed. For the purposes of this report, highway "renewal" is defined as preservation, rehabilitation, or reconstruction.

Many of the nation's roads are especially critical to meeting the mobility and economic needs of local communities, regions, and the nation. The interstate system, for example, while making up only 1.2 percent of the nation's road mileage, carries over 24 percent of vehicle-miles traveled (VMT). The nation's most important roads are carrying traffic well in excess of their design capacity, and many are heavily congested. These highways are generally so important that when it comes time to renew them, the work must be done with as minimal an impact as possible on mobility and commerce.

That renewal is a significant national issue is beyond dispute. Facts from *Special Report 260* and *Highway Research and Technology: The Need for Greater Investment* (National Highway Research and Technology Partnership, 2002) collectively outline an impending highway crisis:

- VMT has increased 76 percent between 1980 and 1999.
- System capacity (in number of lane miles) has increased only 3 percent in the same time frame.
- The U.S. population is predicted to grow 20 percent by 2025.
- VMT is projected to increase another 50 percent by 2020.
- Truck volume is predicted to double from 8 billion tons to 16.8 billion tons by 2020.
- The cost of congestion is estimated in excess of $70 billion annually in 68 major cities.
- Twenty-nine percent of the national bridge inventory (585,542) is structurally deficient or functionally obsolete.
- Based on 1998 obligations, resurfacing is being performed on 12.8 percent of the national highway system (NHS) annually (20,500 miles). This is a 7–8 year resurfacing cycle for the 160,000-mile NHS.
- About 3,200 miles are totally *reconstructed* annually, implying a 50-year replacement cycle. This suggests we need a system of highway renewal (preservation, repair, resurfacing, etc.) that allows highways to perform satisfactorily for 50 years—"perpetually renewable" roadways.
- Motorists have very little tolerance for delay, especially multi-year delays related to highway work.
- About 830 people are killed and 42,000 injured annually in highway work zones.

According to the Federal Highway Administration (FHWA) *1999 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* report, 59 percent (95,000 miles) of the pavement on the NHS is in fair, mediocre, or poor condition. The FHWA *2002 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance* report, which employs a new reporting method, shows

improvement. It rates 57 percent (91,000 miles) in the fair, mediocre, or poor range. As in 1999, urban pavements are in poorer shape than average, with 67 percent in the fair, mediocre, or poor range.

According to the 2002 report, 29 percent of the NHS bridge inventory is structurally deficient or functionally obsolete. Thirty-two percent of bridges in urban areas, including nearly 27 percent of urban interstate bridges, are deficient. These bridges carry high traffic volumes, and over half of them are under local jurisdiction, making rapid renewal attractive to local highway agencies as well as to state agencies. If bridge renewal projects cannot accommodate full traffic loads, the potential for delays is enormous.

Additional capacity (that is, number of highway lane miles) is not expected to grow very significantly in the next 20 years, even as traffic volumes increase. This will compound the problem of accommodating traffic during renewal operations.

The need for major renewal is clear. How to fund this work, deliver the projects without public outcry over the delays, and deliver a superior highway product is not so clear. Thus, the research described in this report is needed to enable renewal to be accomplished while "providing outstanding customer service for the 21st century."

Institutional Challenges

In several isolated, high-profile "rapid renewal" projects, highway agencies have successfully reduced traffic disruption to a bare minimum (see Section E). In nearly every case, however, doing so required extensive human and financial resources. So, although rapid renewal can be accomplished successfully, the expected increase in the number and complexity of these projects will stress agencies' human and financial resources. Highway agencies continue to undergo dramatic organizational changes, adjusting from project-oriented organizations to system organizations and striving to maintain maximum operating efficiency of an integrated system. Renewal projects must now be analyzed as to their impacts on the entire system within a region or jurisdiction.

Implementing rapid renewal strategies will require a commitment to organizational change by departments of transportation (DOTs) and other project owners. Renewal projects must be corridor and network based and driven by the goals of rapid renewal. The public must be involved early, and visualization tools are needed to aid the public in understanding the implications of a project. Design and construction processes must be integrated and be consistently repeatable. Monitoring systems are needed to support performance-based specifications; continuous health-monitoring systems will aid in project selection. Contracting strategies must be in place to take advantage of fast-track construction methods, and innovative financing opportunities must be available.

Financial pressure, the need for rapid construction techniques, and the concomitant need for innovative contracting strategies will first occur on large or "mega" projects. As these strategies become routine, they will "trickle down" to smaller projects and those sponsored by smaller agencies. The renewal objective of consistent application will happen over time as the perception of risk is reduced and the benefits are clearly demonstrated.

The Renewal Goal

TRB *Special Report 260* defines the overall research program goal for renewal: "To develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities." The strategic objectives for the research plan focus on developing a continuous, systematic approach that includes tactics in three areas:

1. Rapid renewal of highways
2. Minimum disruption to the public
3. Long-lived facilities

Characteristics of the Renewal Plan

The research plan is structured around the strategic objectives. It is composed of 38 projects as described in Section F and summarized in Table 1. As required in *Special Report 260*, the plan

- Addresses highway needs from a systems perspective
- Proposes research in nontraditional highway-related areas
- Explicitly acknowledges the interdependence of highway research and technology programs

Rapid renewal has been achieved only under special high-profile circumstances because very real barriers exist to consistent application of renewal methods. 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. However, limitations of current prefabricated structural systems technology prevent maximizing off-site work. Likewise, limits on sensing technology inhibit rapid inspection and construction acceptance.

Transfer of risk to contractors makes innovative contracting strategies unworkable without financial or other contractual adjustments. Financing is a barrier to planning renewal projects to minimize disruption, because the systems approach often leads to bigger projects. Timely coordination with railroads and utilities is a major barrier to rapid construction and can be a disruption to their services as well. Research is necessary to enable highway agencies to develop financing strategies and mutually satisfactory mitigation strategies for railroads and utilities. Until these technical problems are solved, the rapid renewal methods cannot be implemented broadly and consistently.

The nation cannot accept shorter facility life spans as the price of rapid renewal. A method for achieving long facility life is to optimize designs and materials, but current designs do not consider constructability, material performance, and in-service performance to the extent necessary to achieve this strategic objective.

The researchers identified 10 tactics for overcoming the barriers to achieving the strategic objectives. The 10 tactics are described below, and Table 1 summarizes the relationship between the strategic objectives, the tactics, the barriers, and the projects. The barriers that exist are complicated and interdependent. The value that the research team found in thinking through the barriers was to ensure that the research projects were sharply focused at removing barriers at the macro level. Table 2 presents a summary of the research projects, objectives, products, and budgets.

Rapid Approaches

Tactic 1. Perform Faster In Situ Construction

Renewal time can be defined as the time it takes to complete those on-roadway construction activities that impact traffic flow and the communities and businesses that rely on that roadway for services. Rapid renewal applies innovative activities or technologies to reduce the time traditionally allocated to these on-roadway activities, thereby minimizing the impact.

Tactic 2. Minimize Field Fabrication Effort

This tactic examines approaches that will minimize the amount of fabrication at the actual project site, thus speeding up the on-site construction phase of the work that actually impacts traffic. New systems

need to be developed that consider design approaches, construction processes, material selection, and safe inspection and maintenance requirements.

Tactic 3. Perform Faster Construction Inspection and Monitoring

To be rapid, a renewal project must be built and accepted quickly before opening to the public. However, current acceptance testing procedures are not done in real time, and if there are problems, subsequent rework requires additional time and money. In a high-pressure, time-constrained project, the demands to keep moving can overwhelm the construction inspection process. The intent is to focus on the development of an innovative, high-speed construction inspection process that can be used to make sure that the overall quality is obtained without delaying the project.

Tactic 4. Facilitate Innovative and Equitable Contracting Environment

One of the main challenges facing agencies in the future is the reduction in human resources available to conduct renewal operations. It is safe to expect that these agencies will be transferring more responsibilities to consultants and contractors. An examination of trends in other countries shows that the transfer can be accomplished but requires new strategies and cooperation among the various interests. For example, design-build contracting, identified nearly 10 years ago in Europe as a way of decreasing the time it takes to design and construct a project, has only now been approved by the FHWA for use in federal-aid work. This topic focuses on developing an environment that may be more conducive to delivery of the type of services needed in the future.

Minimize Disruption

Tactic 5. Plan Improvements to Mitigate Disruption

There are more ways to minimize the impact of renewal if the analysis starts early in the project development process. This means not only selecting the renewal items of work that need to be done but also the best way to assemble and procure the work. Agencies need to strategically define, analyze, package, and renew highway corridors and projects so as to minimize current and future traffic disruptions as well as overall initial and life-cycle costs. Financial solutions are urgently needed to provide the ability to address very high cost renewal projects in a sustainable manner.

Tactic 6. Improve Customer Relationships

The key to improving customer relations is to get customers involved in the decision-making process, with the hope that they become willing “partners” with the agency as decisions are made and implemented. Customers include those using the facility and those who live near it and are impacted by the renewal activities. Additionally, utilities and railroads share roadway right-of-way (ROW) and have a huge stake in renewal activities. Unresolved or undetected utility issues have been recognized as one of the leading causes of construction delays. It behooves the highway agencies to address fundamental relationships and explore innovative agreement arrangements to minimize this impact. This tactic directly addresses those most impacted by the renewal work and looks for creative solutions and partnerships.

Tactic 7. Improve Traffic Flow in Work Zone

It’s a given that traffic must traverse renewal sites. There will always be a need to move traffic quickly and safely through work zones. Many of the traditional work zone approaches are simply inadequate to address the high-traffic environment of rapid renewal projects. The goal is that work zones and work sites of the future will be safer and more efficient for both motorists and construction workers.

Produce Long-Lived Facilities

Tactic 8. Design and Construct Low-Maintenance Facilities

Producing long-lived facilities not only reduces ownership costs but also significantly reduces the disruption to the users over the life cycle of the facility. Building for long life, using low-maintenance

designs and materials, and designing facilities for easier maintenance need to be simultaneously achieved. Through improved material selection, design processes, and integration with construction technologies, facilities must be designed to reliably achieve the desired performance life. The goal is to integrate performance-related designs with innovative construction processes that will result in long-life solutions.

Tactic 9. Monitor In-Service Performance

Technology provides an opportunity to address a key strategy for providing improved service to the public both for planned maintenance and security. Having the ability to continuously monitor in-service performance and the necessary decision support systems will result in lower life-cycle user and ownership costs as well as improve safety to the public.

Tactic 10. Preserve Facility Life

One of the essential components of a rapid renewal program is preservation of existing facilities for the longest possible time at the required level of performance. Additional techniques are needed to extend the life of roadways that carry high traffic volumes, to strengthen bridges without total reconstruction, and to retrofit bridges that were not built with redundant structural members.

Table 1. Relationship of Research Projects to Research Objectives

Strategic Objectives	Tactics	Barriers	Research Projects
Rapid Approaches	1. Perform Faster In Situ Construction	• Traditional approaches are slow and costly. • Limited data collection and sharing. • Not enough emphasis given to human limitations and performance.	1-1.1. Utilities Location Technology Advancements 1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction 1-1.3. Replacement of Conventional Materials with High-performance Materials in Bridge Applications 1-1.4. Rapid Rehabilitation Strategies of Specialty Structures 1-1.5. Micropiles for Renewal of Bridge Foundations 1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System 1-1.7. Facilitating the Use of Recycled Aggregates 1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments
	2. Minimize Field Fabrication Effort	• Traditional techniques for bridge and pavement construction are built on site.	1-2.1. Modular Bridge Systems 1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology 1-2.3. Modular Pavement Technology
	3. Perform Faster Construction Inspection and Monitoring	• Limits on sensing technology.	1-3.1. High-Speed, Nondestructive Testing Procedures for Design Evaluation and Construction Inspection
	4. Facilitate Innovative and Equitable Contracting Environment	• Methods specifications constrain efficiency in quality. • Sub-optimized contracting approaches and use of incentives. • Unbalanced risk allocation between owners and contractors. • Lack of rapid decision-making can constrain project activities.	1-4.1. Performance Specifications 1-4.2. Alternate Contracting Strategies for Rapid Renewal 1-4.3. Incentive-based Specifications to Assure Meeting Rapid Renewal Project Goals 1-4.4. Development and Evaluation of Performance-based Warranties 1-4.5. Risk Manual for Rapid Renewal Contracts 1-4.6. Innovative Project Management Strategies for Large, Complex Projects

Table 1. Relationship of Research Projects to Research Objectives (continued)

Strategic Objectives	Tactics	Barriers	Research Projects
Minimize Disruption (for users on and adjacent to project)	5. Plan Improvements to Mitigate Disruption	• Planning not corridor based. • Traditional project-based objectives. • Financing constraints.	1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process 1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development 1-5.3. Strategic Approaches for Financing Large Renewal Projects
	6. Improve Customer Relationships	• Difficult to mitigate impact to users and public services • Ineffective coordination with utilities and railroads. • Insufficient consideration to adjacent environment.	1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection 1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects 1-6.3. Utilities-DOT Institutional Mitigation Strategies 1-6.4. Railroad-DOT Institutional Mitigation Strategies 1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods
	7. Improve Traffic Flow in Work Zone	• Traditional approaches are inadequate for high traffic volumes.	1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety
Produce Long-Lived Facilities	8. Design and Construct Low-Maintenance Facilities	• Maintenance is not adequately considered during design and construction. • Lack of predictable performance models.	1-8.1. Durable Bridge Subsystems 1-8.2. Design for Desired Bridge Performance 1-8.3. Composite Pavement Systems 1-8.4. Stabilization of the Pavement Working Platform 1-8.5. Using Existing Pavement in Place and Achieving Long Life
	9. Monitor In-Service Performance	• Lack of performance-related metrics and analysis systems.	1-9.1. Nondestructive Evaluation Methodology for Unknown Bridge Foundations 1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems 1-9.3. Monitoring and Design of Structures for Improved Maintenance and Security
	10. Preserve Facility Life	• High traffic volumes. • Lack of methods to extend life.	1-10.1. Preservation Approaches for High Traffic Volume Roadways 1-10.2. Bridge Repair/Strengthening Systems 1-10.3. Techniques for Retrofitting Bridges with Non-redundant Structural Members

Table 2. Summary of Projects

Note: All projects will show the relationship to the renewal mission of developing a consistent, systematic approach to performing highway renewal that is rapid, causes minimal disruption, and produces long-lived facilities.

Tactic 1-1. Perform Faster In Situ Construction			
Project	**Major Objectives**	**Major Products**	**Cost/ Duration**
1-1.1. Utilities Location Technology Advancements	• Identify promising technologies for further development. • Develop technologies and supporting systems for locating and documenting utility locations.	• State-of-the-art manual for locating utilities • New tools and methods for locating utilities	$5,000,000 5 years
1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction	• Develop design guidelines and quality control test procedures for construction of ground improvement techniques. • Develop performance-based construction specifications for selected soil improvement technologies.	• National implementation of cost-effective techniques for roadway widening into cuts • Development of new techniques to widen roads in cut-fill sections • Performance-related specifications and construction inspection certification programs	$2,000,000 5 years
1-1.3. Replacement of Conventional Materials with High-Performance Materials in Bridge Applications	• Develop techniques for using high-performance materials in conventional ways such that efficiency and life are increased.	• Standard drawings, specifications, and guidelines for using high-performance materials in conventional systems for improved efficiency and effectiveness	$2,150,000 3 years
1-1.4. Rapid Rehabilitation Strategies of Specialty Structures	• Develop guidelines for management of specialty structures. • Develop guidelines for the rapid repair and rehabilitation of specialty structures. • Develop guidelines for the monitoring of specialty structures.	• Guidelines for collecting, incorporating, and using input parameters for asset management of specialty structures • Guidelines for the adaptation of existing, conventional systems and for the development of new rapid repair and rehabilitation systems • Guidelines for the design and implementation of sensor systems in new and existing specialty structures	$4,000,000 6 years
1-1.5. Micropiles for Renewal of Bridge Foundations	• Implement routine use of micropiles for renewal of bridge foundations nationwide.	• National specification for micropiles • Inspector training course and a national certification standard for inspectors of micropile projects	$1,000,000 2 years

Table 2. Summary of Projects (continued)

Project	Major Objectives	Major Products	Cost/ Duration
Tactic 1-1. Perform Faster In Situ Construction			
1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System	• Assess the needs and create an implementation plan for developing and implementing the intelligent project delivery system.	• Comprehensive needs assessment and implementation plan for developing an intelligent project delivery system for highway renewal	$1,000,000 5 years
1-1.7. Facilitating the Use of Recycled Aggregates	• Enhance the use of recycled aggregates for rapid renewal operations.	• A guide to using recycled in PCC and ACC for rapid renewal projects Test methods, in AASHTO format, for testing recycled aggregates and mixtures made with those materials	$2,500,000 3 years
1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments	• Determine the impact of human fatigue on work activities commonly associated with highway construction projects. • Develop strategies for organizing, structuring, and executing rapid renewal projects that incorporate fatigue reduction into the project planning process.	• Recommendations for reducing worker fatigue and improving safety • Fatigue management plans	$1,500,000 2 years
Tactic 1-2. Minimize Field Fabrication Effort			
1-2.1. Modular Bridge Systems	• Develop modular bridge systems that are compatible with short construction times. • Develop policies, procedures, and methodologies for the development, acceptance, and adoption of modular bridge systems.	• Standard drawings and specifications for the design and construction of modular bridge deck, superstructure, substructures, and foundations • Policies, procedures, and methodologies for the development, acceptance, and adoption of new bridge systems	$9,550,000 6 years
1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology	• Develop approaches to designing bridges that efficiently integrate modern construction technology.	• Standard drawings and specifications for bridge systems and construction technologies that increase construction efficiency	$4,000,000 4 years
1-2.3. Modular Pavement Technology	• Improve pavement quality control through use of pre-cast and modular technologies. • Develop design protocols for modular pavement renewal systems.	• Design standards for modular pavement systems, including structural design procedures, support and connection details, material requirements, etc. • Guide specifications to facilitate the implementation of modular pavement technology	$2,500,000 4 years

Table 2. Summary of Projects (continued)

Tactic 1-3. Perform Faster Construction Inspection and Monitoring			
Project	**Major Objectives**	**Major Products**	**Cost/ Duration**
1-3.1. High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	• Develop and/or implement rapid construction inspection techniques for a variety of construction materials, including subgrade, base, structures, PCC and ACC pavement layers, for use in rapid renewal applications.	• AASHTO-format test procedures for rapid design evaluation and construction inspection	$5,000,000 5 years
Tactic 1-4. Facilitate Innovative and Equitable Contracting Environment			
1-4.1. Performance Specifications	• Develop specifications that better address the type and complexity of work anticipated in rapid renewal. • Develop specifications that can be used effectively in different contracting scenarios—design-build, warranties, etc.	• New performance-based specifications for AASHTO in interactive computer language, with clear determination of risks and required future research to fully implement the specification • Performance-based specifications book for alternative contracting scenarios	$2,225,000 5 years
1-4.2. Alternate Contracting Strategies for Rapid Renewal	• Determine how various alternative contracting strategies can be used effectively in various rapid renewal scenarios. • Quantify the sharing or transfer of risk between the DOTs and the contracting industry as a result of these strategies.	• Guidebook on alternative contracting strategies with clear descriptors, uses, experiences, strengths, weakness, perceived benefits and risks • Decision support tools	$2,000,000 4 years
1-4.3. Incentive-based Specifications to Assure Meeting Rapid Renewal Project Goals	• Improve delivery of rapid renewal projects and products through incentive-based specifications. • Provide a way for DOTs to reward contractors for well-managed, efficient, and high-quality work.	• Project goal incentive clauses and instructional guidelines • A new incentive-based specification for overall project quality	$1,500,000 3 years
1-4.4. Development and Evaluation of Performance-based Warranties	• Improve the effectiveness of warranties and guarantees in rapid renewal projects. • Develop product warranties and guarantee language that better address inherited condition of the facility, design responsibilities, contractor flexibility in selecting products and equipment procedures, in-service traffic and environmental issues, and unforeseen factors.	• Warranties and guarantees—manual of proposed practice for rapid renewal projects • Guidelines on ways to minimize risk of warranties and guarantees on DOTs and construction industry	$1,500,000 4 years

Table 2. Summary of Projects (continued)

Tactic 1-4. Facilitate Innovative and Equitable Contracting Environment			
Project	**Major Objectives**	**Major Products**	**Cost/ Duration**
1-4.5. Risk Manual for Rapid Renewal Contracts	• Better understand the relationship between risk, bonding, insurance, warranties, etc., their risk to the construction industry, and their long-term impact on the DOTs.	• Risk and risk transfer manual for the highway construction industry	$1,000,000 3 years
1-4.6. Innovative Project Management Strategies for Large, Complex Projects	• Better manage administrative functions between DOT and contractor as impacted by rapid renewal projects. • Accelerate decision-making process required for rapid renewal projects.	• A guide (decision aid) to innovative project management for a variety of renewal processes, especially large scale projects	$750,000 2 years
Tactic 1-5. Plan Improvements to Mitigate Disruption			
1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process	• Determine the optimal organization of corridor improvements into biddable construction packages, accounting for budget, traffic management, constructability, safety, minimal disruption to the traveling public, industry capabilities, and rapid renewal strategies. • Develop a life-cycle cost protocol for the overall impact of construction corridor improvements, using user-cost inputs and various cost scenarios, to determine tradeoffs and impact on downstream disruptions.	• Practices and methodologies for establishing and planning corridor improvements with construction alternatives included • Life-cycle cost analysis manual for optimizing corridor improvements • Corridor establishment and management training program	$1,250,000 3 years
1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development	• Integrate preservation and rehabilitation methodologies into the overall corridor planning process as a means to minimize public disruption, optimize budgets, maintain reasonable levels of service, and delay, postpone, or replace major reconstruction alternatives. • Organize preservation and rehabilitation strategies, their life expectancy, risk, and applicability to various levels of loading and environmental conditions for typical corridor management scenarios.	• Report on current and potential repair strategies, their life expectancy, and the impact they will have on minimizing disruption while maintaining the infrastructure • Guidelines for selecting and programming fixes within a corridor • Guidelines for determining proper timing	$1,500,000 3 years

Table 2. Summary of Projects (continued)

Tactic 1-5. Plan Improvements to Mitigate Disruption			
Project	**Major Objectives**	**Major Products**	**Cost/ Duration**
1-5.3. Strategic Approaches for Financing Large Renewal Projects	• Identify ways to fund and finance large (mega) renewal projects while addressing their impact on other DOT programs. • Identify innovative ways that finance and revenue streams could be linked closer to those that are specifically benefiting from the mega-project.	• Guidelines • Financing strategies	$1,000,000 3 years
Tactic 1-6. Improve Customer Relationships			
1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection	• Improve agency and public interaction and collaboration before and during renewal operations.	• Guidelines for establishing successful public and agency relationships • Public-private partnership program for delivering the visual tools needed to communicate complex projects to the public	$2,500,000 3 years
1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects	• Provide businesses affected by renewal operations the information they need to operate and ensure the continuity of emergency response services during renewal projects.	• Method to present site-specific impacts to business owners for each phase of a renewal project • Guidelines document for working with businesses	$1,500,000 4 years
1-6.3. Utilities-DOT Institutional Mitigation Strategies	• Develop appropriate institutional arrangements to facilitate effective utility management during the entire project development process. • Provide recommendations on specification and national and state-level policy changes that would enable innovation and remove barriers inherent in current utility relocation policies.	• Best practice manual with an assessment of the potential benefits • Model agreements that can be executed at the national, regional, and local levels	$3,000,000 6 years
1-6.4. Railroad-DOT Institutional Mitigation Strategies	• Identify strategies and institutional arrangements that will facilitate beneficial relationships between railroads and public agencies, including experimental arrangements. • Investigate and develop innovative partnering techniques whereby railroads and the highway community are working cooperatively.	• Best practice document with an assessment of the potential benefits • Model agreements for cooperation between the railroads and the appropriate highway organizations	$1,750,000 4 years

Table 2. Summary of Projects (continued)

Project	Major Objectives	Major Products	Cost/ Duration
Tactic 1-6. Improve Customer Relationships			
1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods	• Apply context-sensitive design principles to specific applications related to rapid renewal projects. • Identify and apply context-sensitive construction operations to minimize the impact of renewal projects on their surroundings.	• Guide to context-sensitive construction including options for various renewal scenarios	$750,000 3 years
Tactic 1-7. Improve Traffic Flow in Work Zone			
1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety	• Develop a work zone design, installation, and maintenance plan for high consistency, visibility, and safety.	• Work zone guidelines manual designed to establish consistent work zone treatments across the country	$2,000,000 3 years
Tactic 1-8. Design and Construct Low-Maintenance Facilities			
1-8.1. Durable Bridge Subsystems	• Develop bridge systems with minimal deck joints that will allow rapid construction and long life. • Develop bridge systems with alternatives to bearings that will allow rapid construction and long life.	• Design methods, details, standard plans, and specifications for bridge subsystems	$6,000,000 6 years
1-8.2. Design for Desired Bridge Performance	• Develop comprehensive design procedures and specifications that integrate material performance (including durability), construction practices and structural performance that will lead to more predictable service life, especially long life, which also considers structural and material redundancy.	• Design procedures • Performance-based specifications	$3,000,000 3 years
1-8.3. Composite Pavement Systems	• Develop performance models and design procedures for long-lasting, easily maintained new composite pavements for rapid renewal. • Investigate and understand the behavior and critical performance parameters of composite pavements. • Develop material requirements for all layers of the composite pavement, including the subgrade.	• Policies, procedures, and methodologies for the development, acceptance, and adoption of composite pavement systems • Design, materials, and construction manuals	$5,000,000 4 years
1-8.4. Stabilization of the Pavement Working Platform	• Develop schemes for the integration of base and subgrade performance into the design and evaluation of existing and new pavement systems. • Determine which emerging technologies offer promise to identify areas of poor subgrade conditions.	• Integrated pavement design procedure • Guidelines and recommendations for design, construction, and quality control of mechanical and chemical treatment of base, subbase and subgrade layers	$1,600,000 3 years

Table 2. Summary of Projects (continued)

Tactic 1-8. Design and Construct Low-Maintenance Facilities			
Project	**Major Objectives**	**Major Products**	**Cost/ Duration**
1-8.5. Using Existing Pavement in Place and Achieving Long Life	• Develop detailed criteria on when an existing pavement can be used in place, with or without significant modification. • Determine the best ways to construct these types of pavements in a high-speed environment.	• New and updated design guides • New construction procedures	$1,000,000 2 years
Tactic 1-9. Monitor In-Service Performance			
1-9.1 Nondestructive evaluation Methodology for Unknown Bridge Foundations	• Implement NDE methodology for unknown bridge foundations.	• Demonstration projects • Standards and specifications	$1,000,000 2 years
1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems	• Identify the performance-based metrics, including material deterioration and bridge life-cycle information, required to quantify bridge performance. • Develop protocols for collection, integration, and dissemination of performance data.	• Protocols for collection, integration and dissemination of performance data • Database of performance data, life-cycle information, and rehabilitation, repair, and replacement operations	$4,000,000 6 years
1-9.3. Monitoring and Design of Structures for Improved Maintenance and Security	• Continuously monitor key infrastructure assets (including long-term durability assessment, catastrophic event monitoring, general asset management assessment and security).	• Data processing techniques • Monitoring plan, including data-reduction procedures	$5,000,000 6 years
Tactic 1-10. Preserve Facility Life			
1-10.1. Preservation Approaches for High Traffic Volume Roadways	• Identify preservation strategies and products that are usable on high traffic volume roadways.	• Guidelines on preservation strategies for high traffic volume roadways	$750,000 2 years
1-10.2. Bridge Repair/ Strengthening Systems	• Develop systems for repairing and strengthening bridges.	• Standard drawing and specifications for the repair and strengthening of bridges	$2,000,000 2 years
1-10.3. Techniques for Retrofitting Bridges With Non-redundant Structural Members	• Develop renewal techniques for addressing and removing non-redundant bridge characteristics.	• Standard drawings and specifications for addressing “non-redundant” bridges	$1,500,000 3 years

TOTALS **38 projects** **$ 95,275,000**

SECTION B. STATEMENT OF THE PROBLEM

As U.S. Transportation Secretary Norman Mineta has said, "Mobility is one of our greatest freedoms." Our nation's 3,951,000-mile highway system not only enables our personal mobility with 91 percent of all person-miles traveled in the United States occurring in private vehicles, but is also the backbone of our nation's economy. See Figure 1. Eighty-four percent of the nation's seven trillion dollars in freight traffic travels on highways, with truck travel expected to grow by more than three percent annually over the next 20 years.

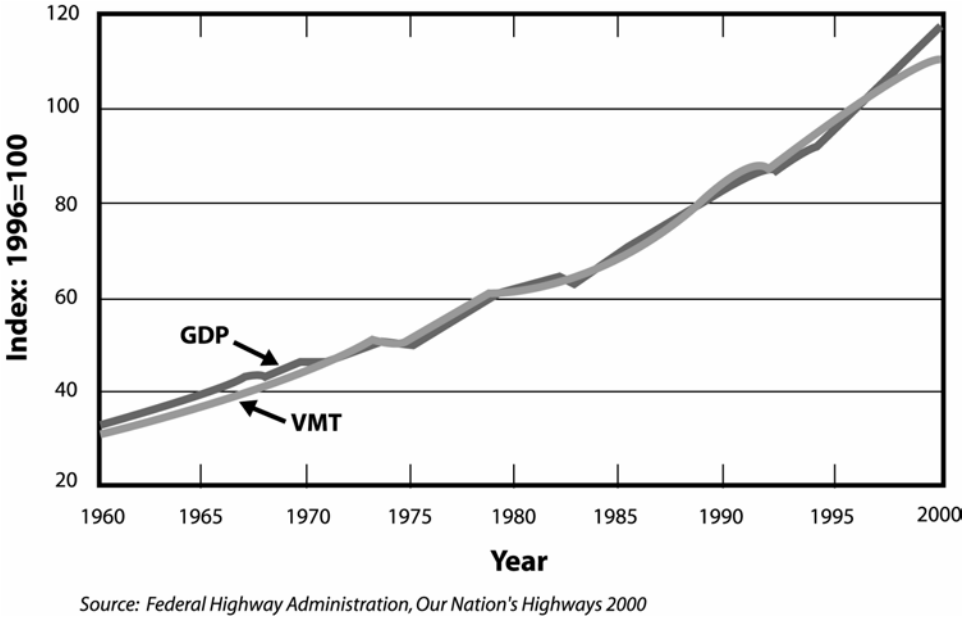


Figure 1. Gross Domestic Product and Travel Relationship

From 1980 to 2000, highway travel increased 76 percent while highway mileage increased only 2 percent. The NHS, which is composed of the high end of the transportation arteries in the nation and represents 4 percent of the national system, is carrying 44 percent of total vehicle miles of travel (VMT). See Figure 2.

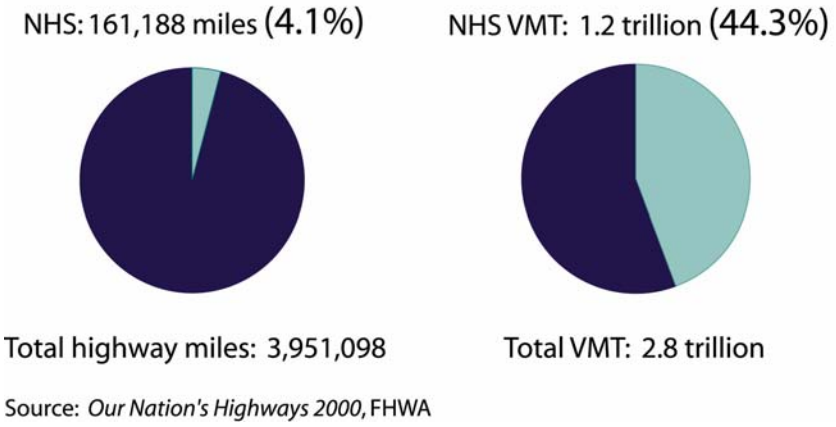


Figure 2. National Highway System Highway Miles and Vehicle-Miles Traveled

However, one has only to look at FHWA's "National Traffic and Road Closure Information" website to get a global assessment of the magnitude of traffic-impacting activities that are occurring on our busiest highways and urban streets. The challenge to maintain a high degree of mobility on the most vital segments of our nation's highways is further illustrated by the following set of facts:

- The U.S. population is predicted to grow 20 percent by 2025.
- VMT is projected to increase another 50 percent by 2020.
- Truck volume is predicted to double from 8 billion tons to 16.8 billion tons by 2020.
- The public has very little tolerance for delays, especially multi-year delays.
- More than 800 people are killed and about 42,000 injured annually in work zones.
- Based on 1998 obligations, resurfacing is being performed on 12.8 percent (20,500 miles) of the NHS annually. This is a 7–8 year resurfacing cycle for the 160,000-mile system.
- Reconstruction was performed on 3,200 miles, implying a 50-year replacement cycle. This suggests the need for a 50-year roadway or "perpetually renewable" roadway.
- Twenty-nine percent (585,542 miles) of the national bridge inventory is structurally deficient or functionally obsolete.

Collectively, these statistics represent a pending crisis that must be addressed. This is further reinforced by a recent Texas Transportation Institute study that estimates the cost of congestion in just 68 urban areas has grown from $21 billion in 1982 to $78 billion in 1999 (36 hours per driver a year and 6.8 billion gallons of wasted fuel). The study also estimated that congestion results in 4.4 billion person hours of delay annually in the 68 urban areas it studied. One normally does not have to travel far to realize that mobility on our most critical highways is compromised due to heavy traffic volumes and the constant repair and reconstruction occurring on the system.

In the Transportation Equity Act for the 21st Century (TEA-21), Congress requested that TRB conduct a study to determine the goals, research agenda and projects, administrative structure, and fiscal needs for a new strategic highway research program. In response to this request, TRB formed a committee of highway industry leaders to develop recommendations. The committee engaged in an extensive outreach process to gather input from throughout the highway community regarding strategic priorities and promising research approaches. The committee's report was published in October 2001. It recommends a Future Strategic Highway Research Program (F-SHRP) with this overarching theme: providing outstanding customer service for the 21st century.

TRB *Special Report 260* further recommends four strategic focus areas:

1. Renewal: accelerating the renewal of America's highways
2. Safety: making a significant improvement in highway safety
3. Reliability: providing a highway system with reliable travel times
4. Capacity: providing high capacity in support of the nation's economic, environmental, and social goals

Renewal is the subject of this report. *Special Report 260* states the overall program goal of renewal is "to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities."

The two major research renewal objectives as stated in *Special Report 260* are as follows:

1. Achieve renewal that is performed rapidly, causes minimum disruption, and produces long-lived facilities.

2. Achieve such renewal not just on isolated, high-profile projects but consistently through the highway system.

Many successful projects have already been built and are featured in articles in professional magazines and trade publications. However, what is often not stated is that these projects have been completed at a price. Tradeoffs in quality, significant costs, exhausted workers, unacceptable traffic impacts, and less-than-desired public satisfaction are results that occur all too often. In addition, there is often an impact to an agency's overall program as resources are diverted to finance the high-profile project. This project will examine the barriers that need to be overcome to enable a consistent, sustainable approach to renewing our nation's busiest highways and urban streets.

The challenge of this report is to strategically address the barriers to rapidly renewing our busiest highways in the nation. The need for major renewal is clear. How to fund this work, deliver the projects without public outcry over the delays, and deliver a superior highway product is not so clear. Thus, the research described in this report is needed to enable renewal to be accomplished while "providing outstanding customer service for the 21st century."

SECTION C. APPROACH

The approach to this project combines the knowledge of a broad-based study team, a thorough literature search, input from national organizations, and input from a large and knowledgeable oversight panel. The study team is led by the Center for Transportation Research and Education (CTRE) at Iowa State University. The team also includes individuals from TDC Partners, Inc., and Purdue University. The knowledge areas represented by the team include the following:

- Principal investigator—former chief engineer of the Iowa DOT Highway Division, with broad engineering and project delivery knowledge
- Co-principal investigator—former FHWA chief of engineering technology and technology applications and current consultant on innovative construction practices
- Staff of CTRE with traffic engineering and public involvement knowledge
- Structures faculty, Iowa State University
- Construction engineering faculty, Iowa State and Purdue Universities
- Geotechnical engineering faculty, Iowa State and Purdue Universities
- Concrete and asphalt materials faculty, Iowa State and Purdue Universities
- Specialty consultants on innovative contracting and construction management with DOT experience in structures and major renewal projects

The challenge for the research team is that the F-SHRP program of research is to be strategically focused and breakthrough in nature. There is a tremendous amount of valuable research ongoing at the national, state, and local levels, and the charge is not to duplicate this work but to address the gaps in knowledge and practice that are vital to enabling rapid renewal of our highway system to occur. The team met with FHWA research staff, National Cooperative Highway Research Program (NCHRP) staff, American Association of State Highway and Transportation Officials (AASHTO) staff, and representatives of selected state DOTs for insight into their program directions. To the maximum extent possible, the team avoided duplicating work that was proposed by others, unless it clearly addressed rapid renewal, minimizing disruption to the public, or long facility life. Accordingly, the team did not pursue a significant amount on long-term modeling or collection of performance data, even those topics are crucial to determining the “stay out” or “long-life” elements of the F-SHRP mission. Similarly, the team did not include asset management as a major topic but did include nondestructive evaluation (NDE) and health monitoring technologies that would provide input to asset management systems. Research on pavements is targeted at modular technologies, composite pavements, and subgrade issues.

The team’s review included national research plans as well as work in progress in the following areas:

- **Pavements:** *A Strategic Plan (Road Map) for Pavement Research* (AASHTO Joint Task Force for Pavements); Long-Term Pavement Performance (LTPP) Program Product Catalog (FHWA)
- **Portland cement concrete (PCC) pavements:** FHWA and American Concrete Pavement Association documents
- **Asphalt cement concrete (ACC) pavements:** *Hot Mix Asphalt Research and Technology: A Commitment to the Future* (National Asphalt Pavement Association, Special Report 178)
- **Preservation:** Foundation for Pavement Preservation
- **Construction:** *Construction Engineering and Management Research* (NCHRP Project 10-58)
- **Infrastructure:** FHWA Stakeholders Forum and supporting documentation
- **Structures:** *Thrust Areas/Business Needs for Bridge Engineering* (NCHRP Project 20-07)
- **Geotechnology:** FHWA documents

The team was divided into six working groups to focus on aspects of the overall renewal problem:

1. Construction Finance and Finance Planning
2. Public Involvement and Traffic Control
3. Advanced Information Technologies
4. Contracting and Management Strategies
5. Roadways—design and construction methods, materials, and equipment
6. Structures—design and construction methods, materials, and equipment

Early in the project, white papers were prepared by each working group based on literature searches and the personal knowledge of the team. A bibliography of over 200 items was compiled in support of the white papers. The working groups met five times during the project. In the early meetings, visions of the future were created to guide and coordinate the development of more specific research project statements. The list below shows the visions of the future that the team developed:

- Agencies will strategically define, analyze, package, and renew highway corridors and projects so as to minimize current and future traffic disruptions and maximize overall initial and life-cycle costs, and in the process, improve environmental stewardship, and minimize impact on the public.
- Agencies will have new tools to finance very high cost renewal projects in order to minimize the impact on the remaining highway program.
- Agencies and the public (general, businesses, emergency services, etc.) will work together creatively and cooperatively to identify best strategies that impact mobility and access before and during renewal operations.
- Agencies, utilities, and railroads will have new streamlined permitting and relocating processes and improved partnerships that will allow for timely and efficient progression of renewal projects.
- Innovative construction operations will minimize noise, traffic, and local inconvenience during renewal projects.
- Innovative bridge and pavement systems that can be constructed within extremely short time frames will facilitate minimizing disruption to motorists.
- Through improved material selection, design processes, and integration with construction technologies, designers will be able to choose a desired performance life and design facilities that will reliably achieve that life.
- Information technologies (IT) will be used to develop a comprehensive intelligent project delivery system (IPDS) to improve the efficiency of design, construction, and maintenance on highway renewal projects.
- Innovative, nontraditional materials will accelerate construction and maintenance and extend product life at a fair and reasonable cost.
- New construction processes will specifically address high-intensity, compressed schedule construction projects.
- A new generation of specifications will allow the contractors to exercise more innovation and attention to quality, especially in rapid renewal projects.
- Agencies will improve project delivery through the selection of various innovative contracting strategies that will best integrate project finance, design, bid, construct, warrant, operate, and maintain alternatives.
- Agencies and contractors will identify a new generation of contracting incentives that further encourage innovation and reward contractors for exceeding rapid renewal project goals.
- Agencies and contractors will collectively better understand risk, risk calculation, risk transfer, and risk sharing as they relate to rapid renewal and innovative contracting alternatives.
- Agencies will have several innovative project management strategies to select from, depending on the type and extent of the renewal process.

- Procedures for design evaluation and construction inspection will be high speed, real time, and in situ using nondestructive, 100 percent sample testing. Test results will be available as work progresses to reduce noncompliant products and the need for corrective action.
- Facility owners will be able to continuously monitor the physical condition of roadways and structures in order to improve maintenance and security, and to revise design.
- Work zones and work sites of the future will be safer and more efficient for both motorists and construction workers.
- Agencies will have access to expert guidance to aid in meeting the F-SHRP objectives in the strategic focus areas (renewal, safety, reliability, and capacity) supporting economic, social, and environmental goals.

Each vision encompassed a different aspect of what is needed to build highways faster, with less disruption, and with improved durability. The group continually critiqued the draft project statements for strategic importance based on the goals and objectives of rapid renewal.

Based on input from reviewers, the visions were eventually abandoned as a useful means of structuring the material and linking the research plan to the strategic renewal objectives developed in *Special Report 260*. In place of the visions, 10 tactics were identified for implementing the strategic objectives of renewal, barriers to executing these tactics were identified, and the research projects were tailored to overcoming the barriers. The tactics and barriers are summarized in Section A. The introduction to each project in Section F identifies the barriers that the project is addressing.

During the research, a bibliographic database was created and posted on the CTRE F-SHRP website. The database contains abstracts of documents identified in the literature search, bibliographic citations, and recommendations for renewal research. The research recommendations were drawn from the literature, from the panel, and from outreach activities.

Outside input was obtained during the project-development process. Staff attended the construction subcommittee meeting of AASHTO's Standing Committee on Highways. Input was drawn from the TRB A5T60 workshops on accelerating highway construction. Purdue's knowledge base as the North Central Superpave Center contributed to knowledge of asphalt paving issues, and the Center for Portland Cement Concrete Pavement Technology at Iowa State University contributed knowledge on PCC issues. The project team met with the geotechnical engineering staff at the FHWA and with James Roberts, former bridge engineer with the California DOT, to strengthen research project statements in these topic areas.

Finally, the team met three times with the renewal project panel and continuously refined the report structure and research project statements guided by the panel's input. The team also met with the F-SHRP oversight panel and further modified the report structure and project statements based on their input. At the two-thirds point in the project, individual panel members assumed responsibility for critiquing draft research project statements in their areas of expertise. The team incorporated the panel's specific comments into the final project statements.

Project statements were evaluated for strategic-level importance following the guide shown in Figure 3. Project statements included in Section F pass the first two screening criteria: they meet the F-SHRP Renewal objectives and they are appropriate for F-SHRP research. The F-SHRP objectives are as follows:

- Rapid renewal
- Minimum disruption to the public
- Long life
- Continuous, systematic approach

All projects included in the research plan passed the first two screening criteria. The remaining projects were prioritized as high or medium priority using six criteria.

1. Is the project researchable?
2. What is the probability of success?
3. Can the project be completed and be in the implementation phase within 10 years?
4. Will the research produce significant national benefits?
5. Does the project avoid duplication and build productively upon other completed or ongoing research?
6. Is the problem important to state DOTs and others?

Low-priority projects were eliminated from the research plan by the first two screening criteria. However, project statements that have merit but that fail to satisfy the first two criteria are included in Section J.

One of the most difficult elements of the project was to distinguish incremental research that could be provided under existing or expected research efforts from breakthrough research appropriate for F-SHRP. Historically, national legislation has provided funding through mechanisms such as NCHRP, FHWA discretionary program, national pooled fund projects, and University Transportation Centers (see Table 3). Recently, Congress has appropriated research funds specifically for certain materials such as concrete and asphalt pavements, geotextiles, and safety hardware.

Each of these programs and processes has its own history and niche in the highway community. The team, with guidance from the panel, assumed that Congress will continue to fund such research programs that will continue both incremental and long-range research efforts.

PROJECT STATEMENT RATING CRITERIA

1. Does the project statement support the strategic vision of F-SHRP as defined in TRB *Special Report 260* (to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimal disruption, and produces long-lived facilities)? Please respond to this question on a scale from 1 to 10 (1 = not at all, 10 = extremely well) and provide written comments if necessary.

   1 2 3 4 5 6 7 8 9 10

   Additional Comments: _____

   If the rating for this question is >5, then proceed to Question 2; otherwise, this project does not meet the essential F-SHRP criteria and no further questions need to be answered.

2. Is the proposed project appropriate for funding under F-SHRP or should it be conducted elsewhere? Please circle your response.

   APPROPRIATE FOR FUNDING UNDER F-SHRP CONDUCTED ELSEWHERE

   If CONDUCTED ELSEWHERE, please identify a possible agency that might be interested in funding this project and then proceed to Question 3.

   Possible Funding Agency: _____

3. Is the level of breakthrough impact for the proposed project significantly high? In order to determine this value, please answer the following questions that relate to the level of impact on a scale from 1 to 10 (1 = low, 10 = high). The average for these five questions represents the level of impact (this assumes equal weighting for each question). Categories for high, medium, and low are defined as follows:
   high (average >= 8); medium (4<= average <8); low (1<= average <4)

   a. Is the project researchable (1 = not very, 10 = extremely)?
      1 2 3 4 5 6 7 8 9 10

   b. What is the probability of success (1 = very little chance, 10 = very likely chance)?
      1 2 3 4 5 6 7 8 9 10

   c. Can the project be completed and in the implementation phase within 10 years (1 = very little chance, 10 = very likely chance)?
      1 2 3 4 5 6 7 8 9 10

   d. Will the research produce significant national benefits (1 = insignificant, 10 = significant)?
      1 2 3 4 5 6 7 8 9 10

   e. Does the project avoid duplication and build productively upon other completed or ongoing research (1 = significant duplication, 10 = completely new research)?
      1 2 3 4 5 6 7 8 9 10

   f. Is the problem important to state DOTs (1 = not very, 10 = extremely)?
      1 2 3 4 5 6 7 8 9 10

   Please indicate the Level of Impact Rating: Average Value: _____

   Categorical Value (please circle one): HIGH MEDIUM LOW

Figure 3. Project Statement Rating Criteria

Table 3. Sponsors that Set the Highway Infrastructure Research Agenda

Sponsor	Highway Infrastructure Research
FHWA	Office of Infrastructure Office of Bridge Technology Innovative Bridge Research and Construction Program Office of Pavement Technology Concrete Pavement Technology Program Superpave Technology and Delivery Innovative Asphalt Paving Material Office of Asset Management System Management and Monitoring Construction and System Preservation Evaluation and Economic Investment Office of Research, Development and Technology Office of Infrastructure Research and Development Bridge Design and Construction Bridge Safety, Reliability, and Security Infrastructure Inspection Asphalt Pavement PCC Pavement LTPP Program
NCHRP (funded by state DOTs through AASHTO)	Research Field C: Design Pavement Bridges Research Field D: Materials and Construction General Materials Bituminous Materials Specifications, Procedures, and Practices Concrete Materials Research Field E: Soils and Geology Testing and Infrastructure Properties Mechanics and Foundations Research Field F: Maintenance Maintenance of Way and Structures
University Transportation Centers (funded by U.S. DOT Research and Special Programs Administration)	Iowa State: Sustainable Asset Management Purdue: Safe, Quiet, and Durable Highways Northwestern: Infrastructure Technology Missouri-Rolla: Advanced Materials and Nondestructive Evaluation Technologies
National associations	AASHTO Standing Committee on Research (sets research agenda for NCHRP) Research Advisory Committee Design Guides Asset Management American Concrete Paving Association Portland Cement Association National Asphalt Paving Association
State DOTs	Research activity in all 50 states NCHRP sponsorship

Note: This table shows only research most closely associated with renewal.

SECTION D. OBJECTIVES AND DESIRED OUTCOMES

The overarching theme of F-SHRP is to provide outstanding customer service for the 21st century. The objective of the "Renewal" portion of F-SHRP as stated in the request for proposals is to develop a specific research plan for renewal. The desired outcome of the research plan is to achieve the overall strategic renewal goal as stated in TRB *Special Report 260*: "To develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities."

The research plan in Section F is composed of 10 tactics and 38 projects for achieving the elements of the strategic goal. The tactics supporting each element are given below by category.

Tactics for rapid approaches:

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

Tactics to minimize disruption:

- Plan improvements to mitigate disruption.
- Improve customer relationships.
- Improve traffic flow in work zones.

Tactics to produce long-lived facilities:

- Design and construct low-maintenance facilities.
- Monitor in-service performance.
- Preserve facility life.

These tactics recognize that the project delivery process for high-volume facilities will look substantially different in the future. Traditional methods break down when there is public pressure to keep a road open and finish renewal work fast. Traditional methods

- Are project based
- Are linear
- Involve customers late in the process
- Require long delivery time
- Use incremental financing
- Lack interdisciplinary leadership
- Rarely consider the impact of multi-year traffic impacts

The desired outcome from this project is implementation of rapid renewal strategies. These strategies will reduce the impact of renewal on roadway users and adjacent communities. User delay cost will be reduced, work zones will be safer, construction times will be shorter, and renewed roadways will last longer.

Achieving these outcomes will require a commitment to organizational change by DOTs and other project owners. To implement the tactics described above, renewal projects must be corridor and network based and be driven by the goals of rapid renewal. The public must be involved early, and visualization tools are needed to aid the public in understanding the implications of a project. Design and construction processes must be integrated and consistently repeatable. Monitoring systems are needed to support performance-based specifications; continuous health-monitoring systems will aid in project selection. Contracting strategies must be in place to take advantage of fast-track construction methods, and innovative financing opportunities must be available.

Completing the research plan will break down the technical and institutional barriers to implementing the tactics. It is anticipated that changes will happen first in agencies responsible for mega-projects." Financial pressure, the need for rapid construction techniques, and the concomitant need for innovative contracting strategies will first occur on large projects. As these strategies become routine, they will "trickle down" to smaller projects and those sponsored by smaller agencies. The renewal objective of consistent application will happen over time as the perception of risk is reduced and the benefits are clearly demonstrated.

SECTION E. OVERVIEW OF RELATED WORK

A bibliography database was created and posted on the CTRE F-SHRP website to display relevant information and to capture the research needs for this project. A search of the database resulted in a list of references that are particularly significant to the renewal strategies.

There are many relevant reports that address accelerated renewal research and strategies. Of these, TRB *Special Report 260: Strategic Highway Research*, is the most significant. It is the catalyst to this research program and the report that sets the foundation for the 10 strategic renewal tactics identified in this research framework. The 10 tactics are (1) perform faster in situ construction, (2) minimize field fabrication effort, (3) perform faster inspection and construction monitoring, (4) facilitate an innovative and equitable contracting environment, (5) plan improvements to mitigate disruption, (6) improve customer relationships, (7) improve traffic work flow in work zone, (8) design and construct low-maintenance facilities, (9) monitor in-service performance, and (10) preserve facility life.

Several reports cover all or most of the renewal topics. They are identified in the major documents section below. Many other reports are more specific to each topic and are shown in their respective sections that follow. Of the many examples, these represent the more significant writing relevant to each topic. Sidebar topics are included to give specific examples of completed projects that exemplify renewal strategies and give significance to the topics identified.

Major Documents

Special Report 260: Strategic Highway Research (TRB, 2001). The overall research program goal is to develop a consistent, systematic approach to performing highway renewal that is rapid, causes minimum disruption, and produces long-lived facilities. The goal is also to achieve such renewal not just on isolated, high-profile projects but consistently throughout the highway system. The following specific research topics would address important unmet needs: (1) construction methods and innovative work schedules; (2) construction equipment, including robotics and automated equipment; (3) innovative materials for greater durability and shortened construction times; (4) nondestructive, real-time sensing and evaluation technologies; (5) innovative management, contracting and finance methods; (6) work zone and corridor traffic analysis and traffic management alternatives; (7) work zone safety techniques and traffic information and traveler notification systems; (8) life-cycle cost analysis; (9) performance measures for performance related specifications; (10) advanced computer technologies; and (11) rapid replacement of bridges and bridge decks.

Construction Engineering and Management Research Program (Russell, Anderson, Trejo, and Hanna, NCHRP Project 10-58, 2002). State highway agencies seek innovative ways to deliver high-quality, cost-effective transportation construction improvements. The purpose of this research was to identify critical construction engineering and management issues. Implementation of future research and development related to these issues will reduce costs associated with the highway projects and improve the quality of the constructed facility. The following are recommended research programs to aid in solving the construction engineering and management problem facing the state highway agencies: (1) evaluations of the use of incentives/disincentives to reduce time to complete highway projects; (2) analysis of nighttime construction activities and impacts on safety, quality, and productivity; (3) expanded use of contractor-performed quality control processes for acceptance of highway projects, (4) implementation of the use of newer materials into highway construction practice; (5) innovative rapid construction/reconstruction methods; (6) improve safety of public and workers during highway reconstruction and maintenance; (7) use of alternative contracting methods and delivery systems to facilitate faster construction/reconstruction; (8) analysis of impacts of strategies to mange traffic during highway projects

on construction methods, productivity, schedule, and quality; (9) recruiting, retaining, and promoting of qualified personnel in highway construction; (10) implementation and evaluation of performance-related specifications for highway construction; (11) identification, evaluation, and implementation of rapid test methods and nondestructive testing to assess quality in construction process; (12) training and workforce development of state highway agency personnel; (13) development of constructability review process implementation plan, (14) determination of strategies to manage the reduced staff size and increased workload of state highway agency personnel; (15) identification, evaluation, and implementation of performance-related acceptance test; (16) development of best practices for community outreach and involvement during construction; and (17) development of best practices for managing environmental restrictions and requirements.

Highway Research and Technology: The Need for Greater Investment (National Highway Research and Technology Partnership, 2002). A broad scope associated with the renewal and preservation of the highway infrastructure was addressed. The scope was divided into three subgroups including asset management, pavements, and highway structures. The areas included in these subgroups were materials for longer lived, more cost-effective pavements; safer, environmentally friendly pavements; enhanced materials, structural systems, and technologies; safety assurance of highway structures for extreme events; enhanced specifications for improved structural performance; and information and automation for structures design, construction, and maintenance.

Infrastructure Renewal Research Agenda (Infrastructure Renewal Working Group, National Research and Technology Partnership Forum, 2001). (Note: These are the working papers for the document listed above, *Highway Research and Technology: The Need for Greater Investment*, and are included here because they provided detailed information pertaining to these topics.) The objective, scope, approach, and research-related findings of the Infrastructure Renewal Working Group are documented in this report. The group's overall area of interest is all research activities associated with the renewal and preservation of the nation's highway infrastructure. The infrastructure includes all national, state, and local government highways and streets, including bridges and other highway-related structures. The research-related findings are broken out into three subgroups: asset management, pavements, and structures. Each subgroup evaluated the techniques, processes, and systems that appear to be working or need strengthening, and remaining work to be done was identified.

Accelerating Opportunities for Innovation in the Highway Industry. Accelerating Highway Construction (TRB Task Force A5T60, 2000). The role of the TRB Task Force A5T60 is to be a catalyst to accelerate innovation. The task force selected the subject of high-speed construction for this workshop topic. The targeted goals were (1) information needs for the future, including lane closure policies, work zone safety data, and congestion and traffic increases; (2) construction and traffic advances such as intelligent vehicle highway systems and technology and innovation flow through safety and education; (3) corridor improvements exploring the "mix of fixes" and corridor management approaches that take a more systematic approach to construction management; (4) contracting and procurement advancements, including evaluating the current state-of-the-art, performance-related specifications, value engineering, quality incentives, and corridor contracts; (5) stay out concepts such as more robust designs and quality control; (6) utilities and the impact that utility delays have on high-speed operations; (7) technology transfer, which requires a very aggressive program to collect and disseminate high-speed construction techniques currently used; (8) safety and health relating to extreme stress workers and managers are under on high-speed, high-visibility projects; (9) training and education; and (10) prefabrication and modular technology advancements.

Thrust Areas/Business Needs for Bridge Engineering (NCHRP Project 20-07, Task 121, 2000). The Highway Subcommittee on Bridges and Structures of AASHTO planned a workshop and selected participants. The information developed in the workshop is a consensus of the participating bridge

engineering professionals and assists the Highway Subcommittee on Bridges and Structures in identifying the major themes for a national bridge engineering agenda. The Highway Subcommittee on Bridges and Structures is using the resulting agenda to evaluate and prioritize research problem suggestions to ensure a quality-based research program. The products of the workshop are six thrust discussions, each of which focuses on a specific business need of the AASHTO bridge engineers. The six thrusts are (1) enhanced materials, structural systems, and technologies; (2) efficient maintenance, rehabilitation, and construction; (3) bridge management; (4) enhanced specifications for improved structural performance; (5) computer-aided design, construction, and maintenance; and (6) leadership.

Get In, Get Out, Stay Out! Proceedings of the Workshop on Pavement Renewal for Urban Freeways (TRB, 2000). This report presents the proceedings from a workshop examining innovative approaches for the efficient and long-lived renewal of freeway pavement while minimizing adverse traffic and community impacts. Another goal was to focus on recent innovations that are immediately applicable and to present an agenda for necessary research and technology development associated with the technologies. The workshop addressed the following topics: highway materials, pavement design, traffic management, traffic operations/work zone control, economics and finance issues, NDE, construction equipment, and overpasses.

NCHRP Synthesis of Highway Practice 273: Project Development Methodologies for Reconstruction of Urban Freeways and Expressways (Saag, 1999). This synthesis presents a review of the current practices associated with the techniques and policies employed by state and local transportation agencies to address the many project development issues required for the reconstruction of existing urban and suburban freeways and expressways. While many of the project development methodologies in practice for reconstruction of urban and suburban freeways and expressways are similar to those used for new construction, there are unique differences that apply primarily to the reconstruction of major urban highway facilities.

Dramatically Reducing Highway Construction Project Times: Suggestions for Research (TRB Research and Technology Coordinating Committee, 1998). The issues associated with dramatically reducing highway construction project times, as well as the potential for research to help achieve such reductions, were addressed by the TRB Research and Technology Coordinating Committee. Opportunities exist to reduce highway construction project times through judicious use of methods and techniques. Innovative contracting techniques, such as incentives and disincentives for expediting construction and the design-build approach, are areas addressed and being used by a number of agencies. Innovative construction technologies, such as off-site precasting and prefabrication and those employing advanced, high-strength materials or composite materials, could also help shorten project times.

Developing Long-Lasting, Lower Maintenance Highway Pavement: Research Needs (TRB, 1997). The purpose of this study was threefold: (1) to determine if it is technologically feasible to construct pavement that will last as long as 50 years without major rehabilitation; (2) to identify the research needed to make long-lived, lower maintenance pavement a reality; and (3) to describe the benefits as well as the constraints associated with the development and use of pavement that lasts longer and requires less maintenance. The study determined that pavement that lasts longer and requires less maintenance than current standard pavement is technologically feasible and is being pursued in several states. Pavement-related research needs recommended by the committee were as follows: (1) address key, unresolved questions, such as improving design procedures, ensuring materials reliability, improving the performance of local materials, and integrating construction and maintenance programs with design expectations; and (2) use data from the LTPP Program.

Tactic 1. Perform Faster In Situ Construction

"Trying to Show That Automation Improves the Bottom Line" (Reina and Roe, 2001). Fiatech, a non-profit research group, hopes to go beyond interoperability and into construction automation to slash 30–40 percent off the cost and time of construction. Projects include using lean production management, geared around just-in-time delivery, and forming public-private partnerships to deploy new technologies. This might include using computer chips to track materials and equipment and three-dimensional (3D) laser scanning to document project status.

CCC: Making the Effort Works! Reducing Utility Delays During Construction (LTS Productions, March 2002). It is well known to highway engineers that uncoordinated utility relocation activities commonly cause costly delays. There are several things that can be done to alleviate this problem. The proper use of information obtained from programs like Subsurface Utility Engineering avoids the need to relocate many utilities. When utility relocations cannot be avoided, early and frequent coordination, cooperation, and communication (CCC), together with the adoption of new technologies, processes, and successful strategies, result in more timely and efficient relocation activities. This results in improved safety and quality in the utility relocation process.

"On-the-Fly" *GPS* (Hadley and Pottle, 1998). The Tongue River Railroad Company of Montana began investigating alternative methods of mapping in place of conventional aerial photogrammetry. Airborne Light Detection and Ranging (LIDAR) surveying technology emerged as a possible alternative. Integrated with differential kinematic global positioning system (GPS) positioning, airborne scanning LIDAR is capable of providing sufficient information for 2-foot (0.6-meter) contour mapping with minimal ground control and minimal time from data collection to product delivery. Because GPS is utilized, there is minimal need for ground control to reference the laser points to a horizontal or vertical datum. "On-the-fly" ambiguity resolution has made kinematic GPS surveying practical for continuous or dynamic integrated data collection. Overall, the cost of using airborne laser mapping was less expensive than traditional surveying because it saved time and staff expenses.

"Raising Highway IQ" (Harris, 1997). The trend is to use new information systems to better manage existing transportation resources. Intelligent transportation systems (ITS) can reduce burdens on roads while freeway management systems, mostly ramp meters, reduce accidents. Electronic toll collection allowed an increase in per-lane capacity, and transit management systems improved on-time performance while reducing costs. Transit signal priority systems decreased transit run times, and a video feed reduced accident clearance times. Advanced transportation management systems disseminate information through changeable message signs, telephone systems, kiosks, computer bulletin boards, highway advisory radio messages, and real-time adjustments to traffic systems.

Faster In Situ Construction

In March 2002, the reconstruction of the "Big I" in Albuquerque, New Mexico, was 96 percent complete. This $220 million reconstruction of the I-40/I-25 interchange was completed in 24 months instead of the 4 to 10 years that would have been required using traditional methods. Forty-five new bridges and 10 rehabilitated bridges were involved, including eight "flyover" bridges that employed precast, segmental construction—the first use on this type of structure in New Mexico. The rapid progress is attributed largely to a unique oversight agreement between the New Mexico State Highway and Transportation Department and FHWA. FHWA representatives were closely involved in the design phase, facilitating the "request for interstate modification" and designation as a "special experimental project" for innovative financing purposes. This gave the FHWA authority to offer a parcel of land to the contractor as an incentive. FHWA approvals were expedited for unique and critical bridges, design exceptions, bid plans, specifications, and estimates. Approvals that usually take months were completed in days. The close working relationship allowed the FHWA to participate first hand, resolving construction and design issues as they arose. The project was let under a low-bid system, but time-driven performance-based specifications were used instead of traditional process specifications. A $2,000 per hour lane rental fee was used to ensure that traffic was maintained as planned. Each partner designated one person with full authority to sign for progress payments and contract changes, eliminating approvals percolating through vertical organizations. An aggressive public outreach program employed a web site, toll-free hot line, and a public advisory group. ("The Big I," *Civil Engineering News,* 2002.)

Punchlister, a new Windows-based tool for superintendents and inspectors, is software from New York City based EK Solutions, Inc. It lets users with portable PCs track outstanding punchlist items in the field and downloads data to PCs for management and report creation. Using pen-based tablets, etc., field users access line items and indicate with a simple check box whether each passes. Punchlister eliminates the need to track punchlists on paper, which required typing lists for distribution. What used to take two weeks now takes 15 minutes. (Roe, 2002.)

The Washington State DOT took a bold step when faced with the prospect of lengthy work zone projects to reconstruct three intersections on U.S. 395 in Kennewick. It shut down each intersection completely for one weekend. The work was done in hours instead of days using quick-setting PCC, and an intensive information campaign for motorists was developed. This major project was completed using innovative methods with minimal impacts on mobility and safety, and an ahead-of-schedule completion was realized. (Nelson, 2002.)

Tactic 2. Minimize Field Fabrication Effort

"Prefabricated Bridge Elements and Systems: A Winning Idea" (*Focus*, 2002). While employing prefabricated elements isn't a new idea, these elements are now being combined and used more extensively to facilitate bridge construction in innovative ways. Prefabricated bridge elements, such as bent caps, can be manufactured either on or off site, under controlled conditions, and brought to the construction location ready for installation. Using prefabricated elements and systems can increase construction zone safety, minimize the traffic impacts of bridge construction projects, make construction less disruptive for the environment, and improve constructability. Safety is improved and traffic impacts are lessened because some of the construction is moved from the roadway to a remote site, minimizing the need for lane closures, detours, and use of narrow lanes. Moving the construction from the roadway can also lessen impacts on the surrounding environment.

"Innovative Bridge Research Program: Building for the Future" (Stidger, 2002). Established in 1998 by TEA-21, the six-year program provides funding to help state and local transportation agencies use innovative materials for bridge repair, rehabilitation, replacement, and construction. The program also has the goal of reducing the maintenance and life-cycle costs of bridges, including the costs of new construction and the replacement or rehabilitation of deficient bridges.

Surface Transportation Research and Technology Assessment (Volpe National Transportation Systems Center, 1999). Given the considerable traffic congestion in major metropolitan areas, the fact that traffic patterns can change relatively rapidly, and the relatively fixed supply of infrastructure, more federal attention to rapid renewal techniques, materials, and design and construction technologies appears to be warranted. New technology applications are being developed by the private sector at an extraordinary rate. Advanced materials and techniques for rapid construction also are likely to be developed by the private sector.

Minimizing Field Fabrication

Using precast substructure units and tightly coordinated, simultaneous, multiple operations, a Colorado construction crew built a new 40-foot bridge in just under 46 hours. The Mitchell Gulch Bridge, originally a 50-year-old box culvert, carries 12,000 daily motorists on State Highway 86 southeast of Denver. The Colorado DOT had originally planned a two-month detour when opening bids for the replacement. Instead, a value-engineered proposal to replace the bridge in two days was submitted. The $360,000 bid was a couple of thousand dollars less than a standard box culvert. Crews simultaneously demolished the old bridge and drove steel H piles 40 feet deep while avoiding existing structures. Precast units, two-paneled 44-foot-wide abutments and 23-foot-long wing walls, were welded together on top of the piers. Eight precast deck-girder units, about 5.5 feet long, 44 feet wide, and 1.6 inches deep, were placed, grouted, and post-tensioned while back-filling and paving began. A Colorado DOT engineer said the method could work for any one-span bridge and may be used on an upcoming Colorado DOT job. ("Crew Completes New Crossing in Two Days, Not Two Months," *ENR*, 2002.)

On Memorial Day weekend in 1998, a fuel truck caught fire, closing the 358-foot long, three-span continuous I-95/Chester Creek Bridge in Pennsylvania. Severe sagging required the Pennsylvania DOT to replace approximately two-thirds of the superstructure. Since shop drawings of the original girders were available, the material was immediately ordered and shop fabricated. New girders were delivered within two weeks of the fire, and the bridge was opened three weeks later, by July 4. (AASHTO Technology Implementation Group, 2002.)

Tactic 3. Perform Faster Construction Inspection and Monitoring

"Designs and Implementations of Automated Systems for Pavement Surface Distress Survey" (Wang, 2000). Some of the important developments in recent years for automated pavement distress evaluation are presented in this paper. The potential and applicability of these new systems are discussed. Also discussed is the modified approach to collecting and processing surface distress through the use of high-performance digital cameras for the acquisition of surface distress data.

Monitoring Construction

Microsensors are being developed to embed in concrete and other materials and can infer levels of deterioration and corrosion. Software is being tested on a cable-stayed bridge project. Other researchers are testing laser scan monitoring of ongoing steel erection for early defect detection. Others are searching for ways to improve jobsite information flow. (Sawyer, "Researchers Challenged to Improve Construction," *ENR*, 2001.)

Researchers in Texas are "listening" for sounds of hidden damage as it occurs with acoustic sensors on a cable-stayed bridge. The Fred Hartman Bridge, a 2,214-foot-long, twin-deck, eight-lane structure crossing the Houston Ship Channel in Bayport, has been filled with 600 acoustic sensors to study the cables. The project is part of a Texas DOT funded study of the consequences of weather-induced oscillations on stays. The system can "hear" wire fatigue breakages in cables and pinpoint them within a couple of feet. Movement can cause significant fatigue cracking near the cable ends, but the damage progresses slowly. ("Listening For Trouble," *ENR*, 2002.)

Tactic 4. Facilitate Innovative and Equitable Contracting Environment

"'Programming' for Success" (Rubin, Rosenbaum, Angelo, and Powers, 2002). There is a growing array of public and private owners whose larger construction missions and tighter schedules are pushing them toward outside program managers (PMs) to deliver the goods. The PM boom has accelerated project delivery, in many cases, and boosted practitioner revenue as well. Transportation owners are experimenting with program management to expedite huge road and rail projects. South Carolina pushed the envelope two years ago by awarding PM contracts to Fluor Corp. and Parsons Brinckerhoff to manage a state highway construction program vastly enlarged by new funds from the 1998 federal TEA-21 program. After a year of making adjustments in their relationship, the state and its PMs are seeing results.

"Evaluating Design-Build Procurement Documents for Highway Projects" (Ernzen and Vogelsang, 2001). A pilot design-build program, sponsored by Arizona DOT, was aimed at completing public construction projects more rapidly than could be done using traditional methods. Information collected for this study was obtained from questionnaire and interview information. The Arizona DOT used a two-step process in procuring the project using design-build, which required proposer responses to a request for qualifications and a request for proposals.

"Allocation of Risks Under Build-Operate-Transfer Delivery Approach for Transport Infrastructure Projects" (Abdul-Malak, Kaysi, and Schoucair, 2001). The need for the build-operate-transfer approach in the development of infrastructure projects has risen in recent years, due to budgetary and financial constraints faced by the public sector. Risk factors that influence the parties of a prospective built-

operate-transfer contract are presented. In particular, the factors pertaining to the precontract stage and to the political, construction, commercial, and financial categories of possible risks are addressed. Schemes alleviating the risks are offered.

Guide to Developing Performance-Related Specifications for PCC Pavements (Hoerner, FHWA-RD-99-059, 1999). This report (four volumes) is offered as a practical guide to developing and using performance-related specifications for the acceptance of jointed plain concrete pavements lots. It discusses all aspects of the research, including the step-by-step procedures, for developing and using performance-related specifications, results of demonstrations of the performance-related specifications methodology, explanations of supplementary laboratory and field studies, and the user guide for the revised PaveSpec 2.0 performance-related specifications demonstration software.

Special Report 249: Building Momentum for Change—Creating a Strategic Forum for Innovation In Highway Infrastructure (TRB, 1996). A significant long-term challenge facing the highway community is to reshape the procurement process for highway goods and services that will encourage and demand innovation. The chief means by which highway agencies purchase goods and services is through a competitive bidding process in which agencies stipulate the design, materials, and construction methods. An alternative to the traditional system is one that defines the required performance of the final product without requiring a specific material or construction process to achieve that performance. The traditional system of awarding contracts on the basis of low bids is hindering some highway agencies and builders from taking advantage of these new construction techniques and concepts. Two examples of alternative contracting methods are cost-plus-time bidding and the lane rental method.

Innovative Contracting

Transportation officials claim New Mexico is the first U.S. state to abandon “prescriptive” water-cement ratio and strength specifications in favor of performance-based mix designs. They have worked to establish specifications that permit contractors to create their own design mix, and hold them accountable for the results. For the $15 million I-40 job, the contractor added 3/8-inch aggregate to an original mix of mostly 1½-inch and ¾-inch aggregate, and added water for evaporation control. They eliminated a lot of the transverse and shrinkage cracks in the process. Performance-based paving is where DOTs need to go, and many are in the process of doing so. Kansas, Minnesota, and Iowa are among those states. Freedom to adjust for environmental variations is the primary benefit of a performance-based job. (Daniels, 2002.)

Tactic 5. Plan Improvements to Mitigate Disruption

Crossroads of the Americas: Trans Texas Corridor Plan (Texas DOT, 2002). The Trans Texas Corridor is an all-Texas transportation network of corridors up to 1,200 feet wide. The 4,000-mile corridor will include separate highway lanes for passenger vehicles (three lanes in each direction) and trucks (two lanes in each direction), high-speed passenger rail, high-speed freight rail, commuter rail, and a dedicated utility zone. The corridor will have a significant positive impact on the state. It will relieve congested roadways and keep hazardous materials out of populated areas and will improve air quality by reducing emissions and providing a safer, more reliable utility transmission system. It will also generate toll revenue to further improve Texas’s transportation system, and it will stimulate economic growth. Issues addressed in the planning process include assessing the impact on currently planned construction projects, determining facilities needed to connect the corridor segments to nearby cities, public involvement, and route analysis and selection. The corridor will be designed for the following operational speeds between connections:

200 miles per hour (mph) for high-speed passenger rail, 80 mph for commuter/freight rail, and 80 mph for toll ways. Several new financing tools will help Texas meet its transportation needs. Legislation enabling toll equity, regional mobility authorities, and the Texas Mobility Fund will help the Texas DOT enhance the existing transportation system. Other potential corridor funding methods include concessions, the federal Transportation Infrastructure Finance and Innovation Act of 1998, assorted other federal programs, and leasing ROW.

"Analytic Minimum Impedance Surface: Geographic Information System-Based Corridor Planning Methodology" (Grossardt, Bailey, and Brumm, 2001). Highway corridor alignment presents a highly complex decision environment in which a variety of social, environmental, and economic factors must be defined and weighted and tradeoffs must be evaluated. These data vary widely in format and quality. Stakeholders from various groups should be integrated into this process efficiently to determine objectives, to select data, and then to quantify the importance. Corridor planning is therefore an appropriate domain for the development and application of enhanced methodologies that conjoin multi-criteria decision-support techniques with the spatial analytic and presentation capacities of a geographic information system (GIS). The analytic minimum impedance surface (AMIS) methodology is presented, and its application to a case study in the southeastern United States is evaluated. AMIS features the structured integration of stakeholder input into a hybrid analytic hierarchy process. The advantages of the approach are highlighted, along with the significance of process design in building an effective methodology. Several potential applications are discussed.

"Weekend Closure for Construction of Asphalt Overlay on Urban Highway" (Dunston, Savage, and Mannering, 2000). Construction of asphalt overlays for urban highways is generally restricted to off-peak hours, often exclusively nighttime hours, and to partial closures to minimize public inconvenience. Such constraints are thought to adversely affect production and quality. In August 1997, the Washington State DOT implemented a pilot project to evaluate the option of a full weekend closure—closure of all lanes in a single direction throughout designated weekend hours—as an alternative to nighttime closures. Two concerns were consistent construction quality between nighttime and daytime paving and general comparison of the full weekend closure with other closure strategies. Surface smoothness (rideability) and in-place density were compared between nighttime and daytime mainline paving for this project, and gradation and asphalt cement content variability was compared with published average values. Production rates were compared with those from a comparably sized nighttime project. The investigation revealed that consistent quality, exceeding reported average values, could be achieved. High paving production rates resulted from close proximity of the hot mix plant to the work zone.

Interstate 80 Pavement Rehabilitation Corridor Study (Wilson and Darter, FHWA-IL-UI-269, 1999). Findings are presented on the past, present, and expected future performance and rehabilitation needs of the pavement on the I-80 highway corridor that traverses northern Illinois. The results presented the report cover the time period from initial construction in the 1960s through 2015. The objective of this study is to provide information for Illinois DOT management and engineers to assist in maintaining this critical east-west highway in operating condition and to determine the funding needed for long-term planning and programming. The results are also useful in planning a future rehabilitation strategy to minimize disruption to the traveling public.

"Highway Financing" (Cooper, 1998). From where do highway revenues come? For the most part, the road users supply these funds. Both the federal government and the states rely on imposts—fees and taxes—on users to fund highway programs. Highway fees consist of motor fuel taxes, vehicle registration fees, license plate fees, and certain levies on heavier vehicles such as trucks. Augmenting these is the most direct of all highway user fees—tolls. Traditional road-user taxes and fees are levied at all levels, and significant portions of the revenues do not support highway programs. If they were dedicated for highways, user revenues in 1998 would cover 82 percent of costs. With federal encouragement, states and

others are using innovative financing techniques, including state infrastructure banks, to finance highways.

Innovative Funding

Arkansas rehabilitated 380 miles, or 60 percent, of its interstate highways in five years. They received five awards in the first seven months of this innovative program. The Arkansas State Highway and Transportation Department (AHTD) is making all of this happen through the Interstate Rehabilitation Program. The department has put together numerous best practices that together create a compelling model for completing a project this size. AHTD's problem-solving strategies for funding began with a review of preferred financial practices along with a few new and innovative ones. An innovative financing program was built, which included a gas and a diesel tax and the sale of Grant Anticipation Revenue Vehicle bonds for the rehabilitation project. These bonds may be retired with future anticipated federal funds in a "buy now, pay later" payment arrangement. (Flowers and Otto, 2002.)

Tactic 6. Improve Customer Relationships

"Major Corridor Investment-Benefit Analysis System" (Kaliski, Smith, and Weisbrod, 2000). The major corridor investment-benefit analysis system recently developed for the Indiana DOT is discussed. The purpose of the system is to provide an analytical tool for use by Indiana DOT in evaluating and comparing the impacts of major corridor highway investments in the state. The system combines a statewide travel demand model, a user benefit-cost analysis model, and a regional econometric model. The conceptual approach behind the model is described, and the results from an application of the model to analyze the transportation and economic impacts of the upgrade of U.S. 31 between Indianapolis and South Bend, Indiana, to interstate level of service is presented. Issues addressed by the model include the impact of travel timesaving and other user benefits on business users of the highway, as well as the potential for the study corridor to attract new businesses or tourists as a result of improved access to markets.

Millennium Paper (TRB Committee on Public Involvement, A1D04, 2000). This white paper, authored by members of the TRB Committee on Public Involvement, provides an overview of developments in the evolution of the process of two-way communication between citizens and government. This is done by way of transportation agencies and other officials giving notice and information to the public and using public input as a factor in decision-making. In the past decade, a radical transformation has occurred in the way transportation decisions are made. A new decision model has emerged and continues to be refined. The model assumes that public input into the assessment of transportation needs and solutions is a key factor in most transportation decision-making.

Better Customer Relations

During Arkansas's rehabilitation program, the public was kept informed with the "Pave the Way" campaign. With expert communication planning, much of the anger and dismay of the traveling public was avoided. They were informed about the depth, time frame, repair method, safety issues, and progress of this multi-year project. This included a region-wide mailing to officials, opinion leaders, law enforcement officers, and media. Billboards at entry points, variable message signs, highway advisory radio messages, rest stop posters, brochures, and billboards were also used. A blend of off-the-road and on-the-road communications was used to reach motorists. Media events and news releases, the Internet, brochures, and speeches helped give motorists fair warning of what they may encounter. The success of this program has been a result of the concerted use of both strategies. (Thoma, 2002.)

The I-15 reconstruction in Utah involved 142 bridges, 18 miles of interstate, eight interchanges with urban crossroads, and three major junctions with other interstates. All work had to be completed before the 2002 Winter Olympic Games. The FHWA and the Utah DOT used design-build contracting to complete on time and on budget, and they developed a public relations initiative to offer latest traffic information to traveling public via website, real-time photos, toll-free telephone numbers, faxes to businesses, advertising, and public meetings. The public relations campaign achieved widespread public approval of the project despite significant disruption to travel in the Salt Lake Valley. (FHWA, "An Olympic Undertaking," *Unifying America: 2001 FHWA Report to the American People*, 2002.)

Tactic 7. Improve Traffic Flow in Work Zone

"Smart Work Zones Improve Highway Safety and Traffic Flow" (Shamo, 2002). With widespread construction on the nation's aging interstate highway system, traffic engineers are increasingly turning to ITS technologies to keep motorists informed of the presence of work zones and make them safer. So-called "smart" work zones also use technology to gather information and monitor conditions to guide agencies' actions. In addition to roadside aids, some offer customized e-mail and pager messages for private users such as trucking companies. Human oversight in operations centers and close inter-agency coordination are required for the technologies to work well together.

Work Zone Operations Best Practices Guidebook (FHWA, FHWA-OP-00-010, 2000). State and local transportation agencies, construction contractors, transportation planners, trainers, and others with interest in work zone operations are given access to information and points of contact about current best practices for achieving work zone mobility and safety. Useful web sites with work zone and related information are included. These initial best practices are drawn from those observed during a work zone scanning tour of 26 states during 1998 and are descriptive rather than prescriptive because they describe approaches used by transportation agencies. These best practices are described and listed in 11 sections. Each of the 11 sections begins with an assessment of the state-of-the-art for work zone practice and a brief description of how transportation agencies can achieve state-of-the-art. These 11 areas, each with their own categories, include Policy and Procedures; Public Relations; Education and Outreach; Prediction Modeling and Impact Analysis; Planning and Programming; Project Development/Design; Contracting and Bidding Procedures; Specifications and Construction Materials, Methods, and Practices; Traveler and Traffic information; Enforcement; ITS and Innovation Technology; and Evaluation and Feedback.

Work Zone Innovation

Innovation played an important part in the Arkansas Interstate Rehabilitation Program. Every work zone of the construction program used innovative techniques to provide consistency for the traveling public. One was to have traffic merge to the left lane initially, regardless of which side of the road was under construction. Projects were worked either one lane at a time adjacent to the work or both lanes simultaneously on one side of the interstate while the other side carried traffic in both directions. Communication increased safety and reduced congestion by including variable message signs, a network of highway advisory radio stations, speed detection trailers, a visible police presence, and a public information and education campaign. (Flowers and Otto, 2002.)

Tactic 8. Design and Construct Low-Maintenance Facilities

"Maintenance Research Master Planning Workshop" (*Transportation Research Circular E-C022*, 2000). The objective of this workshop was to develop a 3-, 5-, and 10-year phased master plan of highway maintenance research needs. The research needs were identified in the following five categories: (1) immediate action, (2) 1–3 year phase, (3) 3–5 year phase, (4) 5–10 year phase, and (5) other needs considered. Several problem statements are listed with topics relating to pavement markings, joint and crack sealing, asphalt overlays, and many other issues relating to maintenance.

"HIPERPAV: A User-Friendly Tool to Help Us" (Forster, 1998). HIPERPAV is a user-friendly, Windows-based computer program that provides guidance on the design and construction of concrete pavement. HIPERPAV enables engineers to make smart decisions about variables that affect concrete pavement performance. Using HIPERPAV, engineers can predict and, thus, prevent uncontrolled cracking during the construction phase (the first 72 hours after placement). This new capability enables the construction of concrete pavement that requires less maintenance, saving a considerable amount of money and reducing traffic disruption over the life of the pavement.

"Cost and Benefits of Automated Road Maintenance" (Hsieh, and Haas, 1993). The need to improve maintenance technology is emphasized. Specifically, 22 automated systems in road maintenance are identified that are used for defect surveys, traffic control, defect treatment, and other supportive activities. These systems showed that automation technology is technically and economically feasible.

Reducing Maintenance

The six-year Innovative Bridge Research Program provides funding to help state and local transportation agencies use innovative materials for bridge repair, rehabilitation, replacement, and construction. The program also has the goal of reducing the maintenance and life-cycle costs of bridges. Since the program began, 157 bridge projects have been funded. "I don't think there's any doubt we're seeing more interest from states in using innovative materials and technologies," says John Hooks of the FHWA. In 2000, projects included the replacement of girders on a single-span bridge in Alabama with fiber-reinforced polymer composite girders, the use of high-performance concrete for the deck slab, high-performance steel for the bridge plate girders of a new bridge in Connecticut, and the incorporation of high-performance steel plate girders into a Georgia bridge. Projects selected for FY 2001 funding include the use of high-performance steel for the girders and steel plate of a bridge in California, the incorporation of fiber-reinforced polymers in the deck slab of a bridge in Iowa, and the use of high-performance concrete to build the deck slab of a Chicago structure. (Stidger, "Innovative Bridge Research Program: Building for the Future," *Better Roads*, 2002.)

Tactic 9. Monitor In-service Performance

"Maintenance Research Master-Planning Workshop" (*Transportation Research Circular E-C022*, 2000). Simple, nondestructive, rapid field-tests are needed to measure the strength of polymer concrete overlays. Polymer concrete bridge overlays have several advantages, including very fast cure times, waterproof, long-lasting wearing surface, etc., but currently there is no design procedure to determine interfacial and in-plane overlay stresses. Construction guidelines are needed to insure proper surface preparation, vibration, and curing procedures. Nondestructive test methods to evaluate properties of overlays are needed.

Surface Transportation Research and Technology Assessment: Promising Technologies and Applications (Volpe National Transportation Systems Center, 1999). Sensing, locating, computer, and communications technologies already play a key role in many current modal research and technology programs, although most of these are focused on improving operational safety and efficiency. Many surface transportation agencies already have established systems for managing segments of their physical infrastructure, particularly pavement and bridges; one example is the FHWA's bridge management system (BMS). These systems help target budgetary resources so as to realize the maximum benefit from infrastructure improvements.

"Nondestructive Evaluation For Bridge Management In The Next Century" (Chase and Washer, 1997). The FHWA's program of research and development in NDE of the nation's bridges is described. The program is currently focusing on developing technologies to address a wide range of problems. This article summarizes FHWA's current research and development program, highlighting advanced bridge deck inspection technology, advanced-bridge-testing and health-monitoring projects, and other advanced NDE projects.

Performance Monitoring

A team of researchers at the U.S. Department of Energy's Sandia National Laboratories has designed a wireless, battery-free sensor that could provide engineers with stress, deflection, and strain measurements in bridges after earthquakes, storms, or bomb blasts. The sensor would be embedded into a structure during construction and forgotten until a need for integrity measurements arises. The device would power itself by converting mechanical energy from vibrations into electrical power using quartz crystals. The power would operate a microsensor system long enough to take a reading and store the data in memory. Remote retrieval of readings would be possible with a handheld tag reader pointed at the structure in the location of the embedded sensor. The creation of the device is in keeping with Sandia's Architectural Surety program to improve the safety, security, and reliability of engineered structures. (Sensor Could Monitor Structural Integrity of Bridges," *Better Roads*, 2002.)

Tactic 10. Preserve Facility Life

"New Practices for Managing Pavement Life" (Stidger, 2002). Many effective treatments and practices have moved onto the scene to help achieve pavement preservation goals. One is whitetopping (concrete overlays of asphalt pavements); there are three types of whitetopping—conventional (greater than 8-inches thick), thin, and ultrathin (between 2- and 4-inches thick). A second is micro-surfacing, a mixture of polymer-modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed, and spread on a paved surface in accordance with a specification. A third is crack sealing; effective crack sealing in ACC pavements can extend pavement life in a cost-effective manner by slowing the rate of condition deterioration. A fourth is performance-related specifications; there are two types of performance-related specification models—performance-prediction models and maintenance-cost models.

"Externally Bonded FRP for Service-Life Extension of RC Infrastructure" (Bonacci and Maalej, 2000). Although the concept of repairing and strengthening reinforced concrete (RC) structures using steel plate reinforcement has been established for more than 30 years, today there is an increasing trend toward the use of externally bonded fiber-reinforced polymer (FRP) composites, such as glass FRP and carbon FRP. This paper summarizes the results of a comprehensive survey of field applications of both steel plates and FRP composites as external reinforcement for the life extension of deteriorating RC flexural members. A literature review conducted to assess the need for infrastructure rehabilitation suggests that the problem with structurally deficient or obsolete structures is one of large magnitude needing immediate attention. Based on the collective findings from a survey of field applications, a review of literature on the state-of-the-infrastructure, and a database of laboratory studies, a list of research priorities is compiled for further studies investigating the use of FRP composites as external reinforcement for RC flexural members.

Preservation Strategy

The Michigan DOT developed the Michigan Capital Preventive Maintenance Program to preserve pavement and bridge structures, delay future deterioration, and improve overall conditions cost effectively and efficiently. A strategy has been implemented for pavement preservation, pavement preventative maintenance, and pavement management. The strategy combines long-term fixes (reconstruction), medium-term fixes (rehabilitation), and short-term fixes (preventive maintenance) in a "mix of fixes" approach. Combining all three programs into a single comprehensive strategy achieves the most manageable highway network. Preventive maintenance is the most influential component of the network strategy because it postpones costly reconstructive activities. It is the only cost-effective means to improve overall pavement condition. More than a program of short-term treatments, preventive maintenance is a management tool that optimizes funding allocations. The challenge is to determine the right time to apply a treatment to achieve maximum benefit. The "mix of fixes" approach helps optimize available funds to meet network condition needs. In estimating the outcome of a "mix of fixes" strategy, the Michigan DOT relies on the Road Quality Forecasting System, which uses current condition data from the pavement management system to predict future network conditions. The Michigan DOT annually assesses the life-extending value of the different treatments. (Galehouse, 2002.)

SECTION F. RESEARCH PLAN

Three strategic objectives will achieve renewal:

1. Perform rapidly.
2. Cause minimum disruption.
3. Produce long-lived facilities.

Inherent within the strategic objectives identified above is that renewal will be achieved consistently throughout the highway system, not just on isolated, high-profile projects.

The researchers have identified 10 tactics for overcoming the barriers to achieving these objectives. Table 4 identifies the tactics and shows the relationships of each research project to the tactics and strategic objectives.

Rapid renewal has only been achieved 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.

Transfer of risk to contractors makes innovative contracting strategies unworkable without financial or other contractual adjustments. Financing is a barrier to planning renewal projects to minimize disruption. Coordination with railroads and utilities is a major barrier to construction and can be a disruption to their services. Research is necessary that allows highway agencies to develop financing strategies and mutually satisfactory mitigation strategies for railroads and utilities. Until these technical problems are solved, the tactics cannot be implemented broadly and consistently.

We cannot accept shorter facility life spans as the price of rapid renewal. A tactic to achieve long life is to optimize designs and materials, but current designs do not consider constructability, material performance, and in-service performance to the extent necessary to achieve this strategic objective. The research plan provides a path to circumvent these barriers.

Table 4. Relationship of Research Projects to Research Objectives

Strategic Objectives	Tactics	Barriers	Research Projects
Rapid Approaches	1. Perform Faster In Situ Construction	• Traditional approaches are slow and costly. • Limited data collection and sharing. • Not enough emphasis given to human limitations and performance.	1-1.1. Utilities Location Technology Advancements 1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction 1-1.3. Replacement of Conventional Materials with High-performance Materials in Bridge Applications 1-1.4. Rapid Rehabilitation Strategies of Specialty Structures 1-1.5. Micropiles for Renewal of Bridge Foundations 1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System 1-1.7. Facilitating the Use of Recycled Aggregates 1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments
	2. Minimize Field Fabrication Effort	• Traditional techniques for bridge and pavement construction are built on site.	1-2.1. Modular Bridge Systems 1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology 1-2.3. Modular Pavement Technology
	3. Perform Faster Construction Inspection and Monitoring	• Limits on sensing technology.	1-3.1. High-Speed, Nondestructive Testing Procedures for Design Evaluation and Construction Inspection
	4. Facilitate Innovative and Equitable Contracting Environment	• Methods specifications constrain efficiency in quality. • Sub-optimized contracting approaches and use of incentives. • Unbalanced risk allocation between owners and contractors. • Lack of rapid decision-making can constrain project activities.	1-4.1. Performance Specifications 1-4.2. Alternate Contracting Strategies for Rapid Renewal 1-4.3. Incentive-based Specifications to Assure Meeting Rapid Renewal Project Goals 1-4.4. Development and Evaluation of Performance-based Warranties 1-4.5. Risk Manual for Rapid Renewal Contracts 1-4.6. Innovative Project Management Strategies for Large, Complex Projects

Table 4. Relationship of Research Projects to Research Objectives (continued)

Strategic Objectives	Tactics	Barriers	Research Projects
Minimize Disruption (for users on and adjacent to project)	5. Plan Improvements to Mitigate Disruption	• Planning not corridor based. • Traditional project-based objectives. • Financing constraints.	1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process 1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development 1-5.3. Strategic Approaches for Financing Large Renewal Projects
	6. Improve Customer Relationships	• Difficult to mitigate impact to users and public services • Ineffective coordination with utilities and railroads. • Insufficient consideration to adjacent environment.	1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection 1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects 1-6.3. Utilities-DOT Institutional Mitigation Strategies 1-6.4. Railroad-DOT Institutional Mitigation Strategies 1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods
	7. Improve Traffic Flow in Work Zone	• Traditional approaches are inadequate for high traffic volumes.	1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety
Produce Long-Lived Facilities	8. Design and Construct Low-Maintenance Facilities	• Maintenance is not adequately considered during design and construction. • Lack of predictable performance models.	1-8.1. Durable Bridge Subsystems 1-8.2. Design for Desired Bridge Performance 1-8.3. Composite Pavement Systems 1-8.4. Stabilization of the Pavement Working Platform 1-8.5. Using Existing Pavement in Place and Achieving Long Life
	9. Monitor In-Service Performance	• Lack of performance-related metrics and analysis systems.	1-9.1. Nondestructive Evaluation Methodology for Unknown Bridge Foundations 1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems 1-9.3. Monitoring and Design of Structures for Improved Maintenance and Security
	10. Preserve Facility Life	• High traffic volumes. • Lack of methods to extend life.	1-10.1. Preservation Approaches for High Traffic Volume Roadways 1-10.2. Bridge Repair/Strengthening Systems 1-10.3. Techniques for Retrofitting Bridges with Non-redundant Structural Members

Tactic 1. Perform Faster In Situ Construction

Renewal time can be defined as the time it takes to complete those on-roadway construction activities that impact traffic flow and the communities and businesses that rely on that roadway for services. Rapid renewal applies innovative activities or technologies to reduce the time traditionally allocated to these on-roadway activities, thereby minimizing the impact.

New construction processes will specifically address high-intensity, compressed schedule construction projects. High-speed, one-pass renewal operations are attractive in areas where traffic must be maintained or closure times must be kept at an absolute minimum. Such renewal methods could be continuous projects where a portion of the road is closed to all traffic. In other cases, renewal may occur at off-peak times with methods that allow a contractor to complete work during the nighttime or during the day in between morning and afternoon peak times. Machinery that can be quickly mobilized and demobilized must be used if renewal will occur at off peak times. Real-time quality control should be instituted so the operator does not continue to build something that has hidden flaws that need to be corrected.

Figure 4. In-situ Processing of Pavements (Source: Iowa DOT)

Designers must be able to account for new materials and streamlined construction techniques in facility design. Designs should consider and plan for the eventual need for repair. For example, to facilitate modular repair of a bridge, the use of standardized member dimensions may be desirable. One-pass paving operations may significantly reduce construction time (see Figure 4). How will the use of such techniques affect structural design? For asphalt, will thicker pavements be needed if less time is available for working each layer of the pavement, or will improved materials and construction procedures allow for the use of thinner pavements? For PCC, will “just-right thicknesses” eliminate curling and avoid cracking? The use of new materials and techniques will involve tradeoffs that must be understood and accounted for in the design phase in order to ensure the desired service life is attainable.

This tactic envisions that IT will play a pivotal role in helping to accelerate the work pace and minimize disruption on renewal projects. The benefit IT can provide is the rapid sharing of information among the participants on renewal projects on a real-time basis to facilitate decision-making and accelerate development of changes, facilitate the distribution of field inspection results, and achieve a better understanding of the project. All offices will share all data involved in the project delivery process, including project planning through maintenance. This approach will ultimately lead to a reduction in delivery time, costly overruns, and errors.

Tactic:
Perform faster in situ construction

Barriers:
- Traditional approaches are slow and costly
- Limited data collection and sharing

Project 1-1.1. Utilities Location Technology Advancements

Funding: $5,000,000 Duration: 5 years Priority: High

Improving identification tools and enabling the accurate location of underground utilities during the preliminary engineering phase of a project, well before construction activities are in progress, will reduce construction delays. These tools will make it possible to develop accurate plans that fully consider underground utilities and, by knowing this information early in the project development process, alternative contracting strategies and pre-location of utilities will be possible.

Currently, many underground utilities that impede progress on highway projects are difficult to locate. In the best cases, accurate as-built drawings exist that indicate the actual alignment and depth of the utility. However, delays still occur because precision and time-consuming hard excavation is typically required to verify the exact location, expose the utility, and protect it. In the worst cases, no information exists on certain buried utilities until the utility is encountered during the construction project. That often results in significant delays to construction progress because work is suspended while utilities are relocated or the facility is redesigned. It is also not uncommon to damage an unidentified utility during excavation with significant negative impact to the users of the utility.

The importance of this topic has been an increased focus by project owners in recent years as the limitations on current capabilities unfolds repeatedly and the complexity of projects increases. Subsurface utility engineering efforts by project owners have proven valuable but advancements in technologies would greatly enhance the effectiveness of current approaches.

The focus of this project will be to identify and facilitate the development of technologies and the supporting systems to more effectively and accurately identify and document underground utility locations. This project is proposed to be pursued as a cooperative effort with both public and privately owned utilities by seeking input, consultation, and potentially joint development.

Objectives

- Document the current state-of-the-art for locating various types of utilities.
- Identify promising technologies for further development.
- Through cooperative approaches, develop technologies and supporting systems for locating and documenting utility locations.

Scope

Better methods are needed to “see” into the earth to find exact locations of underground utilities. The objective of the project is to develop better tools to locate utilities and approaches to document utility

locations so that they are accessible during the entire project delivery process. This project needs to be pursued as a cooperative partnership with public and private utility owners.

This project will be conducted in three phases. In the first phase, researchers will identify promising technologies for further development. During the second phase, several projects will be launched to develop the identified technologies. It is likely that matching funds will be provided to developers who have access to other sources of funding. During the final phase, researchers will synthesize the results of the project.

Tasks

Phase I

1. Document the current state-of-the-art for locating utilities through both literature review and discussions with appropriate utility forums.
2. Conduct a literature review to identify potential methods and technologies for improving identification of utility location.
3. Identify organizations that have used improved methods for utility location.
4. Conduct field visits to investigate emerging methods of utility locations.
5. Develop a best practice document based on Tasks 1, 2, 3 and 4.
6. Hold four regional workshops with national stakeholders to share best practices and identify additional location tools and approaches that could be improved or developed through further research and development.
7. Recommend a list of utility location strategies for further development.
8. Prepare report.

Phase II

9. Coordinate the development of these systems with private/public joint projects. Several concurrent projects will be launched. In some cases, matching funds will be provided to assist projects that have other resources. Each project will provide a report.

Phase III

10. Synthesize findings from Phases I and II.
11. Facilitate deployment and technical transfer of the new technologies and systems through demonstration projects.
12. Prepare a final report.

Coordination with Other Projects

- 1-3.1—High-Speed, Nondestructive Testing Procedures for Design Evaluation and Construction Inspection
- 1-6.3—Utility-DOT Institutional Mitigation Strategies

Products, Benefits, and Implementation

Products

- State-of-the-art manual for locating utilities
- New tools and methods for locating utilities
- Demonstration projects
- Regional workshops
- Final report

Benefits

- Greater efficiency in designing and constructing projects due to better location information
- Faster and more economical construction
- Few disputes and less administrative effort

Implementation

- Patent rights
- Investment to commercialize new technologies

Research Period and Funding Requirement

Phase I: 1.5 years, 400,000
Phase II: 4 years, $4,000,000 (8 concurrent projects averaging $500,000 each)
Phase III: 2 years, 600,000
(Note: Phases overlap or occur concurrently.)
Total: 5 years, $5,000,000

Tactic:
Perform faster in situ construction

Barrier:
Traditional approaches are slow and costly

Project 1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction

Funding: $2,000,000 Duration: 5 years Priority: High

This project will result in alternative methods to facilitate rapid roadway and embankment construction with improved long-term performance. The project will focus on two elements: (1) construction of new embankments and roadways over unstable soils and (2) rapid widening of existing embankments and roadways.

Part A. Construction of new embankments and roadways over unstable soils

The long-term performance of the roadway is directly related to the stability of the roadbed supporting the pavement. This is particularly important on rapid renewal projects where time is of the essence and traditional approaches for dealing with settlement are unacceptable. NCHRP Synthesis 147 describes a suite of methods that were available in 1989 for embankment construction over unstable ground. Since then, new techniques, particularly in the ground improvement field, have been developed and implemented by the FHWA in Demonstration Project 116. A need exists to update NCHRP 147 and incorporate the new techniques into those methodologies that are still tried and true for construction over unstable ground.

Part B. Rapid widening and reconstruction of existing embankments and roadways

Existing roadways are located in at-grade, fill, or cut or some combination of these situations. Widening of roadways in different situations can pose difficult problems, depending on factors that range from the proximity of existing utilities to the geologic conditions. Each situation can benefit from proper selection of geotechnical treatments to speed construction, reduce cost, and decrease post-construction maintenance.

Part B.1. Widening and reconstruction of roadway embankment sections

A common occurrence on renewal projects is the addition of new traffic lanes, which requires the widening of existing embankments. One important problem for this type of construction is that the added loads due to the increase in cross section of the embankment can cause additional and differential settlement below existing roadways and pavements, and below the newly added embankment sections. Conventional approaches, such as placing driven piles with concrete pile caps below the ground before the new embankment sections are constructed, result in high-cost and constructability constraints. Even ground modification techniques present problems in urban areas where ground heave or lateral stress increases can impact existing facilities. New methods of settlement control systems are vitally needed to meet the needs of the expanding highway infrastructure.

In roadway widening and reconstruction over unstable to marginal ground, column-supported embankments, which may include micropiles, stone column technology (including vibro-concrete columns and geopiers), soil mix elements, etc., in combination with geosynthetics, have the potential to reduce cost and increase constructability for embankment widening applications. Costs and installation time can be particularly decreased if column elements can be installed in either a lattice array or in moderately spaced groups rather than in a uniform, closely spaced pattern. These systems will increase the vertical stiffness of the embankment foundation and reduce settlement. A geosynthetic cap layer can be placed over the columns to ensure a more uniform foundation settlement by distributing the loads among the columns and bridging between elements. The columns and the geosynthetic cap layer would also be expected to increase the factor of safety against slope instability of the embankment foundation. Additional advantages of column-supported embankments may include the following:

- Cost per column element (e.g., micropiles, stone column technology, and soil mix elements) may be less than driven pile.
- Drainage provided by the columns (i.e., stone column techniques) can speed up consolidation of the ground, and thus the soil can be pre-loaded before the final embankment cross section is completed.
- Column systems are potentially more flexible than piles and offer resistance to lateral loads or free field ground motions (e.g., earthquake).

Part B.2. Widening of roadways in soil cuts

Ground anchor and soil nail wall systems are reliable, economical solutions for roadway widening into cut slopes. Design technology, performance-based specifications, and construction control techniques are fully developed. Both technologies have been the subject of multiple FHWA demonstration projects that spanned a 10-year period. Both technologies are codified into FHWA geotechnical circulars. Construction trade groups have teamed with panels of federal and state engineers to develop generic specifications. Both technologies permit top down construction, which can be accomplished more cheaply than any other procedures with minimal disruption of traffic on the existing road section, yet many highway agencies and/or their consultant designers do not consider these systems as the primary option during design of road widening into cuts. Two items which may ease national acceptance of these techniques are (1) the ready availability of a national performance-based specification on Internet sites of federal highway agencies, construction trade groups, and recognized highway groups such as AASHTO and (2) the development of a national inspector certification program for construction inspectors. Also, since these technologies are heavily dependent on contractor performance, development of remote monitoring of wall construction via live streaming video could prove an attractive addition to on-site inspection.

Part B.3. Roadway widening in cut-fill sections

A common technique of constructing roadways across sloped areas involved simply cutting into the hillside and pushing the excavated material over the opposite side to create a platform on which the road was to be constructed. Many of these cut-fill sections exist at marginal ground stability on the downhill side. Although cut solutions mentioned above can be used to widen on the uphill side, widening of the roadway is usually done on the downhill side due to concern about uphill stability. Downhill widening is best done by minimizing additional loading to the slope. In the past, most projects used downhill walls supported by permanent anchors to retain the widened section. Construction was slow and traffic disruptions frequent due to suspension of road-based drilling rigs out over the slope. Experimental technologies now exist to speed construction and reduce downhill loading. Soldier pile walls can now be constructed downhill and backfilled with geofoam blocks that are placed on a geosynthetic base and capped with a thin concrete slab. The permanent road sections are then constructed on the concrete cap. Temporary excavations into downhill slope areas can be stabilized by soil nails to permit work equipment off-road access, thus minimizing traffic disruptions. Design procedures, construction specifications, and instrumented test installations are needed before this technology can be placed into routine use.

Objectives

Part A

- Identify existing and alternative practices for design and construction of embankments and roadways over unstable ground conditions that reduce settlement and facilitate rapid construction.
- Determine the need to update NCHRP Synthesis 147.

Part B.1

- Document new pilot studies and any previous case histories where embankment and roadway construction over unstable ground utilized ground improvement and/or column-geosynthetic systems were used to control settlement below earth embankments. The emphasis should be on techniques that permit lattice or disparate groups of columns rather than closely spaced column elements.
- Develop design guidelines and quality control test procedures for construction of ground improvement techniques.
- Develop performance-based (i.e., settlement magnitude and rate) construction specifications for selected soil improvement technologies.

Part B.2

- Assemble a technical working group of interested highway design and construction personnel to discuss items that will lead to a national acceptance of soil nail and anchor wall technology for roadway widening into cuts. Focus on the need for readily available national performance-based specifications, inspector certification program development, and new innovations in inspection, such as remote video logging of construction.

Part B.3

- Review national and international uses of combined element wall (soldier pile, geosynthetic, geofoam, soil nail) installations or other techniques using lightweight materials in downhill widening of roadways. Document or develop design criteria for such installations.
- Institute a series of test projects to demonstrate the viability of the technique. Document via instrumentation and observation the performance of the system. Refine design and construction control processes and develop a performance-based construction specification for the system.

Scope

Part A: Review the existing information in NCHRP Synthesis 147 in relation to new information developed by FHWA and other in recent demonstration projects for the purpose of updating NCHRP 147.

Part B.1: All of the above column techniques have defined basic design/construction procedures in FHWA documents. However, some modification of those procedures may be needed for situations where lattice or spaced column arrays are used. There are several issues that must be investigated to demonstrate the viability and efficiency of the soil improvement technologies in relieving the settlement below new and widened embankments. These issues include (1) the internal stability of column elements for different lattice arrays or moderately spaced groups of column elements, (2) prediction of arching of the ground between reinforcing elements based on ground conditions and applied loads, (3) definition of ground conditions beneath the embankment that would preclude certain or all column technologies, (4) selection of geosynthetic cap materials based on column element type selection, and (5) relative cost of soil improvement systems.

Part B.2: Review past and current implementation efforts for both soil nail and ground anchor wall systems in regard to roadway widening in cuts. Assess current specifications including their availability, inspector certification programs for construction control of these techniques, and new construction control techniques such as remote video of construction operations.

Part B.3: Document the national and international use of combined wall (soldier pile, geofoam, geosynthetic, soil nail) systems for downhill widening of roadways. Develop or refine existing design methods to the point where a series of test installations can be constructed and monitored. Based on the test installations, develop design and construction information to permit routine use of the technology.

Tasks

Part A. Construction of new embankments and roadways over unstable soils

1. Form an NCHRP technical committee of national experts to review and critique NCHRP Synthesis 147 to determine whether an update is needed to include methods particularly suited to accelerated construction of roadways.
2. Make recommendations and prepare revisions as needed to NCHRP Synthesis 147.

Part B.1. Rapid widening and reconstruction of existing embankments and roadways

3. Conduct a literature review of column-geosynthetic systems used to support embankments and roadways.
4. Review and revise as needed existing design/construction methods for column elements and determine feasible lattice or group column spacings.
5. Develop column-geosynthetic systems that facilitate rapid construction while providing improved slope stability, reduced settlement, and reduced cost over conventional methods (i.e., pile driving).
6. Form a technical committee of national experts to review and critique column-geosynthetic systems and to select those systems with the greatest chances for success for full-scale construction and long-term performance monitoring.
7. Conduct field pilot studies for embankment/roadways supported on column-geosynthetic systems.
8. Perform instrumentation and continuous monitoring to validate design approach and long-term performance.
9. Prepare engineering database, design methods, and performance-based construction specifications.
10. Make recommendations and prepare a final report.

Part B.2. Roadway widening into cuts

11. Form a technical working group composed of highway agency representatives, federal highway engineers, construction trade group representatives, and AASHTO working group members involved in geotechnical and highway construction subcommittees to discuss implementation of these technologies nationwide. Items to be decided include a consensus performance-based generic specification for both ground anchor and soil nail wall systems, a national inspector certification program for construction inspector of these specialty operations, and the need to develop a remote monitoring process for wall construction using live streaming video.
12. Implement any findings of this working group.

Part B.3. Roadway widening in cut-fill section

13. Review uses of wall systems for downhill road widening that utilize soldier piles-lightweight materials and geosynthetics and/or soil nails.
14. Document existing design and construction techniques and refine/develop design/construct techniques for these systems.
15. Construct a series of instrumented test installations to demonstrate the technology viability, cost, constructability, and reliability. Report on the value of this technology for incorporation in projects to accelerate construction operations.
16. Develop interim guidelines for national use of the system and develop a list of future research needs, if appropriate.

Coordination with Other Projects

- 1-1.5—Micropiles for Renewal of Bridge Foundations
- 1-2.1— Modular Bridge Systems
- 1-8.4—Stabilization of the Pavement Working Platform

Products, Benefits, and Implementation

- Performance monitoring results, design methods, and construction specifications for a wide range of unstable soil improvement technologies
- Guidelines for application of new alternatives to facilitate rapid embankment widening using column-geosynthetic systems
- National implementation of cost-effective techniques for roadway widening into cuts
- Development of new techniques to widen roads in cut-fill sections
- Performance-related specifications and construction inspection certification programs
- Development of remote construction inspection techniques
- Training programs

Research Period and Funding Requirement

Total: 5 years, $2,000,000

Tactic:
Perform faster in situ construction

Barrier:
Traditional approaches are slow and costly

Project 1-1.3. Replacement of Conventional Materials with High-Performance Materials in Bridge Applications

Funding: $2,150,000 Duration: 3 years Priority: Medium

Construction processes typically associated with bridges are often time consuming, which leads to traffic disruptions, which in turn are sources of safety problems for the traveling public. This project will develop techniques for using high-performance materials in bridge applications that will significantly reduce these problems, are readily inspected, and have adequate strength and serviceability requirements.

In the recent past, high-performance materials have been used successfully in several applications (e.g., FHWA Innovative Bridge Research and Construction Program). Continued research, including field demonstration projects, should lead to potential new uses that, in turn, will reduce construction time. Before these uses will be universally adopted, there is a need to document their performance through demonstration projects.

Objective

- Develop techniques for using high-performance materials throughout the entire bridge structure in conventional ways such that construction efficiency, durability, strength, and serviceability are increased.

Scope

This project will develop techniques for using high-performance materials in conventional ways that improve design or construction efficiency.

Tasks

1. Perform a literature review to identify existing conventional systems that are effective in rapid replacement situations.
2. Identify how high-performance materials could enhance the systems in Task 1.
3. Perform field demonstrations on the most promising bridge systems that utilize high-performance materials.
4. Working with industry, develop recommended details and specifications suitable for use by bridge owners.

Coordination with Other Projects

- None required

Products, Benefits, and Implementation

The products of this work will be structural details, specifications, and guidelines for using high-performance materials in conventional systems for improved efficiency and effectiveness. The benefits of this work will be that the developed systems will allow existing rapid replacement systems to be implemented more efficiently. Successful implementation of the results of this project will rely on successful demonstrations and easy to use tools.

Research Period and Funding Requirement

Tasks 1 and 2: $150,000
Tasks 3 and 4: $2,000,000
(Note: This project's scope could be divided into two separate projects based on a combination of tasks as indicated above.)
Total: 3 years, $2,150,000

Tactic:
Perform faster in situ construction

Barrier:
Traditional approaches are slow and costly

Project 1-1.4. Rapid Rehabilitation Strategies of Specialty Structures

Funding: $4,000,000 Duration: 6 years Priority: Medium

Specialty structures (long-span bridges, very high traffic volume interchanges, tunnels, etc.), although relatively small in number, represent significant assets. Further, these specialty structures are frequently used because traditional structures simply will not satisfy the site-specific requirements. These structures typically represent the only convenient access in the immediate vicinity. As these structures often employ nontraditional designs due to their complex behavior and construction, the renewal of these structures will necessitate nontraditional tools and techniques.

As specialty structure renewal begins in earnest, a great opportunity exists to begin the steps needed to develop effective, long-term management systems, including identifying the type of information that can be most useful and that can be realistically and accurately obtained. If these management systems are developed properly, decisions for rehabilitation, repair, and replacement (RRR) can be made that significantly increase life. Developing and tailoring a management system to correspond with the specific needs of renewal systems being developed makes this effort unique compared to current work in progress on existing asset management systems. In addition, consideration should be given to retaining the architectural aspects of specialty structures such that they will maintain a specific appearance over the life of the structure.

Construction processes (i.e., RRR) typically associated with specialty structures are relatively time consuming. This can lead to traffic disruptions, which in turn are sources of safety problems for the traveling public. This project will develop rapid renewal systems and construction processes for the repair and rehabilitation of specialty structures, which significantly reduce disruptions while increasing safety. There are a number of ways to decrease specialty structure construction times, including the use of modular systems, modification of current systems to utilize construction technologies more efficiently, use of high-performance materials, use of innovative foundation elements or earth retention systems, and the development of policies, procedures, and methodologies associated with the use and acceptance of new systems and construction technologies.

European construction has evolved to the point where traffic disruptions drive the urban highway design and construction process. Combined systems using bored pile diaphragm walls and ground anchors enable new underpasses and abutment relocations to be built quickly from the top down with minimal traffic disruption. New foundation types, such as continuous flight auger piles and micropile systems used in Europe and Asia, can be installed with relatively small equipment in limited headroom areas, at low vibration levels and minimal removal (and waste) of foundation soils.

Objectives

- Develop guidelines for management of specialty structures.
- Develop guidelines for the rapid repair and rehabilitation of specialty structures.
- Develop guidelines for the monitoring of specialty structures.

Scope

This project will detail renewal strategies for specialty structures including how to manage, repair, rehabilitate, and monitor them.

Tasks

Part A. Specialty structures

Specialty structure renewal input parameters for asset management and inspection:

1. Define the group of specialty structures that would benefit from renewal input parameters for asset management.
2. Define input parameters for each general group of specialty structure.
3. Develop guidelines for collecting, incorporating, and using input parameters for asset management of specialty structures.

Specialty structure systems for rapid repair, rehabilitation, and construction:

4. Define the group of specialty structures that would benefit from rapid repair and rehabilitation.
5. Evaluate the applicability of conventional repair and rehabilitation techniques for use on specialty structures.
6. Develop guidelines for the adaptation of existing conventional systems and for the development of new rapid repair and rehabilitation systems.

Monitoring of specialty structures for improved maintenance and security:

7. Define the group of specialty structures that would benefit from monitoring for improved maintenance and security.
8. Define important monitoring metrics for each general group of specialty structure.
9. Evaluate the effectiveness of potential sensors and sensor systems for monitoring of specialty structures.
10. Develop guidelines for the design and implementation of sensor systems in new and existing specialty structures.

Part B. Tunnels and other underground facilities

11. Conduct a review of the technical literature to identify tunnels where major maintenance activities have been performed. The objectives of the task are to (1) identify and rank the importance of each source of deterioration, (2) assess the impact of each source on rehabilitation cost and traffic disturbance, and (3) identify successful rehabilitation strategies.
12. Develop chemo-mechanical performance models of ground and support. The models should be able to reproduce the fundamental behavior of the ground including time dependent movements originated by chemo-mechanical mechanisms involving water and stress change (e.g., squeezing and swelling, freeze/thaw near portals), the behavior of the support which should include the chemo-mechanical mechanisms that govern shrinkage and creep in concrete and corrosion in steel, and the effects caused by traffic loads and vibrations. The models should explore the interaction between the ground and support from construction to operation and include the interaction at the interface between the ground and support, as well as water drainage. Ground support at portal areas should consider the use of new technologies such as soil nail wall systems and the impact of non-routine forces due to earthquakes, freeze-thaw, etc.
13. Develop recommendations for earthquake-resistant design of underground facilities. It has been generally assumed that underground structures are safer than aboveground structures during a seismic event. However, the recent failures of the Daikai station and the Shinkansen tunnels in

Kobe, Japan, during the Hyogoken-Nambu earthquake in 1995, as well as other well-documented cases, show that tunnels are sensitive to dynamic loading. In this task, a survey of current design methodologies of tunnels in seismic areas will be conducted and recommendations for design will be made based on the results of the survey, if deemed appropriate, or on new recommendations if needed.

14. Develop monitoring techniques and strategies. The current practice is based in most cases on periodic visual inspection of the support and, at most, on very few measurements of pre-installed devices such as piezometers, strain gauges, and extensometers. While this level of inspection has merit, other methods may offer additional advantages such as a systematic and automated survey and early warning of impending problems. In this task the following nondestructive testing technologies could be evaluated: sonar, thermography, geo-radar, ultrasound, mechanical impedance, and acoustic emission. The outcome of the task should be the evaluation and recommendation of monitoring techniques best suited to (1) monitor the performance of the tunnel and (2) provide a quick response in case of emergency.
15. Develop guidelines and specifications for optimum rehabilitation procedures. The procedures should be targeted to upgrade existing support (e.g., injection of grouts, application of shotcrete and bolts over existing liner, replacement of liner), prevent water leakage (e.g., injection of grouts, impermeable liners) and sintering of material in drainage conduits, upgrade ventilation systems, upgrade fire protection including consideration of safe houses, and renew the pavement and other facilities within the tunnel.
16. Document the research in a final report.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-9.3—Monitoring and Design of Structures for Improved Maintenance and Security

Products, Benefits, and Implementation

Products

- Guidelines for collecting, incorporating, and using input parameters for asset management of specialty structures
- Guidelines for the adaptation of existing, conventional systems and for the development of new rapid repair and rehabilitation systems
- Guidelines for the design and implementation of sensor systems in new and existing specialty structures
- Rational tools to quantify and determine the cause and degree of damage to tunnels and underground facilities
- Design tools to predict the life of tunnels and underground facilities
- Design tools for rapid, long-lasting rehabilitation of tunnels and other underground facilities

Benefits

Benefits of the project will include improved management strategies for high-cost, high-use specialty structures.

Implementation

To implement this work, guidelines must be written in such a way that is understood by practicing engineers.

Research Period and Funding Requirement

Part A: 6 years, $2,500,000
Part B: 3 years, $1,500,000
(Note: Phases overlap or occur concurrently.)
Total: 6 years, $4,000,000

Tactic:
Perform faster in situ construction

Barrier:
Traditional approaches are slow and costly

Project 1-1.5. Micropiles for Renewal of Bridge Foundations

Funding: $1,000,000 Duration: 2 years Priority: High

Renewal of structures over waterways frequently requires work to be done on the structural foundations because of a perceived structural deterioration of the foundation elements, scour of the supporting foundation materials, or a need to widen the structure. Repair methods using cofferdams are neither cost-effective nor timely. New foundation techniques involving micropile elements can be used for both renewal and widening applications without the need for road closure or time-consuming over-water construction operations.

The FHWA proposed generic performance-based specifications for these micropiles in June 2000, but these have not been widely implemented or adopted by groups such as AASHTO. Widespread adoption of any new technology requires confidence by the owner in the reliability of the final product. Generic specifications should be vetted through foundation trade construction groups and placed on websites for easy downloading and use by highway agencies and their consultants. National use of common specifications will also stabilize contractor bidding and standardize construction monitoring of these elements.

New efforts are needed to train inspectors in the construction of these innovative foundation elements. New testing methods are needed to quickly verify element capacity and structural soundness. New equipment for pile foundations, such as the PAL-R dynamic pile testing device, sends real-time pile load test data via phone lines to foundation engineers who can determine pile acceptability. These devices reduce contractor delays for load testing and speed foundation acceptance decisions. Similar remote transmission devices for dynamic load tests on micropiles have been researched by the FHWA and need to be brought to the implementation stage.

Objective

- Implement routine use of micropiles for renewal of bridge foundations nationwide.

Scope

The issues that impact implementation of micropile technology are development of national micropile specifications, development of inspection training for micropile construction, certification of inspectors for micropile construction, and development of rapid test methods that utilize remote transmission of real-time data.

Tasks

1. Form a technical committee composed of highway agency representatives and construction trade groups involved with micropiles.
2. Identify existing barriers to using micropiles and approaches to addressing the barriers.
3. Develop a national specification for micropiles using the FHWA specification in publication SA-97-070 as the model. Publish the specification in an easily downloadable format on the web sites of national groups such as FHWA, AASHTO, and interested contractor trade groups.
4. Develop an inspector training course and a national certification standard for inspectors of micropile projects.
5. Develop and/or refine existing technology for rapid testing methods to determine the load capacity and structural characteristics of micropiles. These methods should permit remote transmission of real-time test data.
6. Implement the rapid test method through a nationwide demonstration on actual construction projects.
7. Prepare final report.

Coordination with Other Projects

- 1-1.2—Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction
- 1-2.1—Modular Bridge Systems
- 1-10.2—Bridge Repair/Strengthening Systems

Products, Benefits, and Implementation

- National specifications for micropiles
- Inspector training course
- National certification standard for inspectors of micropile projects

Research Period and Funding Requirements

Total: 2 years, $1,000,000

Tactic: Perform faster in situ construction	→	**Barrier**: Limited data collection and sharing

Project 1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System

Funding: $1,000,000 Duration: 5 years Priority: Medium

A strong IT communication system will play an important role in accomplishing the renewal goals of rapid delivery with minimal disruption and will influence the way we rebuild and renew our nation's highways. This project fills a necessary gap in this area by providing valuable research into how to best develop such a comprehensive, integrated project delivery system. A significant amount of research has already been performed in this area but in a piecemeal fashion. Some researchers have combined pieces into subsystems, but to date there has been no effort to develop the type of comprehensive project delivery system investigated in this project. A thorough needs assessment is the first and most important step in developing such a system.

An intelligent project delivery system (IPDS) will consider enhancements to all phases of a project using appropriate IT. There are four components to an effective IPDS: (1) intelligent design, (2) intelligent procurement, (3) intelligent construction, and (4) intelligent maintenance and operations as described below. It is envisioned that these four components operate in a project web-based environment.

Intelligent Design: Intelligent design involves inputs from several sources: requirements from scenario-based project planning; knowledge and experience from construction, operations, and maintenance personnel; vendor/supplier capabilities related to new materials and methods; and information from life-cycle data management models. Designers develop plans and specifications using multi-dimensional (multi-D) drawings in two three, and four dimensions. The use of object-oriented computer-aided design (OO-CAD) is used to graphically access project information. Construction and operations personnel point and click on portions of the drawing and relevant information such as specifications, procurement status, and shop drawings appear. Intelligent design implies that the design will be optimized from both a construction and maintenance perspective with considerations for modularization and prefabrication. Design considerations should include the use of automated construction techniques such as tele-operated, programmable, or autonomous equipment during the construction and maintenance phases.

Intelligent Procurement: Intelligent procurement involves using IT to streamline the construction bidding and procurement process. Interested contractors or suppliers can use the multi-D electronic drawings provided to them to more quickly understand the project requirements and assemble their bid packages. Electronic data can be imported to scheduling and estimating software to reduce bid preparation time. Bids are filed electronically to transportation agencies. Another aspect of intelligent procurement is the use of automated contractor prequalification and qualification methods.

Intelligent Construction: Intelligent construction involves the use of IT to streamline the construction process. Contractors use electronic multi-D drawings to facilitate the construction process by making it easier to understand the design intent. Electronic data can be used for automating certain construction processes such as stakeless trimming, paving, and grading operations using GPS. Considerations should be made for the use of other automated techniques (e.g., automated concrete floor finishers and remote-controlled soil compaction equipment). Project web-based management systems keep all parties (e.g., owner, general contractor, subcontractors, designer) informed of design and schedule changes. Advanced field data collection systems are used to collect key data, such as quantities of work, in place, and quality issues are directly linked to appropriate project management software. These field data (inspection reports, photographs, and field problems) can be entered into an integrated four-dimensional (4D) GIS database for enhanced life-cycle data management. Additionally, laser scanning can be used to develop as-built drawings more quickly and accurately.

Intelligent Maintenance and Operations: Intelligent maintenance and operations involves using IT to determine optimal maintenance cycles and to collect highway assessment data. Operations personnel can use the vast amounts of information collected during the previous project phases to better maintain the facilities. Maintenance histories can be included in the same 4D GIS system begun during the construction phase, providing complete life-cycle information on the highway. Designers can then use this information to design projects in the future since they will know what materials and construction methods worked better than others. Intelligent maintenance and operations should consider use of automated repair equipment to improve worker safety and improve productivity.

The IPDS can provide rapid sharing of information among the participants on renewal projects on a real-time basis to facilitate decision-making and provide a more efficient, streamlined renewal process. This will lead to better communication between all parties in a renewal project; more efficient design, procurement, construction, and maintenance; more rapid design and construction; fewer errors; less disruption to the traveling public; lower project delivery times and cost overruns; and reduced life-cycle costs.

Objective

- Assess the needs and create an implementation plan for developing and implementing the IPDS.

Scope

The scope of this research involves developing a needs assessment and implementation plan to create a more intelligent approach to designing and building highway renewal projects. The focus is on the use of advanced IT to promote a coordinated, integrated project approach to planning, designing, constructing, and operating highway renewal projects. Future research efforts, beyond the scope of this project, will be required to actually develop and implement this system.

Tasks

1. Develop and understand information data requirements and framework for the system:
   - Conduct interviews with transportation agencies, designers, contractors, operations personnel, and the traveling public to understand information requirements/flows and current deficiencies.
   - Develop a comprehensive map revealing information flow and identify potential areas for improvement.
2. Identify and evaluate promising IT, including both hardware and software:
   - Explore the use of multi-D visualization techniques (e.g., 3D and 4D CAD, OO-CAD, laser scanning, and virtual reality), life-cycle data management concepts and systems, web-based project management techniques, and other useful technologies.

- Identify the most promising hardware and software technologies for specific applications through written surveys and face-to-face interviews with designers and constructors. Hardware could include portable field computers, personal digital assistants, laser scanners, and radio frequency identification tagging. Existing software could include AASHTO transportation programs, Bid Express, MicroStation, and AutoCAD.
- Summarize findings and make recommendations.

3. Develop an overall implementation plan:
   - Identify consensus standards requirements.
   - Prioritize work requirements.
   - Establish organization structure.
   - Identify barriers to implementation and strategies to address the barriers.
   - Establish budget.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-6.3—Utilities-DOT Institutional Mitigation Strategies
- 1-6.4—Railroad-DOT Institutional Mitigation Strategies

Products, Benefits, and Implementation

The primary product from this research is a comprehensive needs assessment and implementation plan for developing an IPDS for highway renewal. This study will provide a valuable roadmap or plan for developing the more comprehensive, integrated project delivery system that will be funded by another program. Implementation of this study will ensure that the most efficient and effective IPDS is developed for managing information flow on renewal projects.

Research Period and Funding Requirement

Task 1: 2 years, $400,000 (1 principal investigator with 2–3 graduate students, funding for travel, a survey, and telephone expenses)

Task 2: 2 years, $400,000 (1 principal investigator with 2–3 graduate students and funding to purchase software and hardware; travel costs may be required to pilot test some applications on actual projects)

Task 3: 1 year, $200,000 (1 principal investigator with 2–3 graduate students; funding will be required to travel to meet with various transportation and industry groups to develop the implementation plan and develop buy-in)

Total: 5 years, $1,000,000

Tactic:
Perform faster in situ construction

Barrier:
Limited data collection and sharing

Project 1-1.7. Facilitating the Use of Recycled Aggregates

Funding: $2,500,000 Duration: 3 years Priority: High

Hauling old materials off the worksite and new materials to the site can significantly increase traffic congestion, noise, dust, and air pollution. Increasing the use of in situ recycled aggregates may reduce these negative effects. By reusing the materials on the project site, it is possible to eliminate hauling and obviate the need to landfill old materials. Recycling existing materials can also reduce the need for new quarries; land for new quarries or pits is becoming increasingly scarce, especially in urban and suburban areas, and permitting regulations are increasingly restrictive. In addition, reusing the materials on site can speed up construction.

Possible chemical reactions between aggregates and cementitious materials can make the use of recycled aggregates problematic in PCC applications, especially in situations where the original source and composition of the aggregates are uncertain. Crushing existing PCC pavements for use as unbound base courses may lead to the migration of cementitious materials into edge drains, which can clog drains. Nonetheless, using recycling materials as aggregate for new PCC applications has been practiced for years in a variety of applications with various levels of success. Research is needed to quantify the effects of recycled aggregates in PCC for various applications, to develop improved methods for utilizing recycled aggregates, to investigate improved test methods to assess the suitability of recycling or reusing materials, and to develop a guide for the use of recycled aggregates in PCC applications.

Asphalt recycling has been practiced since the 1960s and, in some areas, is almost necessary for a contractor to remain competitive. This research would extend the applicability of using recycled materials in asphalt applications to increase use of in situ recycling procedures, improve the speed of construction, and improve testing of materials and mixtures, with an emphasis on rapid renewal applications.

Conventionally, though not exclusively, old asphalt pavements are recycled into new asphalt pavements, and old PCC pavements are recycled into new PCC pavements. Both pavements can be recycled into base courses. There may be circumstances, however, where it may be advantageous to mix the materials. For example, coating crushed PCC with an asphalt emulsion could provide a high-quality angular base course yet prevent the migration of cementitious material into drains. Use of reclaimed asphalt pavement as an aggregate for PCC could reduce alkali-aggregate reactions. While such “mixed uses” may not be the norm, they should be investigated to determine if and when they would be beneficial.

Research is needed to synthesize existing information; quantify the environmental benefits of recycling, especially in situ recycling; assess the performance of recycled materials and impacts on life-cycle and user costs; and recommend methods to facilitate the increased use of recycled materials for rapid renewal.

Objective

- Enhance the use of recycled aggregates for rapid renewal operations.

Scope

This research will address the use of recycled aggregates in bases as well as concrete and asphalt mixtures, use of high fines materials in asphalt and concrete applications, and test methods to ensure the recycled materials are of sufficient quality for the application. The research will address the performance of recycled pavement materials compared to virgin materials. The research will consider recycling on-site materials, particularly existing pavement materials, into new base or pavement courses. The impacts of in situ recycling on traffic and the environment will be weighed against impacts on performance. This research effort will require both laboratory testing and limited field trials of selected recycling alternatives.

Tasks

1. Review literature. A thorough review of literature in the Unites States and abroad will be conducted to identify existing in situ recycling techniques appropriate for use on rapid renewal projects. The literature review will encompass recycling of PCC and asphalt pavements as well as existing unbound bases.
2. Identify barriers to rapid, in situ recycling. Through the literature review, supplemented by a survey, interviews, or other means, identify difficulties associated with rapid, in situ recycling. The search for barriers to implementation should include material issues (alkali-aggregate reactions, unknown aggregate properties, variability, and quality control, etc.), construction issues (lack of equipment, speed of recycling, dust and noise generation during recycling, etc.), performance issues (lack of performance history, life-cycle cost impacts, reliability, durability, and friction concerns, etc.), and other issues, as appropriate.
3. Conduct case studies of successful recycling projects. Identify several projects where various in situ recycling techniques of differing materials were successfully implemented and investigate what made the projects successful. What types of testing were performed before and during recycling? How was material variability handled? What could have been done to improve the process? What were the overall impacts on traffic flow and adjoining property owners? The case studies should investigate these issues and others, as appropriate.
4. Develop an experimental plan. An experimental plan will address the barriers and issues identified in Task 2. The plan should attempt to resolve those issues that will have the greatest impact on improving rapid, in situ recycling techniques for renewal projects. Laboratory testing, accelerated testing, and limited field trials may be included.
5. Conduct the experimental plan. Following approval of the experimental plan by a technical panel, conduct the research to examine the issues identified.
6. Develop a guide to recycling. Based on the findings of this study, develop a simple guide to in situ recycling for rapid renewal projects. The guide should detail design, construction, materials, and performance considerations. In addition, it should be suitable for use by highway agencies and industry to help them decide when and how to best recycle existing materials into new pavement courses.
7. Recommend test procedures. Based on the research findings, recommend test procedures for design and construction quality control for recycling various in situ materials (PCC, ACC, unbound bases, etc.). Test procedures shall include testing of the material to be recycled as well as new materials incorporating the recycled material, as appropriate. Present any new or revised test procedures, if required, in AASHTO format.
8. Prepare final report. A final report will be prepared to fully document the research conducted.

Coordination with Other Projects

- 1-8.3—Composite Pavement Systems
- 1-8.4—Stabilization of the Pavement Working Platform

Products, Benefits, and Implementation

Products

- Guide to using recycled in PCC and ACC for rapid renewal projects
- Test methods, in AASHTO format, for testing recycled aggregates and mixtures made with those materials
- Improved techniques for beneficiating recycled aggregates, as appropriate

Benefits

- Reduced impacts on traffic flow by reducing the movement of haul trucks to and from the site
- Possible reductions in noise, dust, and air pollution due to reduced hauling
- Reduced demand for new materials
- Increased speed of construction
- Improved testing methods leading to improved pavement performance
- Reduced costs

Implementation

Implementation of the results of this research will lead to increased speed of construction; reduced traffic; reduced environmental and societal impacts; wider use of recycled materials; and reduced life cycle and/or user costs. Implementation will be facilitated by the development of AASHTO test methods and specifications for use.

Research Period and Funding Requirement

Total: 3 years, $2,500,000

Tactic:
Perform faster in situ construction

Barrier:
Not enough emphasis given to human limitations and performance

Project 1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments

Funding: $1,500,000 Duration: 2 years Priority: High

The impact of fatigue on the quality of work and the safety of workers, inspectors, and managers, especially on rapid renewal highway projects, is considered serious and in need of further investigation and solutions. “We put our best people on the most difficult projects and work them long and hard in difficult situations at night and on weekends. And when they do a good job, we reward them with more of the same” (Graff, 2002). Many contractors report that employee family life is negatively impacted the longer the rapid renewal project lasts.

Worker, inspector, and manager fatigue on rapid renewal projects could eventually contribute to more on-site accidents, lower overall productivity rates, and lower quality of work. This in turn could lead to lower morale and less teamwork. Ultimately, fatigue could lead to higher costs to the construction work, delays, and higher employee turnover rates.

While there is ample anecdotal information on fatigue and its impact on safety and teamwork, it is not well documented. There are three discrete responses to fatigue issues on a rapid renewal project:

1. Individual workers, inspectors, and managers need to know more about fatigue, its relationship to work hours, stress conditions, rest periods, and diet, and ultimately to overall performance and safety.
2. Departments of transportation (DOTs) and contractors need to analyze the construction schedule set for rapid renewal projects to determine the potential for fatigue on the overall workforce. This will include some analysis of the number of shifts required along with the time allotted for potential rest periods. Should DOTs take this into account in the bid documents and establish “forced” shutdown periods? Or is this an individual contractor responsibility?
3. Finally, it is important that DOTs and contractors understand the impact of how fatigue in individuals collectively causes stress and deterioration in team working relationships. Are there ways to recognize team fatigue and increased stress? How should managers mitigate its impact? Are there different organizational structures that work better? Again, should DOTs and contractors plan for project shutdowns to mitigate this impact?

Finally, the public, including politicians, needs to be aware that DOTs and the contractors have recognized this issue and incorporated mitigation mechanisms into the rapid renewal program.

Objectives

- Determine the impact of human fatigue on work activities commonly associated with highway construction projects.
- Quantify the fatigue element in hourly, weekly, and monthly scenarios for workers, inspectors, and the management team.
- Develop strategies that reduce fatigue for the workforce.
- Develop strategies for organizing, structuring, and executing rapid renewal projects that incorporate fatigue reduction into the project planning process.
- Assure that the public and politicians are aware of the importance of mitigating fatigue on rapid renewal projects.

Scope

This project will investigate fatigue as it relates to rapid renewal projects, providing an overview of sleep, fatigue, and alertness and how they impact performance, teamwork, and the potential for accidents and injury. The project will then discuss ways to mitigate fatigue by identifying safe limits for workers and supervisors.

The project will also identify different rapid renewal scenarios (night work, continuous extended hours, monthly, and yearly) and how fatigue may be minimized within each of them. The researcher will prepare "safe" work-hour scenarios and relate the scenarios to the size of the workforce needed to accomplish a targeted level of renewal activity. The researcher will also identify "safer" bidding strategies for rapid renewal project-required break points. All of these will be put into the context of an overall fatigue management program document.

Finally, the researcher will develop a toolbox of aids that could be used by both DOTs and contractors to help educate and condition the workforce about fatigue issues, to improve alertness, and to identify ways that fatigue can be mitigated during work time and between work shifts.

Tasks

Phase I

1. Review the industrial and construction fatigue literature and identify those factors that lead to fatigue in highway construction workers and management. Included in the review should be a linkage to actual and potential types of accidents and productivity. The researcher should address the impact that working adjacent to high-speed traffic may have on worker fatigue and productivity. This analysis should clearly be stratified to address different classifications of workers, including inspectors and managers.
2. Conduct a survey of a cross section of workers and managers who have worked on rapid renewal projects to collect information on the extent of fatigue on individuals, knowledge of fatigue and its impact on performance rates, and quality of work.
3. Identify and develop a toolbox of aids that could be used to educate workers and managers on fatigue issues and ways to mitigate it during work and between work shifts. The toolbox should clearly address the specifics of working adjacent to traffic and how workers should be aware of how fatigue and alertness may impact their reaction times and overall well-being. The toolbox should clearly identify those fatigue-mitigating measures that relate to hourly effects as well as weekly and monthly effects.

Phase II

4. Identify typical rapid renewal scenarios that are expected to become more common in the future. The scenarios should include continuous night work, continuous hourly work covering full construction seasons, and continuous, intense multi-year projects. Identify ways that fatigue may

influence performance within these scenarios and include potential impact on employee performance, accident records, turnover, team building, etc. The researcher should use data from real projects in each of these scenarios. Compare these data to "normal" projects, with reasonable hours.

5. Identify fatigue management plans for these specific scenarios. Include establishment of hourly requirements, required time off, within work hour efforts, suggested work stoppages, etc.
6. Identify different ways that DOTs and contractors could deal with overall fatigue and stress and its impact on team building and decision-making.

Phase III

7. Prepare an outreach effort to include discussion on fatigue and its impact on performance and safety. Discuss various toolbox solutions. Discuss project structuring issues under the fatigue mitigation plans developed in Phase II.

Phase IV

8. Examine the potential market size of the highway construction workforce needs over the next 10 years. Determine the potential number of rapid renewal projects that might be included in the overall program. Determine the impact this renewal effort will have on the overall workforce, including potential impact on safety, worker turnover, worker training needs.
9. Develop broad strategic plans to assist DOTs and contractors in (1) understanding the situations, (2) adjusting training and outreach efforts, and (3) identifying ways to provide incentives to the workforce to work in these environments and be rewarded for exceptional performance.

Coordination with Other Projects

- 1-4.6—Innovative Project Management Strategies for Large, Complex Projects

Products, Benefits, and Implementation

Products

- Recommendations for reducing worker fatigue and improving safety
- Fatigue management plans
- Toolbox of best practices
- Estimate of impacts on future workforce
- Training and recruitment program

Benefits and Implementation

The DOTs and the construction industry will have a collective understanding of the fatigue issue and its impact on the workforce. They will be able to address the issue at the project structuring phase. They will also have tools to help mitigate fatigue once the work is underway. Mitigation of fatigue could lead to better safety records and better team coordination.

Research Period and Funding Requirement

Total: 2 years, $1,500,000

Tactic 2. Minimize Field Fabrication Effort

This tactic examines approaches that will minimize the amount of fabrication at the project site, thus speeding up the on-site construction phase of the work that actually impacts traffic. New systems need to be developed that consider design approaches, construction processes, material selection, and maintenance requirements.

Figure 5. Pre-cast bridge construction (Source: Bridge Engineering Center, ISU)

Design engineers must have a variety of tools that allow quick and cost-effective decisions to be made. In the past, when an asset was replaced, it was completely demolished and a new one constructed in its place. A need exists to develop complete systems that allow for short on-site construction times (see Figure 5). This includes developing and applying sustainable materials, products, systems, and technologies that reduce life-cycle costs, extend useful life, and improve constructability. New bridge and pavement systems, compatible with short construction timeframes, will minimize disruption to motorists. Rapid construction and repair systems will help reduce traffic disruption and improve the level of performance of the highway infrastructure. The research plan addresses prefabrication, modular, standardized, and roll-in strategies for bridges and pavements.

Tactic:
Minimize field fabrication effort

Barrier:
Traditional techniques for bridge and pavement construction are built on site

Project 1-2.1. Modular Bridge Systems

Funding: $9,550,000 Duration: 6 years Priority: High

Construction processes typically associated with bridges are often time consuming, which leads to traffic disruptions, which in turn are sources of safety problems for the traveling public. This project will develop modular bridge systems that significantly reduce these problems, are readily inspected, and have adequate strength and serviceability requirements.

Recent developments in modular bridge systems have already been made for both superstructure and substructure applications. With fabrication of these systems completed off site at the same time as foundation work is completed on site, these systems help minimize traffic disruptions and improve safety in the work zone. With fabrication of these systems done ahead of time and out of the critical path, they can also increase quality (e.g., due to the fabricator's controlled environment for curing concrete, etc.) and thereby lower life-cycle costs. Another advantage of modular bridge systems is that, if they are appropriately designed, it will be possible to replace only damaged elements (i.e., replaceable components) rather than replacing large portions of the structure, and to replace these components while maintaining traffic on a portion of the structure. This also reduces construction times and disruptions to the traveling public. A challenge is to design the systems to accommodate safety inspections such that the need to limit or close traffic lanes during these inspections is eliminated.

In some renewal projects, it may be possible to use a portion of the existing structure. Depending upon its age and condition, it may be necessary to strengthen some of its elements. In other renewal situations, it may be only necessary to widen the existing structure. If the existing structure has been appropriately designed, widening can be accomplished by simply and quickly installing prefabricated modular systems.

Objectives

- Develop modular bridge systems that are compatible with short construction times.
- Develop policies, procedures, and methodologies for the development, acceptance, and adoption of modular bridge systems.

Scope

This project will develop modular deck, superstructure, substructure, and foundation systems, including standard drawings, specifications, and training materials. Consideration should be given to the application of high-performance materials.

Tasks

Part A. Modular bridge systems for bridge decks

1. Conduct a literature review to identify existing modular and replaceable deck systems that are currently in use.
2. Evaluate the material from Task 1, identify additional needs, and submit a summary report.
3. Develop modular bridge deck systems, including those utilizing high-performance materials, that address the needs from Task 2 using analytical and laboratory studies.
4. Conduct field demonstration projects to evaluate the effectiveness of the deck systems.
5. Working with industry, develop standard drawings and specifications for design, materials, and construction suitable for use by bridge owners.
6. Develop training materials and administer training for practitioners.

Part B. Modular bridge systems for bridge superstructures

7. Conduct a literature review to identify existing modular and replaceable superstructure systems that are currently in use.
8. Evaluate the material from Task 7, identify additional needs, and submit a summary report.
9. Develop modular bridge superstructure systems, including those utilizing high-performance materials, that address the needs from Task 7 using analytical and laboratory studies.
10. Conduct field demonstration projects to evaluate the effectiveness of the superstructure systems.
11. Working with industry, develop standard drawings and specifications for design, materials, and construction suitable for use by bridge owners.
12. Develop training materials and administer training for practitioners.

Part C. Modular bridge systems for bridge substructures and foundations

13. Conduct a literature review to identify existing modular and replaceable substructure systems that are currently in use.
14. Evaluate the material from Task 13, identify additional needs, and submit a summary report.
15. Develop modular bridge substructure and foundation systems, including those utilizing high-performance materials, that address the needs from Task 13 using analytical and laboratory studies.
16. Conduct field demonstration projects to evaluate the effectiveness of the substructure systems.
17. Working with industry, develop standard drawings and specifications for design, materials, and construction suitable for use by bridge owners.
18. Develop training materials and administer training for practitioners.

Part D. Modular components for bridge widening

19. Conduct a survey of bridge owners to identify the types of widening projects typically encountered.
20. Develop modular systems, including those utilizing high-performance materials, for widening bridges.
21. Perform field demonstration projects to evaluate techniques and systems.
22. Working with industry, develop standard design and specifications for design, materials, and construction suitable for use by bridge owners.

Coordination with Other Projects

- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-2.3—Modular Pavement Technology

Products, Benefits, and Implementation

Products

- Standard drawings and specifications for the design and construction of modular bridge deck, superstructure, substructures, and foundations

- Policies, procedures, and methodologies for the development, acceptance, and adoption of new bridge systems
- Modular bridge training materials

Benefits and Implementation

The benefit of this work will be that the developed systems will be constructed ahead of time and out of the critical path, thereby reducing construction times and reducing disruption to the public. Implementation of the results of this project will rely on successful demonstrations and easy-to-use tools.

Research Period and Funding Requirement

Part A
Tasks 1 and 2: $100,000
Tasks 3 and 4: $2,250,000
Tasks 5 and 6: $500,000
Part B
Tasks 7 and 8: $100,000
Tasks 9 and 10: $2,250,000
Tasks 11 and 12: $500,000
Part C
Tasks 13 and 14: $100,000
Tasks 15 and 16: $2,250,000
Tasks 17 and 18: $500,000
Part D
Tasks 19–22: $1,000,000
(Note: This project's scope could be divided into separate projects based on the parts and tasks given above.)
Total: 6 years, $9,550,000

Tactic:
Minimize field fabrication effort

Barrier:
Traditional techniques for bridge and pavement construction are built on site

Project 1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology

Funding: $4,000,000 Duration: 4 years Priority: Medium

Typical cast-in-place bridge construction processes such as building formwork, placing reinforcing steel, and allowing concrete to cure are time consuming. On rapid renewal projects, these and other linear-based activities also disrupt traffic and degrade highway safety. These impacts could be reduced by off-site fabrication of bridge components coupled with construction approaches, such as roll-in technologies.

When bridges are designed, the equipment that will be used to construct the bridge is often ignored. If bridge systems could be developed that utilize optimum construction systems, construction times could be reduced while also increasing the quality of the resulting product.

This project will develop bridge designs that consider the conditions of rapid renewal projects and will incorporate features and approaches that encourage optimal construction efficiency, as well as being easy to inspect, and meet adequate strength and serviceability requirements. The intent is not to duplicate the work under Project 1-2.1, Modular Bridge Systems for New Construction, but to focus on how to modify current approaches to designing various types of structures so that modern construction technologies can be fully utilized.

Objective

- Develop approaches to designing bridges that efficiently integrate modern construction technology.

Scope

This project will compliment Project 1-2.1, Modular Bridge Systems for New Construction, and will investigate the various types of bridge systems commonly used (other than specialty bridges) and develop approaches to bridge design that fully integrate modern construction technologies and additional approaches that may be identified by this project. The focus of this project will be in rapid renewal applications.

Tasks

1. Conduct a literature search on innovative bridge construction approaches and technologies.
2. Conduct multiple focus groups to identify existing problems between the design and construction processes that inhibit efficient bridge construction.
3. Develop new bridge designs that are more compatible with existing construction techniques and technologies.

4. Develop new construction techniques and technologies that are compatible with existing bridge systems and potential new bridge systems.
5. Perform laboratory tests and evaluate new construction techniques and technologies and bridge systems.
6. Perform field demonstration projects to evaluate techniques and systems.
7. Working with industry, develop standard drawings and specifications suitable for use by bridge owners.
8. Develop training materials.
9. Prepare final report.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems for New Construction

Products, Benefits, and Implementation

The products of this work will be a set of standard drawings and specifications for bridge systems and construction technologies that increase construction efficiency and training materials. The benefits of this work will be that the developed systems will allow bridge replacements and repairs to be accomplished more efficiently. Successful implementation of the results of this project will rely on successful demonstrations and easy-to-use tools.

Research Period and Funding Requirement

Total: 4 years, $4,000,000

Tactic:
Minimize field fabrication effort

Barrier:
Traditional techniques for bridge and pavement construction are built on site

Project 1-2.3. Modular Pavement Technology

Funding: $2,500,000 Duration: 4 years Priority: Medium

Modular pavements speed up construction without sacrificing quality. Traffic disruption can be greatly reduced through reduced lane closures.

Modularization can accelerate renewal by facilitating multitasking in lieu of sequential construction, allowing, for example, fabrication of the replacement slab off site while subgrade and base repairs are in progress. The technology has great potential for rapid pavement repairs. Modular panels can be used for isolated repairs, intersection improvement, ramp replacement, pavement replacement under overpasses, and longer mainline pavement replacement.

Modular pavements use pre-fabricated segments for quick pavement replacement. This type of technology has been used by the military for rapid repair of airfields and has seen some civilian highway use. The process allows most of the work to occur outside the traffic stream. If PCC slabs are used, for example, all curing and strength gain can occur without impeding traffic. In addition, the concrete placers and finishers can work in relative safety off the roadway.

Design procedures are needed for modular systems, as well as joint and material specifications, quality control/quality assurance (QC/QA) procedures, and more. Structural design procedures do not currently exist for modular highway pavements; this is a critical need since the modules typically are thinner than conventional pavements yet need to carry the same amount of traffic. The support conditions and connections between panels are critical to the success of this technique to prevent uneven settlement or rocking of slabs. The modules must be fabricated and placed to match grade, profile, and thickness in both the longitudinal and transverse directions. This can be especially complex for intersections, interchanges, and ramps where complicated geometries must be accommodated.

The challenges that modular concrete pavements present to state DOTs include

- Achieving equivalent load repetition as for conventional concrete since modular PCC is thinner (8 inches) than conventional PCC (14 inches)
- Determining the proper prestress level to be applied (transversely)
- Achieving smoothness (very important parameter) to avoid diamond grinding
- Achieving vertical alignment between adjacent panels
- Determining optimal panel size (to accommodate mainline and shoulder)

Another issue facing agencies is that currently most modular pavement systems are proprietary and therefore difficult for agencies to specify. Generic or alternate specifications are needed to facilitate implementation of these rapid systems.

Objectives

- Place pavement in exceptionally short construction windows of less than eight hours.
- Improve pavement quality control through use of pre-cast and modular technologies.
- Develop design protocols for modular pavement renewal systems.
- Perform accelerated testing.
- Develop detailed operation guidelines.

Scope

This project will involve testing in the laboratory, accelerated loading testing, and possibly field trials.

Tasks

1. Conduct literature review and feasibility study. Conduct a critical review of U.S. and foreign literature, including military reports, to determine the state of the art in modular pavement technology. Review existing modular pavement applications to assess benefits and disadvantages, strengths and weaknesses, successes, and areas needing attention. Report on the feasibility and cost effectiveness of using modular pavement segments for specific rapid renewal applications.
2. Develop research approach. Identify promising technologies and determine gaps in the state-of-knowledge. Design a research plan to address those gaps through a coordinated experimental design incorporating laboratory testing, testing under accelerated loading, and field trials as appropriate. The experimental approach should address design, fabrication, material, construction, and performance issues.
3. Develop design procedures. Develop mechanistic structural design procedures for modular pavements. Evaluate the capacity of modular pavements to carry repeated traffic loads compared to conventional pavements. Determine base support requirements for long-term performance. The design procedures should suggest conditions under which it is appropriate to consider modular pavements and conditions that preclude the use of modular pavements.
4. Develop fabrication and material requirements. Develop or refine fabrication and material designs to ensure pavement smoothness, alignment of adjacent panels, determination of panel size, prestress levels, required material properties, and other factors.
5. Develop a construction program, including bidding, installing, and quality control. Prepare guide specifications for implementing modular pavement technologies for spot repairs and lengthy pavement sections. Recommend inspection and testing procedures to ensure quality.
6. Develop a long-term evaluation program. Recommend a long-term evaluation program to validate the results of the research and collect information needed to establish performance characteristics, service lives, and life-cycle costs.
7. Develop final report. Document the research through a final report including guide specifications in AASHTO format, recommended inspection procedures or tests, implementation plan, and validation plan.

Coordination with Other Projects

- 1-8.4—Stabilization of the Working Platform

Products, Benefits, and Implementation

Products

- A feasibility study on the potential uses of modular pavement systems for specific rapid renewal applications.
- Design standards for modular pavement systems, including structural design procedures, support and connection details, material requirements, etc.
- Guide specifications to facilitate the implementation of modular pavement technology.
- A long-term evaluation plan to assess the performance of modular systems and lead to refinements in designs and materials.

Benefits

This research will provide another fully developed tool that can be readily implemented for the rapid renewal of pavements. Increased speed of construction, reduced lane closures, increased worker and public safety, and good pavement performance are potential benefits of this technology.

Implementation

Implementation of the findings of this project will be facilitated by the development of design standards, guide specifications and inspection procedures in AASHTO format. The implementation of modular pavement systems will allow rapid repair and construction, minimized traffic impacts and increased worker and driver safety.

Research Period and Funding Requirement

Task 1: $400,000
Task 2: $25,000
Task 3: $1,000,000
Task 4: $500,000
Task 5: $450,000
Task 6: $50,000
Task 7: $75,000
Total: 4 years, $2,500,000

Tactic 3. Perform Faster Construction Inspection and Monitoring

As the saying goes, “it takes 10 workers one day to pave a mile; it takes 10 days for one worker to say it meets specifications.” To be rapid, a renewal project must be built and accepted quickly before opening to the public. However, current acceptance testing procedures are not done in real time, and if there are problems, subsequent rework requires additional time and money. In a high-pressure, time-constrained project, the demands to keep moving can overwhelm the inspection process. An innovative, high-speed inspection process could make sure that the overall quality is obtained without delaying the project.

In an era of rapid construction, it is more important than ever that we develop methods to rapidly assess the quality of the product supplied. Assessing the quality of materials and construction in civil engineering has been problematic historically. Infrastructure projects typically consist of large volumes of highly variable materials that are being placed under less than ideal conditions. Rapid assessment should provide sufficient information to predict the value of the facility over a long period of time (see Figure 6). The application of more rapid nondestructive testing will require that we reconsider the number of locations that can be sampled, thereby improving our understanding of the constructed facility and reducing variability.

Figure 6. Laser Scanning (Source: Iowa State University)

Tactic:
Perform faster inspection and construction monitoring

Barrier:
Limits on sensing technology

Project 1-3.1. High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection

Funding: $5,000,000 Duration: 5 years Priority: High

Rapid renewal demands rapid inspection testing. Defects in materials or construction must be identified during construction so that corrections can be made quickly and with a minimum of disruption. Returning to a project to remove and replace defective material is contrary to the goals of rapid renewal and minimizing disruption. The public has little tolerance for repeated lane closures or traffic restrictions in the same location. This research would benefit renewal by providing rapid test results to facilitate rapid design, construction inspection, and performance monitoring; it would minimize disruption by avoiding returning to the site to correct problems discovered after construction; and it would extend service life by ensuring construction and material quality.

Improving and accelerating inspection techniques have been longstanding goals, but the impetus to develop these faster methods is much stronger for rapid renewal than for conventional projects. In addition, technological developments make achieving these goals more attainable today. For example, high-speed inspection may require automation of the data collection and analysis procedures; improved sensors and high-speed, handheld non-contact sensors facilitate measurement on the fly. Handheld computers allow immediate data analysis and entry of data into databases that may be accessed by everyone involved in a project. Self-inspecting construction procedures and materials can also speed the process while reducing the chance of worker injury. With specialized equipment, a one-pass operation could analyze a facility for a variety of properties at the same time, such as condition, deterioration, distress, smoothness, friction, structural strength, and more. In situ nondestructive tests would seem to have an advantage in terms of speed, ease, and relevance to performance, but other methods could be used if suitably rapid and reliable.

To the extent possible, inspection tests should be coordinated with tests for design and performance monitoring and all the data should be incorporated in an asset management system. The move to performance-related specifications implies that the characteristics monitored during and after construction should be those that drive ultimate performance, not merely those properties that are easy to measure. This, however, may require predictive equations or models that relate early-age properties with long-term performance. Similarly, designs should use the same fundamental material properties to ensure performance. In some cases, rapid renewal requires that designs be developed quickly; high-speed testing techniques can facilitate rapid design as well as inspection.

Rapid data collection and analysis is needed for such issues as subgrade, base, underlying pavement strength (accelerated and improved back-calculation); foundation and substructure adequacy; when a

facility can safely be opened to traffic; and material and construction quality related to performance. The data obtained must be reliably linked to performance.

Objective

- Develop and/or implement rapid construction inspection techniques for a variety of construction materials, including subgrade, base, structures, PCC and ACC pavement layers, for use in rapid renewal applications.

Scope

Accomplishing the objectives of this research will require a thorough review of existing testing methods and new technologies for inspection from the United States and overseas, followed by evaluation of promising technologies. Where existing procedures are not available, research and development will be required to devise new inspection techniques.

Tasks

All tasks should consider a variety of construction materials including, but not limited to, subgrade soils, unbound bases, structural concrete, and PCC and ACC pavement layers.

1. Conduct literature review and survey. Conduct a review of U.S. and foreign literature to identify potential rapid construction inspection techniques. Also, conduct a survey of transportation agencies and industry to determine which inspection procedures currently cause the most delay. The survey may also help to identify promising inspection methods in use or in development. The technologies may include rapid test methods; nondestructive, non-contact testing; self-inspecting materials or processes; and one-pass inspection procedures or other techniques that can provide feedback on construction quality within 24–48 hours or, preferably, even faster. Where promising methods are identified, interview users of the method and data to assess the speed, ease of use, relevance, and accuracy of results.
2. Evaluate the state-of-the-art and develop experimental plan. Based on evaluation of the findings of Task 1, recommend a plan to assess existing technologies for application to rapid renewal project inspection. The plan should identify existing promising technologies as well as unfilled needs for rapid inspection. The experimental design will require at least two components: an assessment of the feasibility of implementing existing technologies for rapid inspection and an approach to the development of new methods to speed the inspection process. Since there is limited funding for the development of new inspection procedures, the plan should set priorities for which gaps to fill that will provide the biggest improvement in the overall construction inspection process. The plan should be reviewed and approved by a technical panel prior to initiation.
3. Assess existing technologies. Conduct case studies and field or laboratory comparisons of promising technologies, as appropriate. Each promising technology under study should be evaluated for its speed, ease of use, accuracy, and relevance as an inspection tool; applicability as a data input for design; and appropriateness for use as a performance monitoring tool after construction.
4. Develop new inspection methods. Where there are inspection needs that cause significant delay during construction or rapid, accurate inspection methods do not exist, conduct the research plan developed in Task 2 to develop those potential methods that may have the greatest impact on construction inspection in terms of speed and accuracy of test results. Laboratory and field comparisons of the new method(s) to conventional test results should be conducted to verify the improvements offered by the new method(s).
5. Prepare test procedures. For those existing or new technologies that demonstrate applicability to rapid construction inspection, prepare or refine test procedures in AASHTO format.

6. Develop a validation plan and training materials to facilitate implementation. Develop a plan to fully validate the applicability of test results generated from the recommended existing and new test procedures to construction inspection, design, and performance monitoring.
7. Document the research program. The final report should include a stand-alone guide to rapid inspection techniques applicable to different materials or types of construction to aid agencies and industry in selecting the best technologies to implement for specific projects.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.3—Modular Pavement Technology
- 1-4.1—Performance Specifications
- 1-8.3—Composite Pavement Systems
- 1-8.4—Stabilization of the Working Platform

Products, Benefits, and Implementation

Products

- AASHTO-format test procedures for rapid design evaluation and construction inspection
- Training materials should be developed for the test methods recommended for rapid renewal

Benefits and Implementation

The benefits of implementing high-speed testing techniques are great. Rapid testing facilitates rapid design decisions, improved construction efficiency and quality, and minimized traffic disruption while corrections are made or failed materials are replaced. Testing performance-related parameters through design, construction, and long-term monitoring helps to ensure that the desired performance life is achieved.

Research Period and Funding Requirement

Task 1: $250,000
Task 2: $100,000
Task 3: $1,750,000
Task 4: $2,500,000
Task 5: $250,000
Task 6: $50,000
Task 7: $100,000
Total: 5 years, $5,000,000

Tactic 4. Facilitate Innovative and Equitable Contracting Environment

One of the main challenges facing agencies in the future is the reduction in human resources available to conduct renewal operations. It is safe to expect that these agencies will be transferring more responsibilities to consultants and contractors. An examination of trends in other countries shows that the transfer can be accomplished but requires new strategies and cooperation among the various interests. For example, design-build contracting, identified nearly 10 years ago in Europe as a way of decreasing the time it takes to design and construct a project, has only now been approved by the FHWA for use in federal-aid work. This does not address the lengthy time it will now take for state highway agencies to gain approval with their legislative officials. This topic focuses on developing an environment that may be more conducive to delivery of the type of services needed in the future.

Most renewal projects are not positioned for success with traditional specification and contracting approaches. A new generation of specifications will allow the contractors to exercise more innovation and attention to quality, especially in rapid renewal projects. Well-developed performance-based specifications are the key to achieving optimum contracting potential. Performance-based specifications, especially as they apply to rapid renewal, will allow the contractor to exercise more innovation and pay more attention to quality. Method or prescriptive specifications have been the staple in the industry for nearly 75 years. Other specifications types such as end-result, statistically based specifications, performance-related specifications, and performance-based specifications have been developed for some products, but rarely do they eliminate method specifications.

While the U.S. highway community has been well served by the low-bid process, the rapid renewal needs of the future are leading many DOTs to look for ways to expedite projects, to enhance contractor innovation, to share or transfer risk, and to expand contractor opportunities to operations and maintenance. There is some evidence that new contracting practices could better address rapid renewal issues than the conventional design-bid-build process that is common throughout all the states. Currently, however, DOTs collectively have the need to develop common nomenclature, explore the potential benefits from these techniques, and to be able to “mix and match” the various strategies effectively in rapid renewal. Inherent in this is the need to determine the risk involved when these techniques are applied.

Figure 7. Reviewing Contracts

Agencies need project management strategies to implement rapid renewal. There is a clear need for rapid decision-making, for the elimination of accidents related to worker fatigue, and for sustainable project management and inspection. Agencies and contractors need to develop management structures that can effectively deliver complicated projects (see Figure 7). Many large projects require fairly complex management structures and reporting responsibilities. Large projects also involve cooperation to ensure that the projects are delivered within time, budget, quality, and safety requirements. Improved management of the design and delivery process as well as the design-build process calls for consideration of new management techniques to handle paper flow and decision-making. Agencies will have several innovative project management strategies to select from, depending on the type and extent of the renewal process.

Tactic:
Facilitate innovative and equitable contracting environment

Barrier:
Methods specifications constrain efficiency in quality

Project 1-4.1. Performance Specifications

Funding: $2,225,000 Duration: 5 years Priority: High

DOT specifications are generally prescriptive in that they attempt to describe how a contractor should conduct certain operations using minimum standards of equipment and materials. These prescriptive specifications, commonly known as method specifications, have performed admirably in the past with an experienced workforce and fairly repetitive operations. However, rehabilitation and reconstruction projects, especially in a rapid renewal scenario, demand more creativity and innovation. Prescriptive specifications do not properly foster this innovation. If contractors were allowed more freedom in equipment and material selection, would they be more innovative? Would new equipment and procedures become available to solve the problems we now face?

The first challenge is to develop alternative specification language that is less prescriptive, adequately describes the performance required in the final product, and is contractually sound and defensible. The term “performance specification” is becoming more commonplace but is still not well defined or understood. Performance-related and performance-based specifications are still under development. Warranty language that describes how a product should perform in service has the potential to reduce prescriptive requirements and concentrate on measurement of the final product.

Specifications that describe how the final product should perform after some level of service should be based on the following:

- Product properties that significantly impact in-service performance
- Factors that are within the contractor’s control

These types of specifications are reliability based and require knowledge of the variability of the materials and processes, as well as performance variability that occurs throughout the life of the structure. These specifications also use life-cycle cost models to help with the selection of desired material characteristics and the determination of the final in-place product value. Although the basic framework for performance specifications has been established for concrete and asphalt pavements, more research is needed on their applicability to different types of construction (e.g., structures, embankments, base courses, and overlays).

The second challenge is to develop performance specification language that works effectively and properly in design-build-maintain-operate-warrant-transfer (D-B-M-O-W-T) type contracts. The contract language should establish the minimum standards as to what design methodologies, material mix design processes, end-result requirements, safety requirements, and maintenance requirements are required or are used as voluntary standards.

The language of contracts is very important in all construction contracts, but it is especially important in a rapid renewal environment. If the DOT desires creativity, innovation, high quality, and an incentive-driven effort by the contractor, the DOT should attempt to minimize the prescriptive nature of current specifications.

Objectives

- Develop specifications that better address the type and complexity of work anticipated in rapid renewal.
- Develop specifications that can be used effectively in different contracting scenarios (design-build, warranties, etc.).
- Identify the need for additional rapid and nondestructive tests that support performance language specifications.
- Determine which highway products are better procured with performance specifications versus method specifications.
- Create an environment of innovation by reducing mandatory method requirements and better describing the end-product fitness for service.

Scope

This work will result in a standard performance specification book that is similar in structure to a typical DOT highway specification book. Where performance requirements, test procedures, models, etc. have not been adequately developed, the researcher should clearly describe the gap and recommend further research in that area. Performance language for D-B-M-O-W-T combinations should be developed as a sample contract for different scenarios that address bridge and pavement issues from design through turn-back to the DOT.

Tasks

Phase I. Background

1. Conduct a detailed literature search of U.S. and international organizations that build highway facilities to collect and sort specifications by product type, specification type, and contract type.
2. Develop baseline definitions of all terms as they relate to specification types and contracting types, coordinating with other renewal contractors.
3. Prepare a thorough comparison of different specification types for the same product, identifying the potential pros and cons of using each type in a renewal project. Develop a clear ranking system for effectiveness in various categories, including risk. To the maximum extent, use testimony from actual users of the specifications.

Phase II. Performance specifications for conventional contracting

4. Develop a detailed outline of a new performance specification book, similar to AASHTO's *Guide Specification for Construction*, for use in low-bid process.
5. Identify any gaps in specifications—test procedures, models, etc.—that should or must be developed to properly implement the specification.
6. Develop a procedure that prioritizes method specifications to show their relative importance. It is assumed that some method specifications will still be required even under a performance-based requirement. Consider using utility theory principles.

Phase III. Performance specifications for D-B-M-O-W-T contracts

7. Develop a detailed outline of a new performance specification by contracting type.
8. Complete guide specifications completely and fully, identifying key specification language, sorting owner-builder responsibilities clearly, etc.
9. Prepare detailed risk assessment of new specifications that clearly show a shift in responsibility from owner to builder and back.

Phase IV. Outreach and product development

10. Conduct four or more workshops, working with groups that provide the various products (asphalt pavements, concrete pavements, embankments, etc.) to collect comments and input. Clearly identify those specifications that could prove beneficial in a high-speed environment. Prepare a summary report on each section.
11. Conduct experimental projects using the new language. Collect feedback for specific users.
12. Prepare interactive software protocols that would allow for easy access to future specifications.
13. Prepare manuals and guides.

Coordination with Other Projects

- 1-4.2—Alternate Contracting Strategies for Rapid Renewal
- 1-4.3—Incentive-based Specifications to Assure Meeting Rapid Renewal Project Goals
- 1-4.4—Development and Evaluation of Performance-based Warranties
- 1-4.5—Risk Manual for Rapid Renewal Contracts
- This critical project will also require extensive coordination and proper time phasing with Projects 1-5.2, 1-5.3, 1-6.1, 1-6.2, 1-6.3, and 1-7.1.

Products, Benefits, and Implementation

Products

- New performance-based specifications for AASHTO in interactive computer language, with clear determination of risks and required future research to fully implement the specification
- Performance-based specifications book for alternative contracting scenarios
- Outline of research needs for nondestructive and high-speed testing that should be used with performance language specifications
- Advanced method specifications that identify priority order of method requirements

Benefits

DOTs and the construction industry will have a common reference base of performance language from which they can perform rapid renewal. The language developed in this project can be used as the foundational document for low-bid, innovative contracting and language and warranty work as well. Contractors will be more innovative in the way they build projects, design and operate equipment, and use their personnel. They will have a much clearer focus on the performance needs of the product. Owners will be able to reduce their inspection forces and concentrate more on the final end product and the means to determine its compliance. There will be fewer claims and less confusion among the various parties because the language will have gone through a very thorough evaluation. Project delivery should be simplified. Finally, overall life-cycle costs could be reduced as the language is better tied to performance.

Implementation

To apply the guide specification, DOTs and contractors will need extensive training and exposure to the new language and test protocols. Trial and demonstration projects and evaluations will be required. A central depository for controlling the document for 6–10 years as modifications and updates occur will also be needed.

Research Period and Funding Requirement

Phase I: $475,000
Phase II: $500,000
Phase III: $500,000
Phase IV: $750,000
Total: 5 years, $2,225,000

Tactic:
Facilitate innovative and equitable contracting environment

Barrier:
Sub-optimized contracting approaches and use of incentives

Project 1-4.2. Alternate Contracting Strategies for Rapid Renewal

Funding: $2,000,000 Duration: 4 years Priority: High

This project will organize, evaluate, and further implement alternative contracting mechanisms to accommodate a greater variety of contracting methods for specific application related to rapid renewal projects. Many states are looking at contracting options that might accelerate project completion time, reduce overall costs, improve quality, and reward contractors for exceptional performance. However, there are inherent risks associated with any new contracting procedure. It is important to fully understand and evaluate different options and apply those that will return the most benefit to the state. To date, individual DOTs have conducted state-only experiments (as opposed to national experiments) with alternative contracting practices. There is the need for better controlled experiments with several states involved in applying the new techniques. This will aid in understanding the effectiveness and limitations of the new strategies.

Objectives

- Determine how various alternative contracting strategies can be used effectively in various rapid renewal scenarios.
- Quantify the sharing or transfer of risk between the DOTs and the contracting industry as a result of these strategies.

Scope

This work will define and organize all the new contracting strategies that have moved into the highway contracting nomenclature over the last 10 years. The work will also explore other contracting innovations from the international community and non-highway public works projects. From this all-encompassing list, the researcher will identify the current barriers associated with implementing these new procedures. Finally, the researcher will identify ways to “mix and match” the strategies in a way that advances the delivery of rapid renewal projects.

Tasks

Phase I. Collecting information

1. Conduct a highway construction alternative contracting literature review and interview process. Identify and organize the alternative contracting strategies that have been applied in the United States in the last 10–15 years. Develop a summary of current state laws that regulate bidding practices and identify barriers to alternate contracting practices. The review should include all the work accomplished under FHWA Special Experimental Project 14 and other DOT experiments, especially by the Florida DOT, and should include interviews to supplement the literature review.

This review should focus on construction contracting only. The review should also identify emerging concepts that are in early formation stages, or have not evolved since first conceived. They should include concepts such as A+B+Q (an overall project quality index), low-bid design-build, etc. Identify and organize the alternative contracting strategies that are currently emerging or in practice in the international communities, again related to construction contracting.

2. Conduct non-construction-related alternative contracting literature review and interview process. This task will also include an examination of ITS and other types of equipment/service contracts for their applicability to construction renewal. Explore non-highway U.S. bidding practices and determine if these procurement practices are applicable to rapid renewal. It should also include a full examination of procurement strategies by the Departments of Defense and Energy, National Aeronautics and Space Administration, U.S. Army Corps of Engineers, major state and water authorities, power facilities, etc.
3. Organize various strategies and identifying benefits and barriers. From the results in previous tasks, organize the alternative contracting procedures in a way that will aid in determining the potential benefits of the procedure—time, quality, innovation, cost containment, services, risk sharing, etc. Identify the barriers that may impact the implementation of these clauses, including legal, administrative, and lack of understanding of risk involved. Conduct a special examination of warranties and post construction responsibilities placed on the contractor to determine the risk and risk-transfer required. Include a rational approach to determine the impact of warranty costs versus the costs of the DOT doing repairs versus without a warranty.
4. Conduct communications and outreach. Conduct national and regional outreach efforts to present the information from Tasks 1–3 and to receive feedback from DOTs and the construction industry. Include in final report.

Upon completion of this phase, it is fully expected that the strategies will include but not be limited to design-bid-build, multiple award low bid, low-bid design-build, best value design-build, A + B + Q with performance incentives, best value construction contract, quality-based selection of design-build (RFQ), design-build-maintain, design-build-operate-maintain, design-build-finance, concessionaires, alliance concept (Europe's integrated supply chain management), performance contracting, negotiated contracts, active asset management, build-operate-maintain-finance-transfer, user-based payment mechanisms, framework contracts, and average bidding.

Phase II. Linking alternative contracting to rapid renewal strategies

5. Develop a decision tool to assist agencies in selecting an appropriate contracting strategy for project circumstances. The tool should also include specific reference to alternative financing strategies and to alternative contracting language for specific items of work.
6. Conduct national and regional outreach efforts to present the information from Tasks 1–3 and to receive feedback from DOTs and the construction industry. Incorporate feedback into report. Organize and conduct experimental projects with lead states applying relatively similar contracting strategies to enhance the evaluation process.
7. Organize, conduct, and evaluate experimental projects on different strategies included in rapid renewal concepts.
8. Prepare final report.

Coordination with Other Projects

- 1-4.1—Performance Specifications

Products, Benefits, and Implementation

Products

- Guidebook on alternative contracting strategies with clear descriptors, uses, experiences, strengths, weakness, and perceived benefits and risks
- Decision support tools
- Implementation manual that identifies barriers and ways to overcome them
- Documentation on lead state evaluations of various practices
- Training manual

Benefits

Both the DOTs and the construction industry will better be able to apply various alternative contracting techniques to rapid renewal projects.

Implementation

This project will implement alternative contracting mechanisms to accommodate a greater variety of contracting methods for specific application related to rapid renewal projects. Implementation is fundamental to the project. In more than one case, it has been suggested that F-SHRP incorporate better controlled experiments with several states in the experiment. Many new contracting techniques have been limited to one state only and it is difficult to assess contracting value.

Research Period and Funding Requirement

Total: 4 years, $2,000,000

Tactic: Facilitate innovative and equitable contracting environment	➡	**Barrier:** Sub-optimized contracting approaches and use of incentives

Project 1-4.3. Incentive-based Specifications to Assure Meeting Rapid Renewal Project Goals

Funding: $1,500,000 Duration: 3 years Priority: High

Disincentives began surfacing in highway specifications in the early 1980s as a way to adjust bid items for work below minimum specification requirements. The downward adjustments helped DOTs to clearly describe "reasonable close conformity" for the first time in a rational way. Shortly thereafter, incentives were added as a way of distinguishing a contractor for doing above-the-minimum work. By most accounts, the addition of the incentive side of the specification did much more to improve quality than the disincentive side of the specification.

Starting in the late 1980s, incentives specifications for pavement smoothness were introduced nationwide and have dramatically improved both asphalt and concrete pavements' smoothness. Later, incentives were added to other product attributes such as strength of concrete or air voids in asphalt. In the early 1990s, in response to the need for accelerating construction, contract time incentives were added through "A+B" bidding and lane rental. By all accounts, contractors perform better and complete projects more quickly because of these incentives. Through incentives, DOTs now have a way of (1) identifying those project goals and product attributes that are of high importance and (2) distinguishing and rewarding those contractors that exceed minimum requirements.

While time incentives have clearly shown their benefit and the need to balance time with quality is critical, there is no overall index for total project quality. This project will focus on the next generation of incentive-based specifications by examining the special needs of rapid renewal projects and identifying the key factors that determine a successful project. This project will examine, define, and propose quantifiable and measurable renewal goals such as the following:

- Total product quality—pavement, bridge, landscape, striping, signing, etc.
- Total project quality—a uniform overall index
- Time management—next generation specifications
- Traffic management
- Public safety in the work zone
- Utility coordination and completion
- Environmental requirements
- Public relations management
- Project workforce safety
- Total project goals—time, quality, cost, and safety—into one overall project index

The researcher, along with the identification of these and other project and product goals, will identify clearly the value of the work received through life-cycle cost examination, user costs, polling, new testing approaches, etc. The researcher will identify both incentives and disincentives in the process.

In addition to looking at the contractor portion, the researcher could be asked to examine the design function as well, looking at ways incentives might be included in that process. For example, the ability to locate utilities and other appurtenances, identifying adverse soil conditions, eliminating omissions, providing accurate construction quantity and cost estimates, etc., could be examined and evaluated.

Objectives

- Improve delivery of rapid renewal projects and products through incentive-based specifications.
- Provide a way for DOTs to clearly highlight key project goals during the bidding process.
- Provide a way for DOTs to reward contractors for well-managed, efficient, and high-quality work.
- Present to the public a way to provide the highest level of service during construction.
- Improve overall product and project quality.

Scope

This project will examine typical project goals, construction specifications, and current incentive programs. The overall project will examine incentives specifically for application in the low-bid process. However, if necessary, product or project quality incentives that require a post-construction, in-service period of evaluation may be suggested as well, through integration into warrant or maintain-warrant concepts.

Tasks

1. Identify typical project goals associated with rapid renewal projects. Identify those that might benefit from incentive-based contracting measures. The examination should include nontraditional goals such as worker safety, public safety, public mobility, public relations, utility coordination, total project quality, environmental goals, and project aesthetics. Identify those goals that could be inversely impacted by high time incentives.
2. Identify typical product performance requirements. Products refer to the total pavement product—for example, bridges, critical embankments, retaining walls, striping, and other elements of the project. Examine the key quality attributes.
3. For each project and product goal identified above, identify performance levels that distinguish above- and below-minimum compliance by a contractor. Develop a quantitative performance measurement strategy for each one.
4. Develop a rational for incentives for each of the project and product goals in Tasks 1 and 2. Identify the interrelationship between time incentives and the project goal incentives.
5. Develop performance data gathering and processing methodologies.
6. Develop guide contract language.
7. Conduct national and regional outreach efforts to present the information from Tasks 1–6 and to receive feedback from DOTs and the construction industry. Incorporate feedback into report. Organize and conduct experimental projects with lead states applying relatively similar contracting strategies to enhance the evaluation process.
8. Develop training program and training aids.

Optional Design Phase

The researcher could also be asked to examine the design function, looking at ways incentives might be included in that process. For example, the ability to locate utilities and other appurtenances,

identifying adverse soil conditions, eliminating omissions, providing accurate construction quantity and cost estimates, etc., could be examined and evaluated. Repeat Tasks 1–8.

Coordination with Other Projects

- 1-4.1—Performance Specifications
- 1-4.2—Alternate Contracting Strategies for Rapid Renewal
- 1-4.4—Development and Evaluation of Performance-based Warranties
- 1-4.5—Risk Manual for Rapid Renewal Contracts

Products, Benefits, and Implementation

Products

- Project goal incentive clauses and instructional guidelines
- New incentive-based specification for overall project quality
- Criteria that better balance overall incentives for time with other project goals
- Outreach documentation
- Training program

Benefits

The work will allow the DOTs to highlight the most critical elements of a renewal project during the bidding process by assigning incentives. The contractor, in turn, will know what the DOT considers important for the overall project and product and will be rewarded for higher performance. It is expected that DOTs and contractors will also have better quantifiable ways to measure heretofore qualitative concepts such as “efficient traffic management” or “exceptional coordination efforts.” It is expected that there will be fewer claims, fewer misunderstandings, and better handoff from the planning/design element of the DOT to the construction/operations side.

Implementation

Implementation is included in the scope of work. It is important that this work be coordinated with the other projects identified above. Eventually, it should be included in the performance specifications manual developed under Project 1-4.1.

Research Period and Funding Requirement

Tasks 1–6: $1,000,000
Task 7: $250,000
Task 8: $250,000
Total: 3 years, $1,500,000

Optional Design Phase
Tasks 1–6: $300,000
Task 7: $150,000
Task 8: $150,000
Optional Design Phase Total: $600,000

Tactic:
Facilitate innovative and equitable contracting environment

Barriers:
- Sub-optimized contracting approaches and use of incentives
- Unbalanced risk allocation between owners and contractors

Project 1-4.4. Development and Evaluation of Performance-Based Warranties

Funding: $1,500,000 Duration: 4 years Priority: Medium

Many states are experimenting with warranties to (1) improve product quality, (2) reward high-performing contractors, (3) assure that all work is performed properly the first time, and (4) reduce inspection workforce requirements. All four of these factors are critical for rapid renewal projects. Warranties are controversial but may be an important part of the rapid renewal contracting mix of the future. This project examines in detail the current warranty situation to identify ways to make it more "risk balanced" and to add enhancement such as early release or incentive rewards. Warranties, in combination with performance specifications, could provide more flexibility for contractors to be innovative within the rapid renewal process. The issue is the costs and the risks associated with this strategy.

Objectives

- Improve the effectiveness of warranties and guarantees in rapid renewal projects.
- Develop product warranties and guarantee language that better address inherited condition of the facility, design responsibilities, contractor flexibility in selecting products and equipment procedures, in-service traffic and environmental issues, and unforeseen factors.
- Quantify risk between DOT and contractors and between contractors and subcontractors through these warranties and guarantees and identify strategies to equalize and minimize the risk.
- Reward contractors for providing higher quality products within the warranty framework.

Scope

This project will include a literature review, development of ways to minimize risk associated with warranties, and development of strategies that will reward higher quality by the contractor. It will also include experimental projects and their evaluation.

Tasks

1. Document the current status of warranties and guarantees in the United States. Include the products that are being warranted, length of warranties, noncompliance to warranty terms, repair requirements, mediation and referee terms, etc. Also identify warranty nullification clauses associated with traffic, extreme events, non-authorized repairs, etc. Distinguish between a warranty and a guarantee in the process.
2. Identify current state of the practice in determining the pre-existing condition of the facility to which the warranty or guarantee applies. Identify the flexibility given to the contractor for selecting materials or providing design input.

3. Identify the potential risk associated with the various types of warranties and guarantees, using the risk manual developed in Project 1-4.5. Risk analysis should include transfer between the DOT and the contractor and transfer between the contractor and subcontractors or suppliers. Determine the risk impact on the design community for warranting their designs. Determine the interrelationship among design, material and construction specifications, material compliance, and workmanship as they relate to the risk transfer.
4. Determine the long-range viability of underwriting warranties with bonds, insurance, guarantees, and other mechanisms. Identify ways the risk can be minimized by incorporating new techniques. These techniques could include the following: incentives for exceptional performance, cash payments during the warranty period, early release from the warranty if actual performance exceeds requirements, elimination of the warranty if initial construction exceeds some predetermined threshold, and others as determined by the research team.
5. Determine the actual or potential value received from performance warranties. Include potential value that could be received from the introduction of new technology, from reduced DOT inspection, and from improved quality.
6. Develop a handbook that captures the above options and allows the use to apply new concepts to warranties and guarantees. Develop guidelines on how to quantify risk of warranties and guarantees on the DOT and contracting industry, using these techniques. Develop outreach documentation.
7. Conduct national and regional outreach efforts to present the information from Tasks 1–6 and to receive feedback from DOTs and the construction industry. Incorporate feedback into report.
8. Organize and conduct experimental projects with lead states applying relatively similar contracting strategies to enhance the evaluation process.
9. Prepare final report.

Coordination with Other Projects

- 1-4.1—Performance Specifications
- 1-4.2—Alternate Contracting Strategies for Rapid Renewal
- 1-4.5—Risk Manual for Rapid Renewal Contracts

Products, Benefits, and Implementation

Products

- Warranties and guarantees manual of proposed practice for rapid renewal projects
- Guidelines on ways to minimize risk of warranties and guarantees on DOTs and construction industry
- Outreach documentation

Benefits

There are mixed expectations of warranties and different reasons for using them. This work should help DOTs and the industry evaluate the effectiveness of warranties. Should DOTs elect to use them to improve rapid renewal projects, the risks will be better identified.

Implementation

This project includes a full experimental evaluation of warranties. The final language should be incorporated into the performance language manual.

Research Period and Funding Requirement

Total: 4 years, $1,500,000

Tactic:
Facilitate innovative and equitable contracting environment

Barriers
Unbalanced risk allocation between owners and contractors

Project 1-4.5. Risk Manual for Rapid Renewal Contracts

Funding: $1,000,000 Duration: 3 years Priority: Medium

This project addresses the general lack of understanding of risk and risk transfer decisions associated with alternate contracting approaches. Fulfilling the objectives of rapid renewal will require the use of innovative contracting processes and a departure from business as usual. Many of these innovative techniques involve shifts in the burden of risk from the state to the contractor. This project will develop a risk assessment manual for DOTs that will illustrate methods that could be used to determine issues such as the nature of risk, risk transfer, risk management, and risk mitigation from a contractual and life cycle point of view. Also this project will determine the economic consequence of the risk transfer on the various parties involved.

Different contractual procedures—such as design-build-operate-maintain-transfer (D-B-O-M-T), build-operate-transfer, warranties, design-bid-build, and design-build—generate different levels of risk for all parties involved. However, much of the risk assessment on these projects is subjective and no systematic/standardized procedure is available to determine the amount of risk involved for different parties, the transfer of risk from DOT to the contractor, etc. Objective guidance on the level and management of risk is needed to ensure industry acceptance of the concept and to assist states and industry in assessing the level of risk associated with various contracting strategies.

Therefore, a risk manual is required that is acceptable to all parties involved and could be used to determine risk, risk sharing, and risk management/mitigation strategies. Such a manual would document (1) different techniques for risk assessment under different contractual procedures, (2) risk sharing between DOTs and contractors, (3) different risk management/mitigation strategies available under various contractual procedures, including performance specifications and warranties, (4) life-cycle risk factors, and (5) strategies for risk abatement and cost-effective management and maintenance of infrastructure.

Objectives

- Quantify risk-transfer and risk-sharing decisions.
- Better understand the relationship between risk, bonding, insurance, warranties, etc., their risk to the construction industry, and their long-term impact on the DOTs.
- Establish procedures for identifying and quantifying risks.
- Develop creative risk mitigation solutions for insurance, bonding, and similar measures.
- Develop methods for determining the financial, safety, and legal risk and risk assignment.
- Develop a clear methodology for assigning risk under alternate contracting techniques.
- Determine the probability of success in underwriting long-term performance risk.

- Develop methods to determine the economic consequence of risk transfer on the various parties involved.

Scope

This project will include a literature review, survey, case studies, interviews, and workshops to better understand the financial, safety, and legal risk associated with various contracting strategies employed on rapid renewal projects.

Tasks

1. Conduct a literature review to establish the state-of-the-art, including what other industries are doing to determine risk and risk mitigation, as well as analytical methods to objectively estimate risk.
2. Distribute a survey to establish the state of practice and to establish the relationship between risk, bonding, insurance, warranties, etc., their risk to the construction industry, and their long-term impact on DOTs. Develop a summary of current state laws that regulate bidding practices and identify barriers to alternate contracting practices.
3. Conduct case studies to understand the risk sharing between the DOTs and the contractors and also to determine the economic consequence of risk transfer on the various parties involved. Case studies should be linked to the use of warranties and performance specifications.
4. Host regional workshops to determine the strategies used for risk management and risk abatement and to control the life-cycle risk factors.
5. Develop a risk manual that includes (1) a reasoned approach to determine the financial, safety, and legal risks, (2) risk sharing and creative risk management/mitigation solutions associated with various contracting strategies employed on rapid renewal projects, and (3) determination of the economic consequence of risk transfer and the probable success in underwriting long-term performance risk.
6. Develop training materials and workshops to promote the risk manual.

Coordination with Other Projects

- 1-4.1—Performance Specifications
- 1-4.2—Alternate Contracting Strategies for Rapid Renewal
- 1-4.4—Development and Evaluation of Performance-based Warranties
- The results of this research could be used by other research projects in establishing the degree of risk and possible risk mitigation strategies; therefore this project should be initiated early in the funding cycle.

Products, Benefits, and Implementation

Products

- Risk and risk transfer manual for the highway construction industry
- Examination of risk transfer between DOTs and industry through case studies
- Outreach documentation
- Training manual

Benefits

This project will provide common language and methodology to calculate risk and to rank innovative strategies, specifications, and warranties. DOTs and contractors will be able to determine and estimate risk as they develop plans and estimates.

Implementation

The manual will help organize a specific methodology for the highway industry. Much like a life-cycle cost methodology, it could then be used to help quantify various scenarios that heretofore were subjective. Once the methodology is accepted, it can then be used in different scenarios—warranties, design-build, etc. Various methodologies should be developed as quasi-standards. It is not clear which AASHTO organization should be the lead, though construction would seem a prime candidate.

Research Period and Funding Requirement

Total: 3 years, $1,000,000

Tactic:
Facilitate innovative and equitable contracting environment

Barriers
- Unbalanced risk allocation between owners and contractors
- Lack of rapid decision-making can constrain project activities

Project 1-4.6. Innovative Project Management Strategies for Large, Complex Projects

Funding: $750,000 Duration: 2 years Priority: High

This project will address the managerial and workforce challenges associated with rapid renewal projects. Large projects involve complex logistical requirements, contractual procedures, multiple contracts, and regulatory requirements that need careful planning and execution for design and construction. DOTs and contractors will have to establish new working relationships for these types of projects. For example, the roles of the DOT in design-build projects, warranty, material and shop drawing approvals, etc., are very much different. Likewise, the contractor decision-making mechanisms must be matched to the DOT structure to promote cooperation and efficiency.

A systematic research effort is required to study the unique requirements of a mega-project. The research should describe (1) how contractors and DOTs work on large projects, (2) what organizational structures are more effective, (3) what decision-making mechanisms work best between the agency and contractor, and (4) methods to streamline and minimize the impact of state and federal requirements on the outcome of these projects. Based on this study, DOTs should be able to develop innovative and effective project management strategies that will accelerate sound decision-making during rapid renewal projects, including managing multiple mega-projects at one time.

Objectives

- Better manage administrative functions between DOT and contractor as impacted by rapid renewal projects.
- Accelerate decision-making process required for rapid renewal projects.

Scope

This research project will include literature reviews, case studies, interviews, and workshops to assess the unique requirements of mega-projects and develop effective project management strategies for mega-projects to facilitate rapid decision-making. A variety of contracting options will be considered.

Tasks

1. Conduct a literature review of public and private management strategies for large complex projects to establish the state of the art. Literature review should include a thorough analysis of international as well as U.S. arrangements.
2. Conduct a survey to establish the state of practice.

3. Conduct case studies and interviews to understand the unique requirements of a rapid renewal project and the risk sharing between the DOTs and the contractors.
4. Conduct regional workshops to determine the strategies used by project owners and contractors that facilitate rapid decision-making, risk management, and risk abatement.
5. Evaluate current management of mega-projects and develop creative and integrated decision-making mechanisms for the future.
6. Based on the first four tasks, evaluate the current situation for making very rapid decisions for high-intensity, short-duration activities.
7. Develop decision-making mechanisms to address issues such as safety to the public and workers, changed conditions, unforeseen delays, weather changes, financial risk, safety, legal risk, risk sharing, environmental, and risk management/mitigation associated with large, complex rapid renewal projects.
8. Conduct regional and national workshops to obtain feedback and input and use this to develop revised and improved scenarios.
9. Develop training material and workshops to promote the decision aid.
10. Develop guide contract language that promotes the most promising concepts.

Coordination with Other Projects

- 1-4.2—Alternate Contracting Strategies for Rapid Renewal
- 1-4.5—Risk Manual for Rapid Renewal Contracts

Products, Benefits, and Implementation

Products

- Guide (decision aid) to innovative project management for a variety of renewal processes, especially large-scale projects
- Workshops and training packages to support adoption of these management strategies by agencies and industry

Benefits

The products of this research will facilitate rapid decision-making. Agencies will have several innovative project management strategies to select from, depending on the type and extent of the renewal process.

Implementation

This project will facilitate the implementation of mega-projects for rapid renewal and the efficient delivery of the project. The implementation may establish new partnering agreements and more than likely will be a negotiating point between DOTs and contractors as a precursor for awarding contracts, especially in design-build scenarios. While the research is aimed at large rapid renewal projects, it is expected that many of the recommendations will be included in smaller projects as well.

Research Period and Funding Requirement

Total: 2 years, $750,000

Tactic 5. Plan Improvements to Mitigate Disruption

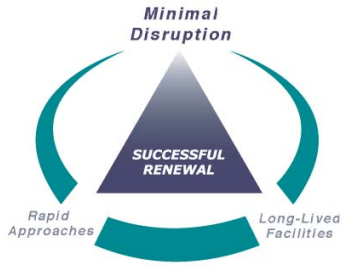
There are more ways to minimize the impact of renewal if the analysis starts early in the project development process. This means not only selecting the renewal items of work that need to be done but selecting the best way to assemble and procure the work. Agencies need to strategically define, analyze, package, and renew highway corridors and projects so as to minimize current and future traffic disruptions and maximize overall initial and life-cycle costs. Financial solutions are urgently needed to provide the ability to address very high cost renewal projects in a sustainable manner.

The only way to simultaneously optimize the F-SHRP objectives is to plan and develop improvements from both a corridor and network perspective, and then specifically select renewal strategies that are appropriate for the subject infrastructure. This tactic outlines specific research needed to fully capture this new concept. It investigates current practices both in the United States and overseas, examines several innovative strategies such as “mix of fixes” and “route management.” It also addresses the impact of corridor concepts on traffic flow, public relations, contractor capabilities, work selection, long-term and short-term funding requirements, downstream implications, and overall corridor performance (see Figure 8).

Figure 8. Nighttime Bridge Construction (Source: Colorado DOT)

On projects that significantly impact the level of service and safety of the traveling public during repair or reconstruction, the tradition of dividing contract work by type—bridge, pavement, safety, signing, etc.—is more and more coming under scrutiny. Additionally, the public has voiced concern about the constant sight of orange barrels on major routes, which in certain corridors may last up to 10 years. This is a direct result of a sequential approach to project selection. Instead of planning and executing construction projects as a function of funding, contractor capabilities (scope of work, bonding, etc), and completion of discrete elements of work, agencies will take a broader view. They will define and analyze highway corridors for renewal so as to minimize traffic impositions, balance network costs, address human and environmental considerations, and still maintain a high level of customer service.

The high cost of large renewal projects prevents agencies from packaging projects to minimize the impact to the traveling public and life-cycle costs. There are four financing objectives in this tactic: (1) to increase investment, (2) to accelerate projects, (3) to improve the utility of existing financing opportunities, and (4) to lay the groundwork for long-term programmatic changes. Investment tools and cash flow improvement tools have been developed that are now available to states. While these tools are proving very beneficial, it is widely recognized that a combination of public and private dollars along with many more creative financing mechanisms will be needed to meet future needs. The goal is to provide agencies with new tools to finance very high cost projects without jeopardizing the regular program.



Tactic:
Plan improvements to mitigate disruption

Barrier:
Planning not corridor based

Project 1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process

Funding: $1,250,000 Duration: 3 years Priority: High

Over the last several years, the transportation planning community has begun using the concept of corridor improvements to describe the current status and future needs for transportation improvements. However, the planner's transportation corridor analysis may not consider the entirety of infrastructure needs within that corridor. The analysis may not consider the impact that significantly different construction strategies may have on the overall budget, disruption to traveling public, disruption to commerce, and impacts on the local community during the actual construction operations.

Many transportation corridors are increasingly congested, limiting construction during traditional work times. DOTs are now recognizing the need to examine various construction alternatives within that corridor to determine the potential disruption these alternatives may have over time. In addition, many DOTs are seeing the need to examine regional networks with multiple corridors in order to examine the impact of constructing multiple corridors concurrently. Without examination of the constructability options early in the planning process, the impact on the traveling public and the local communities may increase dramatically.

Future corridor improvement analyses should address several important constructability factors:

- What is the optimal selection of renewal activities—roadway, bridge, soils, drainage, safety improvements, signing, and other upgrades—that should be packaged into discreet construction contracts?
- How should DOTs address those components within the corridor that have significantly different remaining service lives?
- How should construction limits be set to minimize disruption to the traveling public and businesses while considering DOTs staffing limitations?
- What is the impact on the regional network when multiple corridors are being considered for reconstruction?
- What is the best way to calculate the benefits gained from various strategies as they relate to work accomplished, budget flow, and traffic mitigation?

One major consideration in packaging of construction work is the impact to the private sector highway construction industry. In most states, the industry consists of small to medium-sized companies that have limitations as to the amount and type of work they are qualified to perform. Experience to date shows that establishing longer project limits to accommodate traffic flow (10–15 miles, for example, rather than 4–6

miles) and to increase the amount of work done within the construction limits to minimize future disruptions might negatively impact the existing industry structure.

Objectives

- Develop and implement a more structured definition of "corridor" as it relates to the selection of construction improvements and disruptions to the traveling public.
- Determine the optimal organization of corridor improvements into biddable construction packages, accounting for budget, traffic management, constructability, safety, minimal disruption to the traveling public, industry capabilities, and rapid renewal strategies.
- Develop a life-cycle cost protocol for the overall impact of construction corridor improvements, using user-cost inputs and various cost scenarios, to determine tradeoffs and impact on downstream disruptions.

Scope

This work will examine how DOTs currently establish project limits and identify ways to establish new project limits. The researcher will then recommend a new corridor planning process that will (1) integrate constructability alternatives and construction packaging strategies early in the planning process, (2) address the impact of multiple corridor and project work on regional network flow, (3) establish the limits or work to minimize disruption during construction, (4) minimize downstream construction requirements that will cause disruption, and (5) improve timelines and optimize budget considerations from both an initial and life-cycle analysis. Software development is not considered fundamental to the research.

Tasks

Phase I. Current and proposed rapid renewal corridor identification

1. Examine current practice of examining transportation corridors as they relate to construction alternatives. Examine the current processes to determine when and how DOTs establish project limits, including the type and extent of work limits, work items, and traffic management, as well as contractor expertise and business structure.
2. Investigate ways to improve the project development process concurrently to ensure early integration of the planning, design, environmental review, work zone traffic control, and construction related processes.
3. Investigate how significantly different construction strategies that minimize disruption can be properly integrated into the planning process:
   - Examine total or partial shutdown of corridors with high-intensity work effort.
   - Examine short-duration closures—six hours or less—over longer periods of time.
   - Examine the impact of packaging non-traffic-impacting work into discrete packages separate from traffic-impacting work.
4. Analyze total traffic impact on corridors as a result of various strategies for performing renewal.
5. Identify innovative approaches to conducting constructability reviews and establishing project limits, based on the results from Tasks 1 and 2.
6. Identify the impact on the construction industry as a result of possible longer project limits and the inclusion of more work within the traditional construction projects. Recommend ways that this impact may be adjudicated.
7. Develop a detailed recommended practice and methodologies for how these concepts can be addressed in the future.

Phase II. Corridor analysis tools

8. Examine various software programs that in whole or in part address the recommended practices developed under Phase I. The examination should include analysis of the overall life-cycle costs for multiple work item corridors (roadways, bridges, etc.). It should also examine the software's

ability to analyze multiple strategies within a corridor that both addresses disruption as it relates to the life-cycle cost analysis through user cost analyses.

9. Identify the strengths and weaknesses of each package. Determine the most cost-effective way to either expand or develop new software. Prepare an estimate of time and funding required to adapt the most promising software.
10. Develop new software, if so directed.

Phase III. Outreach and training efforts

11. Prepare outreach and communications documents that capture Phase I. Present at four regional workshops. The first two workshops should be timed after Task 1 and as a part of the investigation process. The last two workshops should present the near final product from Phase I. Audiences should include both DOTs and contractor representatives to ensure balanced feedback.
12. Convert workshop structure into a training program and training manual.

Coordination with Other Projects

- 1-1.2—Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction
- 1-1.4—Rapid Rehabilitation Strategies of Specialty Structures
- 1-1.5—Micropiles for Renewal of Bridge Foundations
- 1-1.7—Facilitating the Use of Recycled Aggregates
- 1-1.8—Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments
- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-2.3—Modular Pavement Technology
- 1-5.2—Integrating the “Mix of Fixes” Strategy into Corridor Development

Products, Benefits, and Implementation

Products

- Recommended practices and methodologies for establishing and planning corridor improvements with construction alternatives included
- Life-cycle cost analysis manual for optimizing corridor improvements
- Corridor establishment and management training program

Benefit

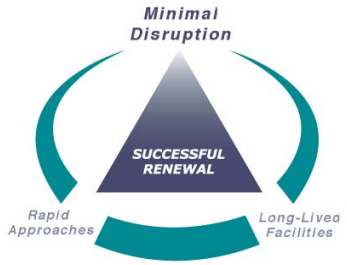
The major benefit to DOTs is that they will be able to determine a more optimal packaging of construction projects in order to minimize disruption to the traveling public.

Implementation

The first round of implementation is included in the research statement. Full DOT implementation will require a modification to the planning process, the development of an internal definition of corridor management, and the involvement of the construction discipline much earlier in the transportation planning process.

Research Period and Funding Requirement

Phase I: $500,000
Phase II: $250,000 (This excludes Task 9, software development. If approved, Task 9 could cost between $500,000 and $1,500,000, depending on the findings.)
Phase III: $500,000
Total: 3 years, $1,250,000



Tactic:
Plan improvements to mitigate disruption

Barrier:
Traditional project-based objectives

Project 1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development

Funding: $1,500,000 Duration: 3 years Priority: High

Using the corridor concept, a DOT will need to determine the most optimal renewal strategies for specific bridges and pavements within a given corridor. Within that corridor, it is very possible that sections of pavement and select bridges are not ready for full reconstruction based on functionality or remaining service life. Should the DOT consider doing as much work as possible during the corridor project and assume that it will minimize downstream impacts on the traveling public? To what service life should reconstructed facilities be built—the longest technologically feasible? Should all work elements deemed ready for full reconstruction be built to the highest long-life standards (with assumed higher initial costs)? Long-life pavement and bridge technology, while needed in the renewal toolbox, may not be prudent, feasible, or cost effective when looking at budget needs throughout the state. But just how effective are preservation treatments? When is the right time? And can they really be effective in high-traffic roadways?

The Michigan DOT has pioneered the concept of "mix of fixes" that identifies a family of renewal solutions for pavements and bridges that could be incorporated into capital improvement projects. These solutions vary in cost and length of expected service life. Relative costs could vary from a value of 1.0 to 25.0 or higher per square unit of work. For pavements, service life could vary from 3–5 years for surface treatments and thin overlays, to 50 years or more for total reconstruction. Generally, the longer the service life desired (synonymous with minimizing downstream project traffic disruptions) the higher the initial cost will be. However, while the Michigan DOT recognizes the need for the "mix of fixes" they also recognize that certain preservation strategies are limited in their effectiveness.

Accelerating renewal and minimizing disruption does not inherently mean that all infrastructure elements within a corridor or project limits are candidates for total reconstruction, replacement, and longest life solutions. How then should options within the "mix of fixes" toolbox be applied in a cost-effective way that minimizes both current and downstream disruption?

Objectives

- Integrate preservation and rehabilitation methodologies into the overall corridor planning process, as a means to minimize public disruption, optimize budgets, maintain reasonable levels of service, and delay, postpone, or replace major reconstruction alternatives.
- Organize preservation and rehabilitation strategies, their life expectancy, risk, and applicability to various levels of loading and environmental conditions for typical corridor management scenarios.

- Identify optimal timing and application of preservation and rehabilitation technologies to maintain or improve levels of service in a corridor.
- Develop a rational way to select long-life, full reconstruction options versus shorter, quicker preservation and repair options as they impact costs and traffic disruptions.

Scope

This project will identify current and next generation "mix of fixes" options and provide assessment tools to help choose the optimal combination of solutions along a corridor. The project will also identify potential technological advancements that, if developed, could improve both the speed and volume of maintenance and rehabilitation work, which could minimize disruptions associated with total reconstruction.

Tasks

1. Identify the "mix of fixes" strategies that are currently available to DOTs, including representative costs, length of service life, and downstream impact of future renewal efforts. Strategies should include various design lives for key work elements (up to 60 years for various pavement scenarios and up to 100 years for various bridge scenarios) and should include those fixes that currently are identified as heavy maintenance items in pavement (i.e., chip seals, surface treatments, microsurfacing, undersealing, grooving, grinding, thin overlays) and in bridges (i.e., patching, corrosion repair, deck overlay and replacement, approach slab repairs).
2. Evaluate how this "mix of fixes" can be integrated into renewal strategies so as to optimize the funds available, minimize impact on traffic, and still keep the facility at desired service levels. Determine the overall reliability of the assumptions made on the life of each of the renewal strategies and the impact that shortened life may have on downstream traffic disruptions. Determine the number of back-to-back short-life strategies that could be applied to bridges and pavements.
3. Determine the optimal time for selecting the proper fix, including advanced methodologies for determining current condition and remaining life of the structure or pavement.
4. Prepare case studies that show the impact of integrating "mix of fixes" strategies into the corridor and broader network demands for funds.
5. Conduct four regional workshops to present findings and recommendations.
6. Prepare guidelines that fully capture the rational of selecting certain fixes, including new strategies for determining proper timing for the fix.
7. Prepare training, communication, and outreach documents.

Coordination with Other Projects

- 1-5.1—Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process
- 1-5.3—Strategic Approaches for Financing Large Renewal Projects
- 1-10.1—Preservation Approaches for High Traffic Volume Roadways

Products, Benefits, and Implementation

Products

- Report on current and potential repair strategies, their life expectancy, and the impact they will have on minimizing disruption while maintaining the infrastructure
- Guidelines for selecting and programming fixes within a corridor
- Guidelines for determining proper timing
- Communications and outreach packages
- Training program

Benefits

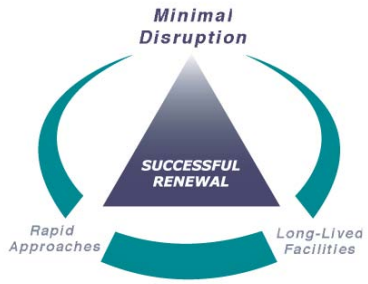
This work will identify strategies and technologies that could be applied into corridor planning so as to minimize disruption without having to resort to major reconstruction. This would help DOTs to assess shorter duration, more rapid repair strategies, and their impact on budgets as well as their potential to minimize disruption.

Implementation

Each DOT will need to integrate this work into both corridor construction planning and bridge and pavement management programs. The work may show that various technologies can lead to considerable payoff by reducing initial and life-cycle costs and minimizing disruption.

Research Period and Funding Requirement

Task 1–4: $750,000
Task 5: $250,000
Tasks 6–7: $500,000
Total: 3 years, $1,500,000



Tactic:
Plan improvements to mitigate disruption

Barrier:
Financing constraints

Project 1-5.3. Strategic Approaches for Financing Large Renewal Projects

Funding: $1,000,000 Duration: 3 years Priority: High

One of the very first criteria for determining the scope of a renewal project is the available funding needed to build the project, both conventionally and then in an expedited fashion. Over the last decade, several DOTs have bundled work into relatively high cost packages in order to complete work expeditiously while minimizing disruptions. These mega-projects, while generally credited with getting the job done quickly, may have had significant impacts on the entire state highway program. Without new money and/or new tools other than borrowing against the future to leverage existing resources, much of the research and process improvement to deal with renewal with minimum disruption may be unrealized.

DOTs expect increasing pressure to organize and build mega-projects. Project 1-5.1 addresses the corridor analysis strategies and the best way to assemble projects. While consolidation of projects may minimize disruption, additional funds will also be required to expeditiously complete the work. This project attempts to develop creative financing strategies for this expected increase in large renewal projects.

Objectives

- Better understand the impact of mega-projects on the overall highway capital budget and in order to meet rapid renewal requirements and expectations.
- Organize and study financing strategies for both planned and completed “mega” renewal projects.
- Identify ways to fund and finance large or “mega” renewal projects while addressing their impact on other DOT programs.
- Identify innovative ways that finance and revenue streams could be linked closer to those that are specifically benefiting from the mega-project.
- Examine several representative DOT mega-projects to apply with these new strategies.

Scope

This work will analyze the financing of mega-projects and their impacts on rapid renewal requirements, including current and downstream funding requirements. The work will use national and state needs study data. The work will identify creative ways to fund these efforts. While each project is unique in its structure and value, case studies may provide insight into how these new techniques could provide benefits.

Tasks

1. Identify and evaluate mega-projects completed over the last 10 years or so, looking at projected and actual impacts of the projects. The analysis should look at the impact these mega-projects have had on other DOT programs.
2. Using both FHWA and DOT planning documents, identify the number, dollar volume, and types of mega-projects that are currently identified. Estimate the percentage that are currently or potentially will be classified as rapid renewal projects. Compare these projects to the overall revenue stream and total projected needs.
3. From this list, identify those "mega" renewal projects that potentially may include non-conventional financing strategies. These non-conventional strategies could include unique partnering arrangements, tolls, targeting financing, land development rights, etc. The strategies should include potential revenue generation from those user groups that specifically gain from the mega-project.
4. Conduct two workshops to present information to DOTs and to solicit feedback, support, and prioritization of concepts.
5. From the results of the first two workshops, examine more fully those revenue concepts prioritized for further examination. Determine the pros and cons from expanding the use of certain techniques. Examine the impacts these techniques will have on both federal and state legislation requirements. Examine the current historical response to any of these strategies from legislators, the financing and bonding industries, the construction industry, the trucking and motoring public, and the general public.
6. From those projects identified in Task 1, run project simulations using these techniques to determine funds generated, associated risks, etc. Solicit feedback from specific DOTs.
7. Prepare an initial set of recommendations, conduct one national workshop and four regional workshops to explain, and gather feedback on the overall recommendations.
8. Prepare final report and recommendations.
9. Prepare outreach documents for managers, legislatures, and the general public.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-2.3—Modular Pavement Technology
- 1-5.1—Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process
- 1-5.2—Integrating the "Mix of Fixes" Strategy into Corridor Development
- 1-10.1—Preservation Approaches for High Traffic Volume Roadways

Products, Benefits, and Implementation

Products

- Guidelines
- Policy statements
- Financing strategies

Products should be stratified—a set for managers, legislatures, financial managers, and the general public.

Benefits

Each DOT will be able to identify and present the impact that renewal will have on its future revenue needs. DOTs will have a menu of options to fund mega-projects.

Implementation

This project will assist those states willing to proceed with adding new revenue sources or in using new strategies to fund specific mega-projects. Fund generation techniques for additional mega-projects will be demonstrated. The findings will also be presented to as many state and federal stakeholders as possible, including legislators.

Research Period and Funding Requirement

Tasks 1, 2, 3, 5, 8, and 9: $600,000
Tasks 4 and 7: $400,000
Total: 3 years, $1,000,000

Tactic 6. Improve Customer Relationships

Involving customers—i.e., those who use the facility and who live near it—in the decision-making process is key to improving customer relations. FHWA's recent customer satisfaction survey showed that the public is much more willing to tolerate high-impact, short-duration roadway closures than previously thought. Clearly cooperating with the public may make more options available to the agency.

Pressure on the contractor to finish a project quickly in order to minimize traffic delays sometimes leads to round-the-clock and year-round construction operations. This may lead to increased noise, dust and odor problems, light pollution, and traffic disruption for the public living near the project or plant. New ways of addressing these prior to construction will allow for more work options for the agencies and the contractor, while improving relationships with the local community. Context-sensitive construction tactics directly address those most impacted by the renewal work and look for creative solutions and partnerships (see Figure 9).

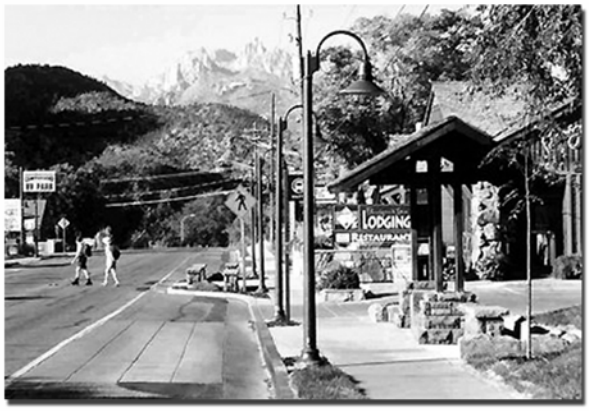
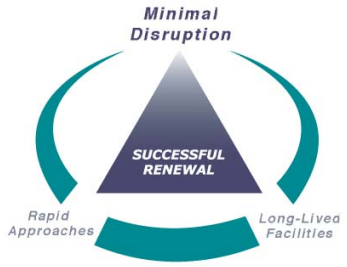


Figure 9. Context-sensitive Solutions (Source: Utah DOT)

Renewal project planners must also accommodate the needs of utilities and railroads that share roadway ROWs and have a huge stake in renewal activities. Utility and railroad conflicts can frustrate efforts to keep renewal projects on schedule and budget. Utilities and railroads, many of which are unfamiliar with the highway design and building industry, have a variety of needs and many different ways of conducting business. These entities cannot simply be ordered to quickly make way for a renewal project because they are providing vital services to their clientele, and planning is needed to make moves. New streamlined permitting and relocating processes will allow for timely and efficient progression of renewal projects for agencies, utilities, and railroads.



Tactic: Improve customer relationships	➡	**Barrier:** Difficult to mitigate impact to users and public services

Project 1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection

Funding: $2,500,000 Duration: 3 years Priority: Medium

Successful renewal projects engage the public and other agencies early and communicate plans continuously throughout. The renewal agency must embrace public input to the design, which affects the environmental and human impacts of the project during and after renewal. Resource agencies and affected interest groups should be contacted early and provided the opportunity for two-way communication.

Objective

- Improve agency and public interaction and collaboration before and during renewal operations.

Scope

The scope of this project is to organize procedures in which project owners address the needs of various public groups, including resource agencies and special interest groups. The procedures will be field-tested and refined in actual practice, and the results will be compiled in a guidelines manual.

Much of the communication process involves visualization. Ideally, interactive visualization tools will be incorporated into the process. This project will identify advances in engineering animation technologies that would improve the ability to communicate dimensions, impacts on property, and project phasing. "Virtual reality," laser scanning, and advanced CAD technology needs will be identified. The project will seek partnering arrangements with the private sector to develop these tools. A key component of the project will be the creation of a partnering process that has potential for successful product development.

Tasks

Phase I

1. Review the literature on best practices in public involvement for road construction projects, including the May-June 2002 issue of *TR News*.
2. Contact selected agencies engaged in renewal projects. Document their public involvement attitudes, processes, and technologies and compare to generally accepted best practices found in the literature. Determine whether the agencies are following best practices; if not, identify the reasons. Also document lawsuits, complaints, and other evidence relating to the success of the public involvement program.
3. For the same agencies, interview some of the stakeholders, such as representatives of the general public, resource agencies, environmental groups, and neighborhood groups. Determine whether

they feel the project was adequately described and whether their interests were adequately represented.

4. Prepare a report that describes the attitudes, processes, and technologies associated with public satisfaction and attitudes, processes, and technologies associated with public dissatisfaction. Relate these findings to the best practices reported in the literature. Identify impediments to applying generally accepted best practices and recommend solutions.
5. Recognizing that every good practice does not need to be applied everywhere, develop measures to monitor public attitudes as a project develops so that corrective actions may be introduced if necessary.
6. Prepare a guidelines document for establishing successful agency and public relationships for highway renewal projects.
7. Test the guidelines. Identify major renewal projects still in the planning or pre-construction stages. Work with agencies to implement the practices outlined in the guidelines document and monitor the results.
8. Prepare a final guidelines document covering recommended attitudes, processes, and technologies for an effective public involvement program.

Phase II

9. Based on the information collected in Phase I, identify visualization and IT that benefit the public involvement process and the extent to which they were used in the test cases. Many visualization tools are available, including photo simulation, cutaway CAD visualizations, animated sequencing, 3D animation, merging of GIS data and animated images, map overlays, and electronic scoring technology for public meetings.
10. Identify impediments to use of visualization tools.
11. Recommend a threshold level of complexity that warrants using visualization tools.
12. Identify advances in visualization and IT or their application that are essential to support public involvement in rapid renewal projects.
13. Contact system developers and identify what is necessary for the private sector to offer these improvements in the marketplace—e.g., standards, market size estimate, awareness of need, and specifications.
14. Develop a model for working with the private sector to produce the products needed. This may be a partnership model, a procurement model, or some other approach.
15. Determine the public expenditure necessary to catalyze industry to make the desired products available within five years.
16. In conjunction with the project panel, make a go/no go decision.
17. If the decision is “go,” implement the model to produce the next generation of visual tools that will assist the public in understanding complex renewal projects and the impact various construction scenarios will have on the public.

Coordination with Other Projects

- 1-6.2—New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects

Products, Benefits, and Implementation

Products

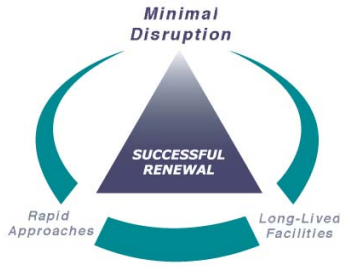
- Guidelines manual for establishing successful public and agency relationships
- Public-private partnership program for delivering the visual tools needed to communicate complex projects to the public
- New visualization tools

Benefits and Implementation

The benefit of this project is that public support for a project will be more readily achieved if a thorough public involvement program is developed early in the project. Visualizing the completed project will aid the public in forming opinions and in contributing meaningful suggestions for improvement. Implementation will be carried out by agencies using the manual and the visualization tools.

Research Period and Funding Requirements

Phase I: 1 year, $500,000
Phase II: 2 years, $2,000,000
Total: 3 years, $2,500,000



Tactic:
Improve customer relationships

Barrier:
Difficult to mitigate impact to users and public services

Project 1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects

Funding: $1,500,000 Duration: 4 years Priority: Medium

Both business activity and response to emergencies are impacted by highway renewal work.

For businesses, this project involves capturing information from design and construction phasing plans and presenting it in a block-by-block or street-by-street format. Project planners should be able to show a business what will happen in its immediate environment over time. The impact on businesses includes access, shipments, and parking for fixed-location businesses and other impacts on delivery businesses. A bridge or ramp closure, parking ban, or detour can have a dramatic impact on businesses in a particular block. This impact may not last the length of the renewal project and may vary in severity.

Similarly, any of these changes can increase the response time of emergency services. The construction work introduces the potential for accidents, and revised traffic patterns increase the potential for crashes. The volume of emergency response activity may increase during renewal work, and the routes to emergency sites may be circuitous. Emergency responders must be aware of all street and bridge closings and areas of increased congestion at each project phase. Continuously updated maps should be available to first responders so they can revise their routes in response to changing access conditions.

Objective

- Provide businesses affected by renewal operations the information they need to operate and ensure the continuity of emergency response services during renewal projects.

Scope

The project should consider the inclusion of alternative routes in the planning process plus signing and communication during the design and construction phases. The visualization tools developed in Project 1-6.1 may be appropriate here to communicate impacts at different phases of construction. The researcher would survey businesses impacted by recent renewal efforts and determine what worked and what didn't in terms of minimizing impact on the businesses. A process would be designed to capture the impacts block by block as a renewal project progresses so businesses can plan. It is assumed that applications of existing technologies can provide the tools to reach the objective. If hardware or software is determined to be necessary, it should be developed through a public-private process.

This project would also develop guidelines for working with first responders before, during, and after a renewal project and develop a framework for producing continuously up-to-date maps of the area affected

by renewal. Commercial off-the-shelf GIS software has functions to modify road links, change impedances, calculate x-minute travel time boundaries, and calculate minimum paths. Any analyst familiar with GIS software could develop the application but would have to think the process through from scratch. The scope of this project would be to describe the data needs and step-by-step process to create a first responder assistance product. An analyst for the metropolitan planning organization (MPO) or DOT district office would update network links for each construction phase as bridges are demolished and rebuilt, ramps are opened and closed, etc. First responders would be informed so they could adjust responses to segments of their response area affected by a new construction phase.

As an enhanced service, minimum-time travel paths could be calculated as the pattern of closures changes, and notes about access points to construction zones could be added. This could be presented in an Internet format so any first-responder could analyze response alternatives directly.

Tasks

Part A. Businesses

1. Identify recent renewal projects and identify businesses affected by each project. Include businesses whose access was directly affected by the renewal project and delivery businesses that were indirectly affected.
2. Develop a survey or interview instrument to determine how well informed the businesses were on the potential impacts and possible mitigation actions they could take. Determine what they would have liked to know about the renewal project but didn't.
3. Evaluate the nature of the impacts a renewal project has on businesses and recommend analysis and communication techniques aimed at mitigating these impacts.
4. Describe the methods used to present micro-area impacts on business access over the duration of the renewal project.
5. Assess the adequacy of visualization and IT tools to communicate the impacts associated with a renewal project.
6. If necessary, recommend improvements to visualization or IT tools that would improve the ability to communicate renewal impacts to businesses.
7. Develop a guidelines manual specifically targeted at informing businesses about the impacts of renewal and strategies to mitigate those impacts.

Part B. First responders

8. Identify what information first-responders need from DOTs and when they need it to adjust their routes to changes in the road network.
9. Develop a white paper targeted at DOTs that clearly describes the information needs of first responders.
10. Develop a step-by-step procedure targeted at GIS analysts for customizing commercial off-the-shelf GIS software to create a first responder assistance product. The procedure should at a minimum include obtaining response boundary information, modifying network links or impedances, preparing x-minute response time maps, and calculating minimum paths.
11. Develop a step-by-step procedure to make this customized product available interactively on the Internet.
12. Prepare a manual containing the results of Tasks 8–11.
13. Identify a DOT or MPO that will build a prototype and fund it to do it.
14. Document the time and cost, unexpected problems, new features that should be added, etc. Provide results to first responders and obtain feedback on the usefulness of the information.
15. Modify the manual based on the prototype experience.

Coordination with Other Projects

- 1-6.1—New Guidelines for Improving Public Involvement in Renewal Strategy Selection

Products, Benefits, and Implementation

Products

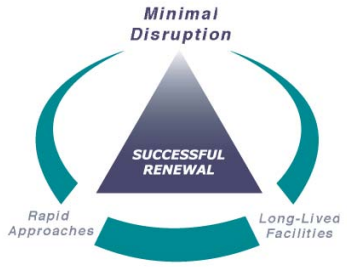
- Method to present site-specific impacts to business owners for each phase of a renewal project
- Guidelines document for working with businesses
- Guidelines to aid DOTs and public road-building agencies in working with first responders
- Framework and step-by-step process for customizing commercial off-the-shelf GIS software to create a first responder assistance product

Benefits and Implementation

- Improved business support for renewal projects due to reduced anxiety about unexpected disruptions curing construction
- More reliable emergency services in the vicinity of the construction zone and over routes impacted by construction

Research Period and Funding Requirement

Part A: 2 years, $750,000
Part B: 2 years, $750,000
Total: 4 years, $1,500,000



Tactic:
Improve customer relationships

Barrier:
Ineffective coordination with utilities and railroads

Project 1-6.3. Utilities-DOT Institutional Mitigation Strategies

Funding: $3,000,000 Duration: 6 years Priority: High

Utilities are the number one cause of construction delays. There are many factors that contribute to this, including lack of information on the existence and location of utilities, not fully considering the complexity of working around and relocating utilities during highway construction, poor coordination and cooperation between project and utility owners, and in some cases lack of responsiveness by the utility owner.

This project will explore how to improve the working relationships and reduce negative impact to both the project and utility owner, and ultimately the public consumer. This project is particularly important because of the consolidation within the utility industry in recent years, making it more difficult to address concerns at the state level when utility providers are regionally and nationally structured.

This is a very complex issue. Utilities are often allowed to share highway rights-of-way by permit with the provision that they will relocate their facility as needed to accommodate highway improvements. Utilities constitute a group of multiple entities that have a variety of needs and many different ways of conducting business, and many are unfamiliar with the highway design and construction industry. These entities cannot simply be ordered to quickly make way for a renewal project because they are providing vital services, and they need time to plan for engineering and development of capital budgets.

Even with good mutual cooperation between the project and utility owner, challenges remain:

- Relocations must be designed so they do not conflict with highway features and other facilities (including other utilities). Increased coordination is required to properly design the relocations. Many opportunities exist to increase efficiency during the design coordination process.
- Funding issues must be resolved. Many utilities are permitted for public rights-of-way at no cost under the conditions that they relocate at no charge at the convenience of the ROW owner. However, on complicated construction projects there is more financial impact to the utility to pre-locate or phase the location of utilities to merge with construction operations.
- During construction, intense coordination with traffic and other renewal activities is required. Many utilities use their own forces or have contracts with certain entities to perform all relocation work. Such arrangements may be difficult on a renewal project where space is at a premium, traffic flows are easily blocked, and the highway authority lets contracts to multiple contractors.

Objectives

- Develop appropriate institutional arrangements to facilitate effective utility management during the entire project development process. This would include model agreements appropriate with national, regional, and local utility providers.
- Investigate and develop innovative partnering techniques whereby utilities and the highway community are working cooperatively. This includes looking at private sector agreements, incentive approaches, and development of utility corridors.
- Assist states in developing pilot projects to incorporate innovative approaches.
- Provide recommendations on specification and national and state level policy changes that would enable innovation and remove barriers inherent in current utility relocation policies.

Scope

This project is intended to facilitate an interactive and creative public policy discussion on how to more effectively address the common public interest in highway renewal with minimal disruption, while mitigating impact to public and private utilities. Innovative and cooperative approaches are sought that contribute to the overarching goal of TRB *Special Report 260*, that of providing outstanding customer service.

This research will be conducted in three phases. Phase I is an initial project to identify strategies that will be pilot tested. During Phase II, pilot tests will be conducted at approximately three separate highway renewal projects (possibly three separate research contracts). The results of Phase II research will be synthesized in Phase III.

Tasks

Phase I. Initial project

1. Identify organizations that are innovative and effective in managing utility issues.
2. Develop a workshop for organizations identified in Task 1. The workshop should result in greater detail for best practices and suggestions for additional innovations. Several possible innovations should be considered:

a. Development of national and regional model agreements with utilities that have a national or regional presence.
b. Development of criteria regarding when utilities should pay for relocation and when highway authorities should offer assistance.

3. Document current best approaches and analyze suggested innovations to identify the barriers to proposed changes.
4. Develop model agreements appropriate for national, regional, and local utilities, including options to address current barriers.
5. Identify highway renewal projects where recommended strategies can be pilot tested. Recommend approximately three highway renewal projects where the recommended strategies can be pilot tested.

Phase II. Pilot testing

6. Facilitate the integration of new approaches on three pilot projects.
7. Monitor the use of the new strategies.
8. Recommend modifications to the strategies that will likely enhance their performance.
9. Identify specification, institutional, and policy changes that will enhance the effectiveness of recommended strategies.

Phase III. Synthesis of pilot projects

10. Prepare final report that includes a synthesis of the Phase II pilot testing results.

Coordination with Other Projects

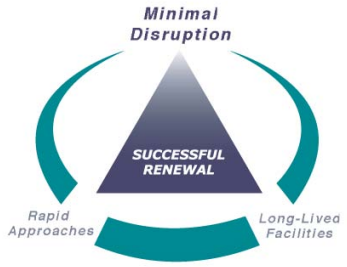
- 1-1.1—Utilities Location Technology Advancements

Products, Benefits, and Implementation

- Best practice manual with an assessment of the potential benefits
- Proposals for utility strategies that will accelerate utility relocations
- Recommended institutional and policy changes that will facilitate timely utility relocations
- Model agreements that can be executed at the national, regional, and local levels
- Final report

Research Period and Funding Requirement

Phase I: 1 year, $400,000
Phase II: 4 years, $2,500,000 (3 pilot projects conducted concurrently)
Phase III: 1 year, $100,000
Total: 6 years, $3,000,000



Tactic:
Improve customer relationships

Barrier:
Ineffective coordination with utilities and railroads

Project 1-6.4. Railroad-DOT Institutional Mitigation Strategies

Funding: $1,750,000 Duration: 4 years Priority: High

The presence of a railroad represents a unique challenge to rapidly renewing a highway facility. This is particularly difficult because of the consolidation of carriers within the railroad industry. Most railroads are very challenging to deal with at the state level and are extremely protective of any operation that could impact the use of their facility. This project will provide the forum for railroad-DOT collaboration and the framework for model business agreements.

Railroads have their own rules for movement of trains and their own communications system. When construction is conducted near a railroad, railroad personnel must be involved to coordinate rail service with construction activity.

The stance that a railroad will take with regard to a highway renewal project will depend, to some extent, on the benefits that it receives from the project and the disincentives for not cooperating. Railroads are private entities that own and maintain their own rights-of-way and provide their own financing for improvements. Negotiating changes that could impact rail service is often much more challenging than a typical highway planner expects.

In many ways railroads have considerably less flexibility than do highway owners in making changes. Detour routes are often unavailable because there is less redundancy in the rail system than in the highway system. When detours are available, they may already be near maximum traffic capacity or another carrier may own them. Long-distance freight trains can tolerate little delay, which typically means very restrictive conditions for the highway contractor. Work that actually impacts the tracks is often accomplished by railroad employees whose work schedule does not optimally correspond to the requirements of the highway project.

Objectives

- Identify strategies and institutional arrangements that will facilitate beneficial relationships between railroads and public agencies, including experimental arrangements.
- Investigate and develop innovative partnering techniques whereby railroads and the highway community are working cooperatively.
- Develop a draft model agreement and streamlined permitting processes.
- Identify barriers that impact effectiveness and propose remedies.
- Facilitate the use of streamlined permitting procedures on several pilot projects.

- Facilitate the use of the draft model agreements on several projects.
- Make recommendations on refinements to the permitting and agreement language.

Scope

This research project is focused on developing a cooperative business relationship with large national and regional rail carriers. This will be accomplished by seeking creative and cooperative approaches. The goal is to execute programmatic agreements between the states and regional and national carriers and to develop a streamlined permitting process for renewal projects.

It is proposed that the project will be conducted in three major phases. Phase II is proposed to be conducted in two subphases. The two subphases could be executed concurrently.

Tasks

Phase I

1. Conduct a literature review, field trips, and interviews to identify best practices regarding railroad relationships during highway renewal programs.
2. Identify example projects that are innovative and effective in resolving railroad issues.
3. Categorize railroad interactions in highway renewal according to importance and frequency.
4. Develop a workshop involving project personnel identified in Task 2 and representatives from the railroad industry. Use the results of Task 3 to structure the workshop. Develop a list of suggestions for improvement. Discuss possibilities for strategic relationships.
5. Analyze suggested innovations to find positive and negative impacts to proposed changes.
6. Develop draft model agreement and streamlined permitting language.
7. Conduct another workshop to develop consensus on the results of Tasks 5 and 6 for the participants at the workshop conducted in Task 4.
8. Finalize the draft model agreement and streamlined permitting strategies.
9. Prepare an interim report.

Phase IIa

10. Select a geographic area or a railroad and highway network for pilot testing of streamlined permitting procedure.
11. Conduct training and meetings necessary to start the pilot testing.
12. Monitor the issuance of permits under the streamlined procedure.
13. Evaluate the use of the streamlined procedure.
14. Recommend modifications to the procedure that will likely enhance its performance.
15. Recommend institutional and policy changes that will enhance the performance of the streamlined procedure.

Phase IIb

16. Locate highway renewal projects where draft model railroad agreements can be pilot tested.
17. Make necessary arrangements to include pilot test model agreements.
18. Monitor the use of the new agreements.
19. Evaluate the use of the new agreements in the pilot projects.
20. Recommend modifications to the agreements that will likely enhance their performance.
21. Recommend institutional and policy changes that will enhance the effectiveness of recommended agreements.

Phase III

22. Synthesize and summarize recommendations of Phases I, IIa, and IIb.

Coordination with Other Projects

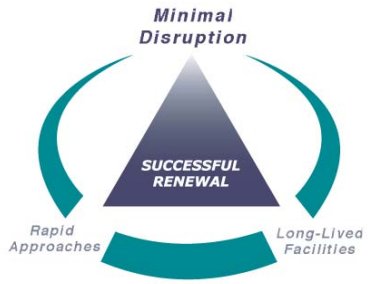
- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-2.3—Modular Pavement Technology
- 1-4.5—Risk Manual for Rapid Renewal Contracts
- 1-4.6—Innovative Project Management Strategies for Large, Complex Projects
- 1-5.1—Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process
- 1-6.3—Utilities-DOT Institutional Mitigation Strategies

Products, Benefits, and Implementation

- Best practice document with an assessment of the potential benefits
- Model agreements for cooperation between the railroads and the appropriate highway organizations
- Streamlined permitting procedures
- Recommended specification, institutional, and policy changes that are necessary to implement streamlined procedures and model agreements

Research Period and Funding Requirement

Phase I: 1.5 years, $700,000
Phase IIa: 2 years (conducted concurrently with Phase IIb), $500,000
Phase IIb: 2 years (conducted concurrently with Phase IIa), $500,000
Phase III: 0.5 years, $50,000
Total: 4 years, $1,750,000



Tactic:
Improve customer relationships

Barrier:
Insufficient consideration to adjacent environment

Project 1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods

Funding: $750,000 Duration: 3 years Priority: Medium

Construction work can have a dramatic impact on neighborhoods, businesses, and traffic on local roads. Various local ordinances attempt to control the elements through noise generation, traffic restrictions, water quality, and other factors. These restrictions may not be in harmony with broader project goals for rapid renewal. The owner agency wants to ensure that they are meeting the goals and objectives of the project, the contractor wants as many options as possible to build the project, and those impacted by the project directly want it completed with as little inconvenience as possible.

Context-sensitive designs can help to balance the community's desires with those of the agency. The concept of context-sensitive design principles arose from a 1998 workshop called "Thinking Beyond the Pavement: A National Workshop on Integrating Highway Development with Communities and the Environment." NCHRP Project 15-19 developed a guide to implementing context-sensitive design principles to help agencies mitigate a given project's impact on the neighborhood or community surrounding the site. These principles should be carried beyond the design phase through construction, maintenance, and operation. As one example, context-sensitive design considerations may lead to the development of environmentally friendly pavements with reduced noise generation levels, reduced wet weather accidents, and improved utilization of secondary and recycled materials.

Context-sensitive construction operations may be especially appropriate for rapid renewal projects. By planning and implementing context-sensitive construction, the contractor can ensure that the work will proceed efficiently, while the impact on the adjacent community is minimized. For example, in residential areas, urban areas or environmentally sensitive areas, conveyor systems may be used to deliver materials to the project location in lieu of truck transportation. This can lessen impacts on traffic, neighbors, and the environment. Urban areas in particular often have limited space available for construction, posing major obstacles for the contractor and potentially major impacts on the public. The principles of context-sensitive design can be extended to construction to help balance the agency, contractor, and community needs, while also facilitating speed of construction and minimizing disruption.

Objectives

- Apply context-sensitive design principles to specific applications related to rapid renewal projects.
- Identify and apply context-sensitive construction operations to minimize the impact of renewal projects on their surroundings.

Scope

This work will build on the concept of context-sensitive design principles, as outlined in NCHRP Project 15-19. This work will identify potential conflicts between rapid renewal goals and neighborhood disruption during construction operations. Factors to be considered include impact on traffic movement in and around neighborhoods, local environmental considerations, delivery of materials to and from the site, establishment of construction limits, impacts on local businesses, and noise ordinances.

Tasks

1. Conduct a literature review and survey. Through a review of literature and a survey of highway agencies and industry in the United States and abroad, identify the type and extent of current federal, state, and local ordinances that impact today's construction operations. Identify projects that include elements of context-sensitive construction operations.
2. Follow up on the most promising examples of context-sensitive operations. Conduct interviews or more detailed surveys of organizations and individuals involved in the projects identified in Task 1 to investigate successful examples of context-sensitive operations; impacts of the operations on stakeholders including the public, the agency, and the contractors, as well as others; and costs and benefits of implementing context-sensitive operations for the stakeholders.
3. Conduct a workshop on context-sensitive construction operations. With the results of Task 2 as a starting point, hold a workshop with interested parties to brainstorm and refine context-sensitive construction operations. One possible format for the workshop could follow the example of the 1998 "Workshop on Pavement Renewal for Urban Freeways," documented in the TRB report *Get In, Get Out, Stay Out!*, where different teams developed approaches to the same, real-life design problem. Industry should be encouraged to participate fully in the workshop deliberations.
4. Prepare a guide to context-sensitive construction options based on the previous tasks. The guide should include a variety of typical construction issues or scenarios associated with rapid renewal projects and options for coping with those issues in a context-sensitive manner. Case studies will illustrate the successful application of context-sensitive concepts. The guide should also include suggestions for agencies to encourage implementation of context-sensitive construction principles, including guide contract language, as appropriate.

Coordination with Other Projects

- 1-4.3—Incentive-Based Innovation for Rapid Renewal Strategies
- 1-4.5—Risk Manual for Rapid Renewal Contracts
- 1-6.1—New Guidelines for Improving Public Involvement in Renewal Strategy Selection
- 1-6.2—New Guidelines for Improving Business Relations During Renewal Projects

Products, Benefits, and Implementation

Products

The major product of this research will be a guide to context-sensitive construction, including options for various renewal scenarios. The guide will offer alternate approaches to managing construction operations to minimize disruption to the areas surrounding the renewal project, including traffic moving through the project, adjacent home and business owners, the environment, and others. Implementation suggestions in the guide will facilitate the adoption of context-sensitive construction operations by agencies and industry.

Benefits

The major benefit of the implementation of context-sensitive construction operations will be the reduced impact of rapid renewal projects on the adjacent community, the environment, traffic, home and business owners, and others. This, in turn, can have longer range impacts such as improved

public perception of the highway agencies and industry leading to a higher level of customer satisfaction.

Implementation

DOTs will need to integrate the guidelines into the design process and the public outreach effort as well. DOTs and the construction industry will also integrate certain recommendations into future equipment design that addresses noise and other ordinances that may inhibit the rapid renewal process.

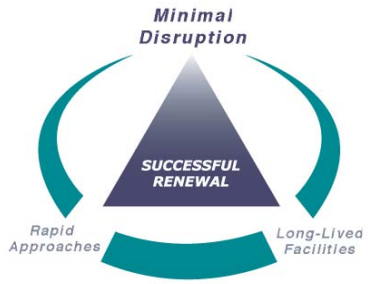
Research Period and Funding Requirement

Tasks 1, 2, and 4: $650,000
Task 3: $100,000
Total: 3 years, $750,000

Tactic 7. Improve Traffic Flow in Work Zones

Figure 10. Work Zone (Source: CTRE)

Most motorists and commercial vehicle operators experience the renewal process as delay. “Road Construction Ahead” is the bane of all travelers. Motorists are quick to observe and report poor motorist information, dangerous merges, and misleading signs. A poor job of work zone management or the perception that repairs are done every summer without the appearance of a “game plan” undermines the public confidence. Meeting the public’s expectation of a safe, predictable trip through a work zone (see Figure 10) with minimum delay requires the integration of design, construction, and communications expertise and application of ITS technologies in the harsh environment of a construction zone. Many of the traditional work zone approaches are simply inadequate for the high-traffic environment of rapid renewal projects. The goal is that work zones and work sites of the future will be safer and more efficient for both motorists and construction workers.



Tactic:
Improve traffic flow in work zone

Barrier:
Traditional approaches are inadequate for high traffic volume

Project 1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety

Funding: $2,000,000 Duration: 3 years Priority: High

Lack of a high level of safety in work zones coupled with the task of renewing the aging infrastructure with a minimal disruption brings about a challenge in the coming years. Despite the advancement in traffic control techniques, more than 800 deaths a year are still attributed to crashes in work zones nationwide. The challenge becomes more significant as growth in highway demand is projected to increase 50 percent by 2020. Thus, development of a “model” work zone is needed to establish consistent traffic control, geometric configuration, and traffic control devices in work zones across the country, particularly on high-volume roadways.

To achieve the goal of improved work zone performance, it will be necessary to (1) design the work zone for expected traffic and lane closure conditions, (2) ensure that recommended work zone traffic control procedures are implemented consistently, and (3) provide accurate and consistent real-time information to motorists. Measures to monitor and reward contractors for application of recommended procedures are needed to ensure application of good practices.

The reasons are self-evident. Drivers should not be confused by a visual barrage of barrels and reflectors. The design standard for signing and work zone geometry should be a rainy night. Drivers must also be convinced that taking a suggested detour, for example, is easy and takes less time; or that the posted variable speed limit is actually being updated according to the current work area traffic condition; or that the presence of warning signs actually means construction is in progress at the time. A motorist whose travel time has increased by taking a detour based on outdated information or who sees reduced speed signs when nothing is happening will likely disregard the information next time. Thus, winning the public confidence is an important undertaking in developing a model work zone. This may not happen unless construction contracts contain safety goals and performance measures.

Design and implementation of a state-of-the-art model work zone demands innovative operational and financial planning. Innovative operational planning of work zones will provide a safe environment in which both workers and motorists operate during construction and maintenance operations. This model work zone shall improve traditional approaches and use advanced technologies to detect incidents and queue formation and subsequently inform motorists of current traffic conditions through advance messaging in real time.

Part 6 (Temporary Traffic Control) of the *Manual on Uniform Traffic Control Devices* (MUTCD) provides standards and guidelines for every element of a work zone (e.g., advance warning and transition

areas, tapers, detours and diversions, and flagger control methods). This goes a long way toward establishing uniform practice, but a more thorough companion document is needed to achieve model or standard work zone scenarios that are applied consistently from state to state. Safety and operational performance standards for contractors will make the application of these practices self-enforcing.

On the ITS front, variable speed control systems, for example, encourage a smooth transition from open highway speeds to appropriate speeds for the work area. Other traffic control techniques such as speed advisory systems, queue detection cameras, and changeable message signs are considered as good candidates for providing real-time information to drivers of what is ahead and how long it will take them to traverse the area. Furthermore, to increase capacity and reduce the conflicts of the merging operation and the length of congestion upstream of the lane closure, a dynamic lane-merge system may be a suitable strategy in more efficiently using the facility. The earlier noted companion document to the MUTCD is needed to achieve model work zones that are consistent from state to state and that incorporate ITS technologies.

Advance work zone traffic modeling is an element in planning and development of a “model” work zone. Advance traffic modeling will provide methods to achieve the following objectives: (1) determine the expected delay and queue length during the construction, (2) examine and optimize the applicability of a traffic control strategy, and (3) study the impact of particular renewal projects on the affected transportation network. The modeling will also allow improving renewal operations in less time and lessening disruption not just on isolated, high-profile projects but consistently throughout the highway system.

In 2001, the FHWA, in partnership with the Maryland DOT, released QuickZone, a spreadsheet-based work zone analysis tool. QuickZone can

- Calculate delay
- Analyze alternative construction phasing
- Assess delay mitigation strategies
- Recommend lane closures based on allowable delay or queue length
- Calculate user cost of delay
- Recommend optimum work zone length
- Support work completion incentives

QuickZone is available for use now, but has not been extensively field-tested, according to the July-August 2001 issue of *Public Roads*. F-SHRP research should support field-testing and investigate needed enhancements, to include traffic-flow simulation and cost-effectiveness calculations.

Objective

- Develop a work zone design, installation, and maintenance plan for high consistency, visibility, and safety.

Scope

This project will produce tools to design work zones for expected traffic and lane closure conditions, recommend performance measures to monitor and reward contractors to ensure that work zone traffic control procedures are implemented consistently, and recommend works zone ITS treatments to provide accurate and consistent real-time information to motorists. The results will be collected into a comprehensive work zone guidelines manual that will complement the MUTCD.

Traffic-sensitive work zone designs require models such as QuickZone that can be used in planning and modifying work zones during a renewal project. This project will field-test available models and recommend enhancements as appropriate. Best practices will be identified in traditional work zone geometric layout and markings (e.g., barrels and cones) and address the use and placement of ITS sensors and communications technology to capture real-time traffic data for communication to the public. Measures will be recommended that can monitor work zone performance and can be incorporated into contract documents.

Tasks

Phase I. Work zone planning and design software

2. Develop the criteria that a work zone simulation model should possess.
3. Identify and evaluate against the criteria new models applicable for work zone planning such as QuickZone, MitSim, and the products of the Travel Model Improvement Program.
4. If a satisfactory model exists, field-test it in partnership with state DOTs and recommend changes or enhancements as appropriate.
5. Reference the model or models in the guidelines and describe how to incorporate them into work zone planning.
6. If no satisfactory model exists, develop a performance specification. Develop a partnership with a software developer to bring an appropriate product to the marketplace. This could be done in conjunction with the Renewal Clearinghouse proposed in Section H.

Phase II. Work zone performance measures

7. Identify variables and appropriate measurement techniques for potential work zone performance monitoring measures. Possible variables include speed adherence, speed variability, crashes, instances of rapid braking approaching the work zone, and photographic analysis of risky driver behavior.
8. Field-test promising variables to determine whether the measurement techniques are sufficiently robust to include in contract language. Report the cost of systems that must be put in place to measure the variables.
9. Recommend measures and measurement techniques to monitor work zone performance. Suggest draft contract language.

Phase III. Work zone guidelines manual

10. Assemble the best practices literature for traditional work zone design.
11. Survey state DOTs and contractors about work zone traffic control to identify engineering practices and problems and institutional issues that may block the application of known good practice.
12. Outline the manual's format (chapters and sections).
13. Develop standards, guidelines, and supports for presenting work zone traffic elements.
14. Document the final product in a manual form.

Coordination with Other Projects

- 1-6.5—Context-Sensitive Construction Operations

Products, Benefits, and Implementation

Products

- Work zone guidelines manual designed to establish consistent work zone treatments across the country
- Measures for contractor safety performance
- Model for work zone planning

Benefits

The benefits of improved work treatments will be reduced fatalities and injuries in work zones.

Implementation

Incorporating performance measures into contracts will be the implementation mechanism.

Research Period and Funding Requirement

Phase I: 1 year, $750,000 (assuming no new software must be created from scratch)
Phase II: 1 year, $750,000
Phase III: 1 year, $500,000
Total: 3 years, $2,000,000

Tactic 8. Design and Construct Low-Maintenance Facilities

Producing long-lived facilities not only reduces ownership costs but also significantly reduces the disruption to the users over the life cycle of the facility. Building for long life, using low-maintenance designs and materials, and designing facilities for easier maintenance need to be simultaneously achieved. Through improved material selection, design processes, and integration with construction technologies, facilities must be designed to reliably achieve the desired performance life. The goal is to integrate performance-related designs with innovative construction processes that will result in long-life solutions.

Figure 11. Geotechnical Work (Source: Iowa State University)

This tactic will narrow the gap in professional practice between design life and actual performance. In order to achieve long-lived, low-maintenance pavements and structures, one has to consider the performance of the entire system as well as those of the individual components. This will require research and development efforts in the areas of materials (see Figure 11), mixture composition, structural systems and components, pavement structure, and modeling. Through improved material selection, design processes, and integration with construction technologies, designers will be able to choose a desired performance life and facilities that will reliably achieve that life.

For many years researchers have investigated life-cycle cost analysis techniques and test methods to predict performance of various pavement elements, such as hot mix asphalt (HMA) materials. These concepts are proving their worth but need to be expanded to other pavement types, refined as needed, and integrated with other considerations. Reliable predictive techniques are critical to the ability to design for a particular service life and must account for the effects of construction and material variability and degradation on performance.

Tactic:
Design and construct low-maintenance facilities

Barrier:
Maintenance is not adequately considered during design and construction

Project 1-8.1. Durable Bridge Subsystems

Funding: $6,000,000 Duration: 6 years Priority: High

Historically, durability has been a problem for some individual bridge subsystems, especially bridge bearings and deck joints. This problem is not unique to the United States. Recent bridge management data from the Netherlands confirms that joints and bearings are the leading maintenance costs for concrete highway bridges. Because these subsystems undergo deterioration at a faster rate than other bridge elements, they require repair and replacement more frequently and this decreases service life and disrupts traffic. If these subsystems could be designed with enhanced durability characteristics, or if they (e.g., joints) could be eliminated, disruptions could be significantly reduced and structures could be expected to last longer after they undergo renewal efforts.

Currently, many bridge subsystems are designed and constructed based on proven historical performance. Unfortunately, some of the commonly used subsystem details (e.g., bearings and joints) have inherent design flaws. Although the specific flaws are recognized, they cannot be economically eliminated with current state-of-the-art design procedures. Further, the environment and location in which these subsystems frequently exist, which are often factors in their accelerated deterioration rates, make their inspection very difficult to impossible. As a result, the need for corrective action is only identified after un-repairable damage has occurred. This combination of design flaws in difficult-to-inspect locations results in bridge subsystems that must be replaced frequently. If bridge designers had a greater number of options for problematic bridge subsystems, better decisions could be made and bridge systems could be designed to deliver a 100-year design life. However, to date no significant effort has been dedicated to the development of new subsystems. By enhancing the performance of these subsystems, longer life facilities could be designed and constructed. In addition, if current state-of-the-art design procedures could be more universally implemented, it may be possible to significantly reduce the number of problematic subsystems and increase bridge service life.

Objectives

- Develop bridge systems with minimal deck joints that will allow rapid construction and long life.
- Develop bridge systems with alternatives to bearings that will allow rapid construction and long life.

Scope

This project will develop bridge systems that minimize or eliminate deck joints and bearings.

Tasks

Phase I. Bridge systems with minimal joints

1. Conduct a literature review to identify current practices in extending joint spacing.
2. Develop new bridge systems (including deck, superstructure, and substructure) that minimize or eliminate the need for deck joints.
3. Conduct laboratory studies of static and cyclic load performance of developed systems.
4. Form a committee of national experts to review and critique laboratory performance of developed systems and to select those subsystems with the greatest chances for success.
5. Construct field demonstration bridges.
6. Perform continuous monitoring of the designs to validate short- and long-term performance.
7. Prepare design methods, details, and standard plans and specifications.
8. Make recommendations and prepare a final report.

Phase II. Monolithic column/superstructure system

9. Conduct a literature review of performance of bridges constructed with monolithic substructures and superstructures.
10. Develop monolithic column/superstructure and other systems that eliminate bridge bearings.
11. Conduct laboratory studies of static, cyclic, and seismic load performance.
12. Form a committee of national experts to review and critique laboratory performance of developed systems and to select those subsystems with the greatest chances for success.
13. Construct field demonstration bridges that have the selected subsystems.
14. Perform continuous monitoring of the designs to validate short- and long-term performance.
15. Prepare design methods, details, and standard plans and specifications.
16. Make recommendations and prepare a final report

Coordination with Other Projects

- None required

Products, Benefits, and Implementation

Products

- Design methods, details, standard plans, and specifications for bridge subsystems

Benefits

Improved subsystem details will reduce required maintenance. This will increase bridge service life and reduce life-cycle costs.

Implementation

To implement new design alternatives, bridge owners must be provided with complete design/construction details coupled with data verifying field performance.

Research Period and Funding Requirement

Phase I: 3 years, $3,000,000 (significant costs include costs associated with constructing full-scale laboratory and field demonstrations)

Phase II: 3 years, $3,000,000 (significant costs include costs associated with constructing full-scale laboratory and field demonstrations)

Total: 6 years, $6,000,000

Tactic:
Design and construct low-maintenance facilities

Barrier:
Lack of predictable performance models

Project 1-8.2. Design for Desired Bridge Performance

Funding: $3,000,000 Duration: 3 years Priority: Medium

Faced with infrastructure renewal, designers must design bridges with a greater emphasis on long-term performance. Many new bridge systems will utilize new materials and many will be constructed with modular components. Current design specifications are not suited to address many of these and other issues associated with renewal. A strategic plan will first have to be developed to determine the contents and format of new specifications. Further, with the ability to collect bridge performance data more efficiently, there is a need to investigate how to incorporate the information from these data into new or revised design specifications. In addition, with an ever-increasing demand for bridges that are easily constructed, inspected, and repaired, designers must be provided guidance in how to prepare these designs.

For a number of years the FHWA has rated over a quarter of the nation's bridges structurally deficient or functionally obsolete. Part of the bridge renewal effort will require changes to conventional design procedures and will require that the transportation industry develop a new approach to facilitate renewal efforts. During the 1990s, the bridge industry made significant revisions to the design procedures for conventional bridge systems in developing the load and resistance factor design (LRFD) specifications. A concerted similar effort, with a much broader scope to the one undertaken in developing the LRFD specifications, will be required to develop performance-based specifications. However, any new provisions that incorporate a rational approach to include design for durability in addition to structural design should be considered within the framework of the current AASHTO Bridge Design Specifications. A strong training/education program also needs to be developed.

In the bridge industry, durability, fatigue, fracture, and redundancy are important issues of service life. These will continue to be significant issues in addressing bridge renewal efforts. Particular focus should be given to addressing these areas in the development of performance-based specifications. An important issue that requires a solution is the selection of the optimum reliability level for bridges. Performance-based design sets the requirements for structural parameters; however, user and owner expectations must also be considered within the framework. As a result, there is a need for the development of risk-analysis procedures as the basis for selection of acceptance criteria.

It is also significant to note the effort by the AASHTO bridge community in the past several years to develop compatible design (OPIS) and rating (VIRTIS) software. Part of the development of new design procedures must include implementing new designs, specifications, etc. into the next generation of AASHTO BRIDGEWare.

Objective

Develop comprehensive design procedures and specifications that integrate material performance (including durability), construction practices, and structural performance, leading to more predictable service life, especially long life, and that consider structural and material redundancy. Consideration should also be given to incorporating changes into the AASHTO Bridge Design Specifications and AASHTO BRIDGEWare.

Scope

This project will develop bridge design procedures that include durability in addition to structural design and will develop tools required for implementation.

Tasks

Phase I. Develop bridge design procedures that integrate construction, material, and performance parameters that will lead to more predictable life

1. Review research and practice regarding the performance-based design of bridges, including investigating the relationship and actual performance and relevant design practice in other countries.
2. Investigate the feasibility of developing “load factors” for performance-based design considerations.
3. Investigate the feasibility of developing “resistance factors” for performance-based design considerations.
4. Review available literature and conduct a survey of bridge owners to investigate the body of data that may be available for determination of “load and resistance factors” for performance-based design consideration.
5. Develop a methodology to initially develop and to revise over time “load and resistance factors” for performance-based design considerations.
6. Develop a work plan for collecting data required for the determination of “load and resistance factors” for performance-based design considerations.
7. Execute the work plan for collecting data required for the determination of “load and resistance factors” for performance-based design considerations.
8. Develop initial “load and resistance factors” for performance-based design considerations.
9. Prepare a final report.

Phase II. Implement new design, specification, etc. into next generation of AASHTO BRIDGEWare

10. Update AASHTO BRIDGEWare as needed.
11. Beta-test updated AASHTO BRIDGEWare.
12. Revise updated AASHTO BRIDGEWare based on beta-test results.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology
- 1-9.2—Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems
- 1-9.3—Monitoring and Design of Structures for Improved Maintenance and Security

Products, Benefits, and Implementation

Products

- Design procedures
- Performance-based specifications
- Training programs

Benefits

Engineers will be able to incorporate performance parameters, in addition to structural parameters, into bridge design.

Implementation

Significant training coupled with design examples will be needed to effectively implement the results of this project.

Research Period and Funding Requirement

Phase I: 3 years, $2,700,000
Phase II: 1 year, $300,000
(Note: Phases overlap or occur concurrently.)
Total: 3 years, $3,000,000

Tactic:
Design and construct low-maintenance facilities

Barriers:
- Maintenance is not adequately considered during design and construction
- Lack of predictable performance models

Project 1-8.3. Composite Pavement Systems

Funding: $5,000,000 Duration: 4 years Priority: Medium

This project will fully develop a high-performance, maintainable pavement system that is currently not being addressed by the traditional pavement design community. Composite pavements, including asphalt overlays and whitetopping, are routinely used for rehabilitation of existing pavements, but their use for new pavements is not typical in the United States. Composite pavements offer the potential benefits of long-life pavement with both structural and functional advantages, as well as an increased recycling of on-site materials.

Composite pavements, typically asphalt overlays over PCC pavements, constitute a large proportion of the U.S. pavement infrastructure. FHWA statistics indicate that approximately 30 percent of the urban interstate system and just over 20 percent of the rural interstate system are composite pavements (*Highway Statistics 2000*). These pavements, however, were not designed and built as composites. Rather, an overlay was added to an existing pavement to improve the ride quality or, less frequently, to improve the structural capacity. Current and forthcoming design guides address the use of overlays (both asphalt and whitetopping) for rehabilitation, but do not address some of the promising new techniques that have special application for renewal projects. This research will focus on two of the most promising new applications of composite pavement systems: (1) an asphalt overlay over a new PCC base and (2) a PCC overlay over a new PCC base.

While asphalt overlays over concrete are commonly used to rehabilitate a pavement, the use of an ultrathin high-quality asphalt overlay over a new concrete base is relatively rare. This technique has great potential to provide a long-lasting pavement needing minimal maintenance. The concrete substructure provides a durable, strong, long-lasting base, while the asphalt surface provides a smooth, rapidly renewable riding surface. Two types of PCC base to be considered include continuously reinforced concrete (CRC) pavement and jointed plain concrete pavement (JPCP). The use of CRC, for example, could reduce the risk of reflective cracking of the overlay, as could the use of polymer overlays similar to those used for bridge decks. The HMA overlay could be optimized for performance in terms of friction, noise, ride quality, and reduced splash and spray. This technique would be well suited to meeting the goals of rapid renewal. Initial construction of a composite pavement may not be rapid, but the pavement would be long-lasting and disruption would be minimized throughout the life of the pavement by providing a surface that can be quickly and easily maintained. Improved performance could also be obtained in the areas of friction and noise, by properly designing and constructing the wearing course.

The second focus of this research will be on the use of a relatively thin, high-quality PCC surface atop a thicker, cheaper PCC base that may include high proportions of recycled or substandard material. The primary advantage of this “wet-on-wet” technique is that it allows in situ recycling in the base course,

which speeds construction. Construction is accelerated by placing the surface on top of the base course before the base course has set to facilitate an excellent bond between the two layers of concrete; this construction technique has led to use of the term “wet on wet” concrete. A few such pavements have been built in the United States and many more have been constructed in Austria.

The behavior of composite pavements is not well understood. Models for the performance of these hybrid systems are needed for design, performance prediction, and life-cycle cost analysis. One of the key deficiencies in the state-of-knowledge is in the bond between the different pavement layers, which has a significant impact on performance. The interface between an asphalt surface and a concrete base is especially problematic, due to increased shearing forces in the asphalt and diurnal temperature extremes. A more sophisticated approach to modeling these interfaces is needed to maximize the performance benefits of these composite pavements.

Objectives

- Develop performance models and design procedures for long-lasting, easily maintained new composite pavements for rapid renewal.
- Investigate and understand the behavior and critical performance parameters of composite pavements.
- Develop material requirements for all layers of the composite pavement, including the subgrade.
- Recommend construction and quality control procedures for composite pavements.
- Develop a long-term evaluation program to provide for future refinements of the design procedures and models.

Scope

This project will include study of existing field trials of two types of composite pavements: (1) HMA overlay over CRC pavement/JPCP and (2) wet-on-wet concrete pavement. Critical performance parameters will be determined, improved design and performance models will be developed, material requirements will be recommended, and design procedures will be codified.

Tasks

Phase I

1. Conduct literature review and survey. Based on a review of worldwide literature and a survey of national and international transportation agencies, assess the state of practice and knowledge regarding high-performance HMA overlays of CRC and JPCP, and wet-on-wet concrete pavements. Identify field applications of these pavement systems.

Phase IIa. HMA overlay of new PCC pavement

2. Perform case studies of high-performance asphalt overlays of CRC and JPCP. Using selected projects identified in Task 1, conduct case studies of these field applications to determine performance to date, material and construction details, design considerations, etc.
3. Recommend laboratory evaluation of critical design parameters for high-performance HMA over JPCP and CRC pavements. Considering the information obtained in Task 2, design an experiment to assess the key performance parameters and develop improved behavioral models and design procedures. This task will include a detailed study of the effects of the asphalt-concrete interface on performance.
4. Conduct laboratory evaluation and model performance. Pending panel approval of the experimental approach outlined in Task 3, conduct the experiment and develop the performance models and design procedures for high-performance HMA overlays of CRC and JPCP.

Phase IIb. Wet-on-wet concrete pavement

5. Perform case studies of wet-on-wet concrete pavements in the field to determine key performance parameters, design and material considerations, construction issues, etc.
6. Develop a design approach for wet-on-wet concrete pavements. Recommend a process for developing design procedures for wet-on-wet concrete pavements, including structural and material design.
7. Develop structural and material design procedures for wet-on-wet concrete pavements. Following panel approval of the approach outlined in Task 6, develop the design procedures for wet-on-wet concrete pavements. The structural design procedure must address the differing quality and stiffness within the composite pavement, and should be compatible with conventional concrete pavement design to the extent possible. The material design should accommodate the use of in situ recycled and substandard materials in the base layer.

Phase III

8. Develop best construction practices guide for composite pavements. Based on the case studies, recommend best construction practices for the two types of composite pavements under study. This guide should include construction quality control as well as recommend equipment modifications.
9. Recommend long-term field evaluation plan. Develop a recommended plan for the long-term evaluation of composite pavements to validate the design parameters and refine future design and construction procedures.
10. Develop training materials. To facilitate implementation of these new composite pavement systems, develop training materials for structural and material design and construction or these two types of composite pavements.
11. Prepare a final report documenting the entire project.

Coordination with Other Projects

- 1-2.3—Modular Pavement Technology
- 1-8.4—Stabilization of the Pavement Working Platform
- 1-8.5—Using Existing Pavement in Place and Achieving Long Life
- 1-9.3—Monitoring and Design of Structures for Improved Maintenance and Security

Products, Benefits, and Implementation

Products

- Procedures and methodologies for the development, acceptance, and adoption of composite pavement systems
- Design, materials, and construction manuals
- Composite pavement training materials

Benefits

These two types of composite pavements offer different benefits related to renewal. The high-performance HMA overlays of CRC offer the potential for exceptionally long service lives with minimal disruption. The CRC provides a strong foundation and the high-quality asphalt provides a renewable carpet to provide good ride quality, minimized noise propagation and increased safety through high-surface friction, and reduced splash and spray. The wet-on-wet concrete pavement can be constructed rapidly while recycling in situ or substandard materials in the base while still providing a durable, high-quality surface.

Implementation

Implementation of the findings of this research will be facilitated by providing design procedures and training materials for design and construction.

Research Period and Funding Requirement

Total: 4 years, $5,000,000

Tactic: Design and construct low-maintenance facilities	→	**Barrier:** Maintenance is not adequately considered during design and construction

Project 1-8.4. Stabilization of the Pavement Working Platform

Funding: $1,600,000 Duration: 3 years Priority: Medium

Rapid development of a working platform provides definite construction advantages, especially for rapid renewal. There is high potential to save time, particularly during inclement weather, with approaches to rapidly stabilizing and constructing subgrades.

Subgrade preparation and base construction constitute time-consuming stages when building new or replacement pavements. Rapid renewal will, in many cases, require the ability to quickly design, construct, and prepare the underlying unbound pavement. Minimizing disruption may also require limited hauling of materials to the project. This can be accommodated by reusing as much of the existing material on site as possible in the renewed pavement structure. The need for rapid construction and minimal disturbance must be balanced against the need for high-quality and long-lasting performance benefits.

Rapid subgrade improvement techniques may include methods such as chemical or mechanical stabilization. Techniques such as soil mixing, grouting, injection, and soil reinforcement are routinely used for ground mass stabilization for buildings, bridges, and other structures. These techniques, however, have not found wide application to pavements, and yet their potential is clear, particularly for rapid renewal. For example, stabilization of base, subbase, and subgrade layers could be accomplished from the top or the side of the platform without removing the pavement. In addition, these techniques can be used to improve the properties and performance of existing standard and substandard soils, and of recycled materials, better and faster than conventional techniques such as lime stabilization. Issues that need study with the injection methods include positive controls on the lateral and vertical extent of the injected material and assessment of the impact of the injected material on the drainage characteristics of both the improved subgrade and the overlying pavement structure.

The construction parameters, long-term performance effects, and the life cycles of these stabilization techniques need to be quantified for pavements. For example, in soil mixing the design parameter is usually the strength of the soil mixture while deformability and curing time are of secondary importance. In this sense, the experience that can be drawn from ground improvement to pavement stabilization is limited.

Advances in the geosynthetic field include new products that can improve pavement performance by both reducing migration of fines and providing reinforcement. Bi-axial geogrids are particularly attractive at locations such as the interface between the approach embankment and the bridge abutment backwall. The “bump at the end of the bridge” is a persistent problem caused by a number of factors related to high cyclic forces, including breakdown of aggregate, buildup of hydrostatic forces, and loss of fines. Multiple-function geogrids should be studied to be used in rehabilitation of abutments and approach fill areas. Also, other geosynthetic types may hold promise to be used with nontraditional marginal subgrade

soils. Reuse of marginal soils would decrease the time for pavement rehabilitation due to elimination of removal, transportation, and replacement operations.

Emerging technologies for monitoring earthwork with non-nuclear devices also offer the possibility of determining the need and/or extent for subgrade and/or base remediation on existing facilities. At present, wide sections of pavement are routinely removed when a surface pattern of reflected subgrade distress is identified by current techniques. New nondestructive technologies such as the use of soil stiffness gauges or time domain reflectometry could be used to accurately examine and quickly rate the condition of large subgrade areas. These technologies should be evaluated and the most promising techniques tested on sites where rehabilitation operations are planned.

New design tools able to properly evaluate the interdependent behavior and performance of pavement, base, and subgrade offer substantial advantages for the design of new pavements and rehabilitation of existing ones. Implementation of construction methods used in geotechnical engineering and innovative, cost-effective soil stabilization procedures have great potential to reduce cost, achieve rapid construction, minimize traffic disturbance, and prolong the life of the pavement.

Objectives

- Develop schemes for the integration of base and subgrade performance into the design and evaluation of existing and new pavement systems.
- Develop recommendations and simple guidelines for the use of soil stabilization techniques for treatment of unbound pavement layers.
- Review and document the use of geogrids for improvement of subgrade performance.
- Determine which emerging technologies offer promise to identify areas of poor subgrade conditions. Test and document use of the most promising products on actual subgrade improvement projects nationwide.
- Quantify the mechanical behavior, performance, and life cycle of treated materials.

Scope

This research will improve pavement performance and increase the speed of construction. This project will integrate the behavior of the unbound pavement layers into the overall performance of the pavement for new construction and rehabilitation. The project will also investigate the implementation of rapid mechanical and chemical soil stabilization technologies to pavements and will develop guidelines and design procedures for each treatment.

Tasks

1. Perform a literature review to (1) identify the origin and mechanisms of pavement failure, in particular failures caused by water infiltration, movement of water and fines within the pavement, and degradation or aging of the base or subgrade treatment; (2) determine and classify current construction methods and technologies for stabilization of working platforms; (3) identify mechanical and chemical stabilization techniques that could be used for pavements; (4) determine typical properties of treated soils, including long-term drainage capacity and effects of degradation or aging; and (5) identify marginal soils that could be treated and/or combined with geosynthetic reinforcement and used to improve pavement performance.
2. Incorporate soil behavior models into design and performance models of pavements. Existing pavement models often use a very simple model for the soil that often neglects its elasto-plastic time-dependent behavior. In this task, well-established soil models will be incorporated into pavement models and through a parametric analysis the differences between the new and old models will be investigated. The new model should be able to evaluate the performance of pavements where some of the layers have been chemically or mechanically treated. Laboratory

and field-tests on treated soils and on pavements with treated layers will be conducted to validate the models.

3. Develop guidelines for the mechanical and chemical treatment of soils for base, subbase, or subgrade. The guidelines should include a decision support methodology to aid in analyzing the cost/benefit of various treatments. Treatments should include soil mixing, grouting, injection, compaction, and soil reinforcement with non-degradable fibers, geogrids, and geotextiles. The work should focus on those techniques that would make possible the rapid strengthening of the soil from the top or the side of the platform without the complete replacement of the pavement. Emphasis should be given to control of injected materials and their impact on the drainage of the pavement structure.
4. Develop design procedures, material specifications, construction and testing requirements, and performance evaluation parameters for mechanically and chemically treated soils in pavements. The procedures and specifications should build on the experience that already exists in soil stabilization and should be adapted and expanded to the particular requirements of pavement performance.
5. Review emerging technologies and methodologies for fast and reliable quality control that could be adapted to assessment of the condition of existing subgrade and/or base materials. The following technologies could be evaluated: electrical resistivity, electromagnetic techniques, time domain reflectometry, ground penetrating radar, tomographic imaging, soil stiffness gauges, and geophysical techniques.
6. Establish guidelines for the use of sub-standard, non-ideal soils, and recycled or waste materials such as crushed old asphalt pavement, copper and zinc slag, paper mill sludge, and rubber tire chips, for fill and pavement rehabilitation.
7. Document the research in a final report.

Coordination with Other Projects

- 1-3.1—High-Speed, Nondestructive Testing Procedures for Design Evaluation and Construction Inspection

Products, Benefits, and Implementation

Products

- Integrated pavement design procedure
- Guidelines and recommendations for design, construction, and quality control of mechanical and chemical treatment of base, subbase, and subgrade layers
- Guidelines for treatment and material specifications for the use of marginal soils

Benefits

The benefits will include rapid techniques for improving the subgrade and base properties to facilitate rapid construction and long pavement life. Some stabilization methods may be appropriate for improving existing subgrade and base conditions without removing the existing pavement, which will have tremendous impacts on the speed of renewal. Proper integration of base and subgrade considerations into the design of a pavement system will greatly extend pavement life.

Implementation

Implementation will be accomplished as DOTs integrate the results of this project into their design approaches.

Research Period and Funding Requirement

Total: 3 years, $1,600,000

Tactic:
Design and construct low-maintenance facilities

Barrier:
Maintenance is not adequately considered during design and construction

Project 1-8.5 Using Existing Pavement in Place and Achieving Long Life

Funding: $1,000,000 Duration: 2 years Priority: Medium

On roadways that have acceptable geometric features, renewal could be greatly accelerated and costs reduced if the existing pavement can be incorporated into rapid renewal projects without having to be removed. During the last 20 years, there have been numerous projects where the existing pavement was modified in place in some fashion or was used as constructed and a new structural pavement was placed on top. Both asphalt and concrete pavement solutions have shown promise, but there is limited in-service performance on heavy duty pavements. Some of the techniques include rubblizing and crack and seat for ACC over PCC pavements and concrete over concrete, concrete over asphalt, and concrete over asphalt/concrete for PCC overlays.

There is insufficient knowledge, experience, and confidence, however, in these techniques on very high volume, high-load roadways, especially for projects looking for long life (50 years or longer). It is believed that lack of uniformity in pavement support and the inability to correct it may reduce the number of eligible projects. Many DOTs would like to have these options in their pavement type selection but are hesitant to experiment on higher risk roadways. Instead, DOTs often lean to full removal and replacement of the existing pavement. Project owners need reliable procedures that allow them to identify when an existing pavement can successfully be used in place and how to incorporate it into the new structural pavement to achieve long life.

Rubblizing: Rubblizing is generally considered a mid-range rehabilitation strategy of approximately 15 years. The thicker the asphalt overlay, the longer the life, assuming adequate and uniform subgrade support. Rubblizing is generally not considered a rapid repair solution. The Michigan DOT reports that visible rubblized pieces over six inches must be manually reduced in size, rubblized surface texture must be relatively smooth, exposed steel must be cut, asphalt patches should be removed prior to rubblization, second passes with rubblizers must be avoided, and traffic should not be allowed on the rubblized surface.

Crack and seat: With crack and seat, it is extremely difficult to verify that the slabs are properly seated; therefore, there is no guarantee that reflective cracking will not develop. A recent national study of break-and-seat projects revealed that the method merely delayed reflective cracking for 3–5 years.

Concrete Overlay over Concrete Pavement Structure: There are two techniques for placing PCC directly over an existing concrete pavement. If an asphalt bond breaker is placed on the new and existing concrete, the technique is generally known as an unbonded overlay. If the new concrete is placed directly on the existing concrete, it is generally referred to as a bonded overly. Both techniques, while around for over 30 years, are limited and are generally considered experimental. The bonded overlay technique has been used successfully on CRC pavements in the Houston area, using steel fibers. However, there is

serious concern about bond. The construction operations can be challenging in heavy traffic. Concrete placed over mixed asphalt/concrete sections does not have a design protocol as yet and has limited performance data for the few projects completed to date.

Concrete Overlays over Asphalt Pavement Structure: This technique is commonly known as whitetopping. There is a new design procedure under development by FHWA, but it has not been evaluated as yet. Overlays of less than eight inches are not common, with little performance history on heavy duty pavements.

A challenge to all the above concepts is handling lane additions—matching foundation, grades, joints, and drainage—prior to constructing the overlay.

Objectives

- Develop detailed criteria on when an existing pavement can be used in place, with or without significant modification.
- Determine the best ways to construct these types of pavements in a high-speed environment.
- Determine the optimal way to add lanes to match specific pavement features and to ensure uniform service performance.
- Evaluate new design procedures currently under development.
- Explore ways to minimize reflective cracking.

Scope

This effort will concentrate on understanding the current state-of-the-art of the above techniques and recommending ways to improve the process and procedures, in hope of improving the life expectancy and application in heavy loaded pavements.

Tasks

Phase I

1. Conduct a literature search and survey to determine the current state of the art in designing and reconstructing pavement in place using the above techniques. Identify the life expectancy of each technique.
2. Analyze the individual design and construction strategies to determine what specific elements of each technique may be a factor in limiting longer life. Identify ways to improve the processes and techniques. Identify strategies that could overcome any anticipated barriers.
3. Select those strategies that have the highest potential for improving life and load carrying capability. (Note: If equipment advances are identified in Task 3, the researcher should assist in the organization of DOT-contractor-equipment partnerships that will further advance these strategies. This could be conducted through the Renewal Clearinghouse proposed in Section H.)
4. Develop a research and implementation plan that includes design and construction elements for those strategies identified in Task 3. The plan should include
    - Improvements to current design procedures, if needed
    - Improvements to determining in-place condition of existing pavements include subgrade
    - Improvements in construction equipment, operations, and testing equipment
    - Improvements in determining post-construction condition of new pavement

Phase II

5. Execute research from Task 4.
6. Develop and oversee a series on national experimental projects aimed at designing, building, and evaluating the strategies
7. Develop design guides, construction specifications, and construction procedures for strategies.

Coordination with Other Projects

- 1-8.3—Composite Pavement Systems

Products, Benefits, and Implementation

Products

- New and updated design guides
- New construction procedures

Benefits

This research will give DOTs additional options and strategies for using existing pavements in their renewal projects. The project results have the potential to bring great time-savings and traffic management improvements.

Implementation

The research includes major implementation strategies. Post research, it is expected that AASHTO, FHWA, and the various industry groups will have a uniform approach to the strategies. It is also expected that additional states will design and build sections using these strategies on heavy duty, heavy volume pavements.

Research Period and Funding Requirement

Phase I: $400,000
Phase II: $600,000 (Tasks 5 and 6 are estimated at $400,000; Task 7 is estimated at $200,000)
Total: 2 years: $1,000,000

Tactic 9. Monitor In-Service Performance

Technology provides an opportunity to address a key strategy for improving service to the public both for planned maintenance and security. Having the ability to continuously monitor in-service performance (and the necessary decision support systems) will result in lower life-cycle user and ownership costs and improved public safety.

Facility owners will be able to continuously monitor the physical condition of roadways and structures in order to improve maintenance and security and to revise design specifications. The ability to monitor changes in pavement and bridge behavior due to normal deterioration or through isolated events (e.g., floods and impact by over height vehicles) can be a valuable resource for pavement and bridge owners. Specifically, bridges with known problems or suspect details can be closely monitored for sudden failure (see Figure 12). In addition, continuous health monitoring provides a mechanism for owners to actively monitor bridges from a security standpoint.

Figure 12. Non-destructive Evaluation (Source: Bridge Engineering Center, ISU)

Tactic:
Monitor in-service performance

Barrier:
Lack of performance-related metrics and analysis systems

Project 1-9.1. Nondestructive Evaluation Methodology for Unknown Bridge Foundations

Funding: $1,000,000 Duration: 2 years Priority: Medium

Bridges over waterways are a high percentage of all highway bridges. In 2000, the FHWA reported that over 91,000 water-crossing bridges in the National Bridge Inventory had unknown foundations. Quick, simple, and inexpensive methods are needed to determine whether techniques to repair/strengthen/widen a bridge are more cost-effective than replacement. This is especially important on rapid renewal projects where time is of the essence, minimizing traffic disruption is key, and project costs typically exceed available budget.

Recently completed NCHRP Project 21-05 outlines the best procedures to investigate these unknown foundation sites and determine the depth of the existing foundation elements. Implementation of the recommendations in NCHRP 21-05 is needed nationwide to reduce the frequency or severity of system disruptions caused by emergency work on these bridges. Demonstration of these techniques to all highway agencies is necessary for confident application to sites with unknown foundations.

Objectives

- Implement NDE methodology for unknown bridge foundations.

Scope

This project will build upon project NCHRP Project 21-05. The issues that impact confident determination of unknown foundation depth are stated in that report. Local experience is needed by highway agencies to determine procedures that best fit their geologic and structural conditions at locations of unknown foundations.

Tasks

1. Establish a demonstration project for NDE of unknown foundations.
2. Demonstrate the NDE equipment in each highway agency. Train highway agency personnel to use NDE equipment and interpret results.
3. Provide technical assistance to highway agencies on assessment of existing unknown foundation sites.
4. Develop standards and specifications for the incorporation of nondestructive test access tubes into foundation elements for new structures.
5. Provide training materials and technical assistance to highway agencies to implement access tube installation on new foundations.
6. Prepare final report.

Coordination with Other Projects

- 1-10.2—Bridge Repair/Strengthening Systems

Products, Benefits, and Implementation

- Demonstration projects
- Standards and specifications
- Training materials and technical support
- Final report

Research Period and Funding Requirements

Total: 2 years, $1,000,000

Tactic:
Monitor in-service performance

Barrier:
Lack of performance-related metrics and analysis systems

Project 1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems

Funding: $4,000,000 Duration: 6 years Priority: Medium

Rational (i.e., accurate data coupled with effective algorithms) bridge management systems (BMSs) are an important tool for bridge owners. Unfortunately, the development and use of these systems are still in their infancy and BMSs are not widely used in making decisions. As bridge renewal begins in earnest, a great opportunity exists to begin the steps needed to evolve effective management systems, including identifying the type of information that can be most useful and that can be realistically and accurately obtained. If these management systems are developed properly, decisions for bridge RRR can be made that significantly increase bridge life. Changes are needed to get all of the facets of work currently in progress with the Pontis bridge management system completed. Developing and tailoring a management system to correspond with the specific needs of renewal systems being developed makes this effort unique compared to current work in progress on existing BMSs.

To effectively evolve Pontis into a system that is useful to all bridge owners, a next generation of Pontis that is a nationwide system needs to be developed. With this approach, greater national communication with respect to the use of Pontis will be established and, as a result, better decisions will be made. However, care must be given to create a system that is flexible enough to accommodate a wide variety of bridge configurations that are exposed to varying environmental conditions. In other words, the system must be flexible enough and customizable to allow regional trends, as well as national trends, to be input. Users of this system would input life-cycle information, including collected performance data, rehabilitation operations and associated costs, repair operations and associated costs, and replacement operations and associated costs. To use this system for making decisions, a bridge owner would query the national Pontis system for potential RRR solutions based on the specific need. Given additional parameters such as cost, time, and conditions, the bridge owner could then refine those RRR solution hits to a smaller subset. Using this approach, it can be ensured that as the nation's bridges are renewed, they will be, based on past performance, near-optimal solutions. With continued input of performance and RRR data, bridge owners will have greater numbers of past experiences in the database. This will allow bridge owners across the county to learn from others' RRR operation successes and failures, thus ensuring long-life structures.

Objectives

- Identify the performance-based metrics, including material deterioration and bridge life-cycle information required to quantify bridge performance.
- Develop protocols for collection, integration, and dissemination of performance data.
- Evolve Pontis into a nationwide system that includes performance data, life-cycle information, and RRR operations.

Scope

This project will enhance Pontis and provide the ability to more accurately model in-service performance.

Tasks

Phase I. Performance-based metrics

1. Conduct a literature review to identify current practices in collecting bridge condition and performance information.
2. Develop a comprehensive summary of BMSs that are used internationally.
3. Evaluate the applicability of performance-based decision-making systems used in other industries (e.g., aircraft, power, and trucking).
4. Conduct a survey of bridge owners on the types and formats of bridge data currently collected in addition to those required by the National Bridge Inspection Program.
5. Develop protocols and techniques for collecting performance-based data.
6. Develop techniques for interpreting time-dependent performance data.
7. Develop protocols for standardizing collected data in a unified format.
8. Make recommendations for modifying Pontis.
9. Prepare a final report documenting findings and recommendations.

Phase II

10. Conduct a literature review to identify current RRR scenarios currently used.
11. Conduct a survey of bridge owners of current RRR scenarios currently used. This survey should include gaining enough information from bridge owners to ascertain, at a very basic level, when/why each RRR scenario is typically used.
12. Prepare a final report that documents current RRR scenarios.

Phase III

13. Evolve Pontis based on the information collected in Phases I and II.
14. Use historical data from a small subset of bridge owners to beta-test the systems in terms of decision-making.
15. Revise decision-making algorithms.
16. Beta-test the software with bridge owners in terms of functionality.
17. Revise the software in terms of usability input from bridge owners.
18. Prepare a final report with recommendations and a software user manual.

Coordination with Other Projects

- 1-9.3—Monitoring and Design of Structures for Improved Maintenance and Security

Products, Benefits, and Implementation

Products

- Protocols for collection, integration and dissemination of performance data
- Database of performance data, life-cycle information, and RRR operations
- Tools to predict performance

Benefits

With better decision algorithms and quantitative data to substantiate decisions, bridge owners will be able to make more cost-effective, efficient decisions.

Implementation

Significant training will be required on how to use the enhanced system—specifically, how to collect and input important information and how to use legacy data for decision-making.

Research Period and Funding Requirement

Phase I: 2 years, $1,000,000 (including major project team time and significant travel expenses)
Phase II: 2 years, $1,000,000 (including significant project team time and substantial travel expenses)
Phase III: 2 years, $2,000,000 (major expense is project team time)
Total: 6 years, $4,000,000

Tactic:
Monitor in-service performance

Barrier:
Lack of performance-related metrics and analysis systems

Project 1-9.3. Monitoring and Design of Structures for Improved Maintenance and Security

Funding: $5,000,000 Duration: 6 years Priority: High

The effectiveness of bridge renewal systems is directly related to performance assessment and asset management. Active bridge monitoring is the most effective way to accomplish this. Bridge monitoring is an important tool for bridge health monitoring, for determining bridge performance for developing and validating effective design specifications, and for bridge security (including potential terrorist acts, acts of nature, accidents, etc.).

It is critical to develop a systematic and focused process for collecting bridge performance data. These data provide useful information for determining appropriate design specifications and for making informed maintenance decisions that contribute directly to a bridge's long life.

Bridge monitoring can be performed by collecting data continuously or by performing isolated tests. Historically, bridges have been monitored while maintaining traffic and/or with the aid of traffic control, diversion, or stoppage. As technology improves, it is becoming increasingly more common to use in situ sensors for the continuous monitoring of the built infrastructure using ambient traffic for the loading. The use of wireless transducers will eliminate the need for site access, which will reduce potential safety risks.

Bridge monitoring also includes load testing for providing accurate load ratings and bridge performance. This type of testing differs from continuous monitoring in that data are taken from isolated, "point-in-time" load tests using controlled loading. It is desirable to improve this process by reducing the time and cost associated with this process and developing methodologies for using ambient data collected from continuous monitoring.

Standards are needed for monitoring (monitoring protocols, data collection and processing, etc.) bridges in a cost-effective and efficient manner. Data collection from monitoring is just one aspect of the process. State highway agencies frequently collect data; however, processing these data requires extensive time, so significant evaluation may not always be possible. The development of custom data reduction tools could facilitate the input of real-time data into databases directly, and facilitate their reduction using engineering analysis. The tools could supply the data, as needed, in a manageable form to bridge management and maintenance groups, design divisions, and asset management groups.

Objectives

- Continuously monitor key infrastructure assets (including long-term durability assessment, catastrophic event monitoring, general asset management assessment, and security).

- Reduce interruption to the traveling pubic and increase safety for inspectors.
- Merge information from construction measurements with long-term health monitoring information.

Scope

This project will investigate cost-effective monitoring capabilities of the nation's infrastructure systems.

Tasks

Phase I. Evaluation of sensors and monitoring systems for effective continuous monitoring applications

1. Define important monitoring metrics with a research focus group that is comprised of public and private stakeholders. The focus of this task should be on bridge renewal systems, as well as on security of pertinent renewal systems. At the very least the following issues should be considered as potential metrics: smart materials, long-term durability assessment, catastrophic event monitoring, general asset management assessment, and security.
2. Document existing monitoring technologies by conducting a literature review and survey to determine current applications of continuous health monitoring sensors and systems. This task will focus on evaluating systems that are currently used successfully and identifying those systems that were used with limited success.
3. Document emerging monitoring technologies using a literature review. Where applicable, these emerging technologies will be compared to conventional systems and current practices.
4. Perform synthesis and develop a final report. The documentation and evaluation of health monitoring systems will be summarized and synthesized to provide recommendations for immediate implementation or further investigation. The recommendations will be provided for each of the issues identified as part of Task 1, recognizing that different needs may exist. The final report will also address the development of potential laboratory and field demonstration projects that could be used to evaluate the most promising monitoring systems.

Phase II. Laboratory evaluation of monitoring sensors and data processing methods

5. Select bridge types for demonstration testing.
6. Develop monitoring plans for selected bridge types; this will include the selection of the specific types of instrumentation to be used and the design of the data acquisition system.
7. Monitor test specimens to collect long-term behavioral data for selected structure types. Load tests with known loads will also be performed to verify system performance.
8. Develop data processing techniques, with particular emphasis on experimental data filtering/processing techniques and analytical processing methods of the data. It is envisioned that these techniques will focus on bridge signature analysis for damage detection. The signature analysis will also be useful for fatigue evaluation, maintenance management, and bridge security.
9. Prepare final report to summarize all work completed, including the general performance of the structures, design of the data acquisition and instrumentation systems, and data processing techniques.

Phase III. Field evaluation of monitoring sensors and data processing methods

10. Select infrastructure field structures for demonstration testing.
11. Develop monitoring plans for the field structures identified for monitoring. This will include the selection of specific types of instrumentation to be used and the design of the data acquisition system.
12. Monitor field-test structures under known and ambient conditions. This task will primarily consist of collecting long-term behavioral data for the subject structures. However, discrete load tests with known loads will also be performed to verify system performance.
13. Develop data processing techniques, with an emphasis on data filtering and data processing techniques. After this review, the research team will develop specific tools for processing data

that would be collected on highway bridges in various states. It is envisioned that these techniques will focus on bridge signature analysis for damage detection. The signature analysis will be useful for fatigue evaluation, maintenance management, and bridge security.

14. Prepare a final report which will summarize all work completed including the general performance of the suspect bridge details, design of the data acquisition and instrumentation systems, and data processing techniques.

Phase IV. Develop application tools and training program for bridge owners

15. Synthesize all of the report information from previous tasks in Phases I, II, and III.
16. Develop application tools for bridge monitoring and evaluation, including design and evaluation recommendations and guidelines.
17. Develop training materials related to implementation of monitoring and evaluation practices.

Phase V. Develop quick, inexpensive load rating techniques

18. Synthesize available technologies that could be used to perform load ratings.
19. Synthesize load rating techniques used by the military and other "quick response" organizations.
20. From the information gathered in Tasks 1 and 2, develop a new approach to load rating that is quick and inexpensive.
21. Perform field verification of the new system by making comparisons with currently available techniques.
22. Prepare a final report.

Coordination with Other Projects

- 1-9.2—Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems

Products, Benefits, and Implementation

Products

- Data processing techniques and a generic monitoring plan, including data-reduction procedures

Benefits and Implementation

The benefits are that these techniques will give bridge owners tools to more effectively monitor the condition and performance of bridges over their life. A clear explanation of the benefit (both cost and engineering based) will be needed to illustrate why these techniques should be implemented.

Research Period and Funding Requirement

Phase I: 0.5 years, $250,000
Phase II: 1 year, $1,000,000 (includes costs associated with construction laboratory mock-ups)
Phase III: 2 years, $2,500,000 (includes costs for field installing sensor systems on in-service bridges)
Phase IV: 1 year, $250,000
Phase V: 1.5 years, $1,000,000
Total: 6 years, $5,000,000

Tactic 10. Preserve Facility Life

Total highway investment by all units of government reached $128.5 billion in 2000. Extending facility life through proactive preservation activities not only shows good stewardship of the public's investment but also significantly reduces disruption. In spite of this significant investment, needs greatly outpace the current investment levels, and the ability to finance renewal projects without jeopardizing other programs remains the biggest challenge facing project owners.

Figure 13. Bridge Preservation (Source: Oregon DOT-Region 4)

Therefore, it is imperative that one of the essential components of a rapid renewal program is the preservation of existing facilities for the longest possible time at the required level of performance (see Figure 13). Additional techniques are needed to extend the life of roadways that carry high traffic volumes, to strengthen bridges without total reconstruction, and to retrofit bridges that were not built with redundant structural members.

Tactic:
Preserve facility life

Barrier:
High traffic volumes

Project 1-10.1. Preservation Approaches for High Traffic Volume Roadways

Funding: $750,000 Duration: 2 years Priority: High

Extending the life of infrastructure elements with the timely use of preservation techniques has been an important strategy for many years, particularly as the demands on capital budgets greatly outpace current revenue. Relatively small investments for preservation activities, if properly timed and applied, can significantly increase infrastructure life. Many helpful proprietary products as well as generic products are currently available. Additional product development and research are ongoing as agencies seek ways to proactively preserve their investment in existing infrastructure.

However, the application of preservation strategies to high traffic volume roadways, whether existing or part of a renewal project, presents a complicated set of challenges. Many of the products and approaches that are acceptable on lower traffic volume roadways are simple not acceptable or workable on high traffic volume roadways. Often either the impact to traffic is too great to use a particular product or application, or the treatment is not successful under high-traffic conditions. Guidance is needed on matching the condition of the infrastructure element to a specific treatment and identifying what the benefit/cost will be.

Objective

- Identify preservation strategies and products that are usable on high traffic volume roadways.
- Develop documentation on the benefit/cost of various treatments.
- Identify potential opportunities for further development of preservation treatments.

Scope

This project will look at domestic and international strategies for infrastructure preservation and develop guidance on which approaches and products are appropriate for high traffic volume applications. Additionally, promising opportunities for further development will be documented. There are three parts to the project to address asphalt-based solutions for flexible and rigid pavements, portland cement based solutions for rigid pavements, and bridge preservation strategies.

Tasks

Part A. Asphalt-based solutions for flexible and rigid pavement surfaces

1. Identify the current state-of-the-art through a literature search and survey of current practices.
2. List the available strategies—chips seals, surface treatments, fog seals, rejuvenators, etc.
3. Identify the potential opportunities and needs in a rapid renewal situation. Clearly distinguish this research from what was tried in the Strategic Highway Research Program (SHRP), what will be tried here, how this is different, and why it is important.

4. Link time to build. Aim for a very short window of six hours or less of productive time. Integrate aggregate quality with advanced binders (modified).
5. Develop pavement evaluation, design procedures, construction specifications (method and performance), advanced QC/QA systems.
6. Describe potential opportunities for future research.
7. Prepare final report.

Part B. Hydraulic cement based solutions for rigid pavement surfaces

8. Identify the current state-of-the-art through a literature search and survey of current practices.
9. List the available strategies—patching, spall repairs, grinding, slab stabilization, undersealing, dowel bar retrofit, etc.
10. Identify the potential opportunities and needs in a rapid renewal situation. Clearly distinguish this research from what was tried in SHRP.
11. Link to time to build. Aim for a very short window of six hours or less of productive time.
12. Develop pavement evaluation, design procedures, construction specifications (method and performance), advanced QC/QA systems.
13. Describe potential opportunities for future research.
14. Prepare final report.

Part C. Bridge preservation strategies

15. Identify the current state-of-the-art through literature search and survey of current practices.
16. List the available strategies—patching, spall repairs, grinding, grooving, waterproofing, chloride removal processes, thin overlays, etc.
17. Identify the potential opportunities and needs in a rapid renewal situation. Clearly distinguish this research from what was tried in SHRP.
18. Link time to build. Aim for a very short window of six hours or less of productive time.
19. Develop deck evaluation, design procedures, construction specifications (method and performance), and advanced QC/QA systems.
20. Describe potential opportunities for future research.
21. Prepare final report.

Coordination with Other Projects

- 1-5.2—Integrating the “Mix of Fixes” Strategy into Corridor Development

Products, Benefits, Implementation

- Guidelines on preservation strategies for high traffic volume roadways
- Methodology and supporting data to determine the benefit/cost of various treatments
- Recommendations for further research opportunities

Research Period and Funding Requirement

Total: 2 years, $750,000

Tactic:
Preserve facility life

Barrier:
Lack of methods to extend life

Project 1-10.2. Bridge Repair/Strengthening Systems

Funding: $2,000,000 Duration: 2 years Priority: High

Significant speed of construction, minimized traffic disruption, reduced costs, etc. can be achieved by repairing or strengthening existing structures rather than replacing them. Systems are needed to repair and strengthen structures quickly and simply with good connections and other details that are economical and that produce long-lasting performance. The use of such systems will avoid extended delays and traffic disruption due to costly replacements when rehabilitation is adequate. In addition, tools are needed to determine whether or not it is most cost-effective to repair/strengthen a bridge or to replace it.

Objective

- Develop systems for repairing and strengthening bridges.

Scope

This project will develop systems for repairing and strengthening bridges, including standard drawings, specifications, and training materials.

Tasks

1. Perform a literature review of repair and strengthening systems currently in use.
2. Conduct a survey of bridge owners to identify current and future repair and strengthening needs.
3. Develop systems that address the needs from Tasks 1 and 2 using analytical and laboratory studies.
4. Conduct field demonstration projects to evaluate the effectiveness of the developed systems.
5. Working with industry, develop standard drawings and specifications for design, materials, and construction suitable for use by bridge owners.
6. Develop training materials.

Coordination with Other Projects

- 1-2.1—Modular Bridge Systems
- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology

Products, Benefits, and Implementation

The products of this work will be standard drawings and specifications for the repair and strengthening of bridges. The benefits of this work will be that the developed systems will allow existing bridges to continue to be used without the need for new construction. Successful implementation of the results of this project will rely on successful demonstrations and easy-to-use tools.

Research Period and Funding Requirement

Tasks 1 and 2: $50,000
Tasks 3 and 4: $1,500,000
Tasks 5 and 6: $500,000
(Note: This project's scope could be divided into three separate projects based on a combination of tasks as given above.)
Total: 2 years, $2,000,000

Tactic:
Preserve facility life

Barrier:
Lack of methods to extend life

Project 1-10.3. Techniques for Retrofitting Bridges with Non-redundant Structural Members

Funding: $1,500,000 Duration: 3 years Priority: Medium

One particular class of steel bridges that requires special attention is fracture critical bridges, many of which are nearing the end of their design lives. Failure of a member in a fracture critical bridge would likely force the closing of the bridge, resulting in major traffic disruption. Often fracture critical bridges must be shut down, or other highways they cross must be shut down, so that inspections can be performed. There exists a need to study the concept of redundancy, recommend a definition of "non-redundant," and to develop renewal techniques for removing "non-redundant" characteristics.

Objective

- Develop renewal techniques for addressing and removing non-redundant bridge characteristics.

Scope

This project will develop techniques for addressing non-redundant bridges.

Tasks

1. Perform a literature review on redundancy.
2. Conduct a survey of bridge owners to identify types of non-redundant bridges.
3. Study the concept of redundancy and recommend a definition of "non-redundant."
4. Develop rehabilitation and replacement techniques for eliminating structural "non-redundancy."
5. Working with industry, develop standard drawings and specifications suitable for use by bridge owners.
6. Develop training materials.

Coordination with Other Projects

- 1-2.2—Develop Bridge Designs That Take Advantage of Innovative Construction Technology

Products, Benefits, and Implementation

Products

- Standard drawings and specifications for addressing "non-redundant" bridges

Benefits

The benefit of this work will be that the developed systems will include redundancy to be established in fracture critical structures.

Implementation

Successful implementation of the results of this project will rely on successful demonstrations and easy-to-use tools.

Research Period and Funding Requirement

Total: 3 years, $1,500,000

SECTION G. MANAGEMENT OF THE RESEARCH

Table 5 shows the budget for each project, including researcher hours, support staff hours, and special equipment costs. Facilities and expertise requirements by project are also shown.

Basis Used to Develop Estimates

- **"Researchers"** includes principal investigators and professional staff or faculty assigned to the project. The average hourly rate for researchers is estimated at $150/hour.

- **"Support Staff"** includes laboratory and field technicians, project financial managers, and secretarial support. The average hourly rate for support staff is estimated at $60/hour.

- **"Special Equipment/Other Direct Costs"** includes laboratory equipment and supplies, field-testing equipment, materials to use in field and laboratory tests, travel, printing, shipping, and other cost items. Generally, 10 percent is allocated to special equipment and other direct costs. For projects that require a state partner to field-test a new material or construction technique, it is assumed that the F-SHRP budget will have to pay for at least some of the incremental cost of the new approach. In these cases, 20 to 30 percent of the project budget is allocated to the special equipment category. Obviously, if state partners are able to cover the entire incremental cost of the new approach, the project budgets can be reduced. This will play out as the projects develop over time.

Notes on Facilities and Expertise

- **Special Facilities:** When private sector partners are listed in the special facilities column, it means that the F-SHRP budget should be used to leverage private sector investment. For instance, Project 1-6.1, New Guidelines for Improving Public Involvement in Renewal Strategy Selection, may require private sector partners. Part of the project involves analyzing the visualization tools that are available. If the analysis finds that improved tools are warranted, negotiations with private sector developers should ensue. It is not likely that an F-SHRP contractor could make a significant contribution to this field with the funds proposed.

- **Special Expertise:** "Law" is listed as a special expertise item in some projects (such as those in the 1-4 series on innovative and equitable contracting) because state or federal procurement or contracting laws might prohibit certain innovative approaches. Similarly, 1-5.3 on financing, 1-6.3 on utilities, and 1-6.4 on railroads are all affected by bodies of law. Researchers must be aware of the legal limitations and propose strategies to address them.

Table 5. Management Plan

Research Projects	Project Duration (years)	Total Budget	Researcher Hours (at $150/hr.)	Support Staff Hours (at $60/hr.)	Special Equipment/ Other Direct Costs (% of total basis)	Special Facilities	Special Expertise
1-1. Perform Faster In Situ Construction							
1-1.1. Utilities Location Technology Advancements	5	$5,000,000	$3,500,000 (23,333 hrs.)	$500,000 (8,333 hrs.)	$1,000,000 (20%)	Test sites, state partnerships	NDE
1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction	5	$2,000,000	$1,400,000 (9,333 hrs.)	$200,000 (3,333 hrs.)	$400,000 (20%)	Test sites, test materials	Geotechnical engineering
1-1.3. Replacement of Conventional Materials with High-Performance Materials in Bridge Applications	3	$2,150,000	$1,505,000 (10,033 hrs.)	$215,000 (3,583 hrs.)	$430,000 (20%)	Test sites, state partnerships, test materials	Material science, structural engineering
1-1.4. Rapid Rehabilitation Strategies of Specialty Structures	6	$4,000,000	$2,800 (18,667 hrs.)	$400,000 (6,667 hrs.)	$800,000 (20%)	Laboratory	Structural engineering, NDE, seismic mitigation
1-1.5. Micropiles for Renewal of Bridge Foundations	2	$1,000,000	$800,000 (5,333 hrs.)	$100,000 (1,667 hrs.)	$100,000 (10%)	Test sites, state partners	Geotechnical engineering, structural engineering
1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System	5	$1,000,000	$800,000 (5,333 hrs.)	$100,000 (1,667 hrs.)	$100,000 (10%)	Private industry partners	Civil engineering, software engineering
1-1.7. Facilitating the Use of Recycled Aggregates	3	$2,500,000	$2,000,000 (13,333 hrs.)	$250,000 (4,167 hrs.)	$250,000 (10%)	Laboratory, accelerated testing equipment	Material science, civil engineering
1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments	2	$1,500,000	$1,200 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	None	Human factors specialists, civil engineering, construction engineering
1-2. Minimize Field Fabrication Effort							
1-2.1. Modular Bridge Systems	6	$9,550,000	$4,775,000 (31,833 hrs.)	$1,910,000 (31,833 hrs.)	$2,865,000 (30%)	Test sites, state partners, test materials, industry partners	Structural engineering
1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology	4	$4,000,000	$2,400,00 (16,000 hrs.)	$400,000 (6,667 hrs.)	$1,200,000 (30%)	Laboratory, test sites, state partners, test materials, industry partners	Structural and construction engineering

Table 5. Management Plan (continued)

Research Projects	Project Duration (years)	Total Budget	Researcher Hours (at $150/hr.)	Support Staff Hours (at $60/hr.)	Special Equipment/ Other Direct Costs (% of total basis)	Special Facilities	Special Expertise
1-2.3. Modular Pavement Technology	4	$2,500,000	$1,750,000 (11,667 hrs.)	$500,000 (8,333 hrs.)	$250,000 (10%)	Laboratory, accelerated testing equipment, test site (as needed)	Civil and construction engineering
1-3. Perform Faster Construction Inspection and Monitoring							
1-3.1. High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	5	$5,000,000	$3,500,000 (23,333 hrs.)	$500,000 (8,333 hrs.)	$1,000,000 (20%)	Laboratory, test sites, sensing equipment	NDE, physics, civil engineering, electrical engineering, software engineering
1-4. Facilitate Innovative and Equitable Contracting Environment							
1-4.1. Performance Specifications	5	$2,225,000	$1,780,000 (11,867 hrs.)	$222,500 (3,708 hrs.)	$222,500 (10%)	State partners	Specifications engineering, civil engineering, law, software engineering
1-4.2. Alternate Contracting Strategies for Rapid Renewal	4	$2,000,000	$1,600,000 (10,667 hrs.)	$200,000 (3,333 hrs.)	$200,000 (10%)	State partners	Civil engineering, law, economic analysis, software engineering
1-4.3. Incentive-Based Specifications to Assure Meeting Rapid Renewal Project Goals	3	$1,500,000	$1,200,000 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	None	Civil engineering, law, economic analysis
1-4.4. Development and Evaluation of Performance-Based Warranties	4	$1,500,000	$1,200,000 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	State partners	Civil engineering, law, economic analysis
1-4.5. Risk Manual for Rapid Renewal Contracts	3	$1,000,000	$800,000 (5,333 hrs.)	$100,000 (1,667 hrs.)	$100,000 (10%)	None	Civil engineering, law, economic analysis
1-4.6. Innovative Project Management Strategies for Large, Complex Projects	2	$750,000	$600,000 (4,000 hrs.)	$75,000 (1,250 hrs.)	$75,000 (10%)	None	Construction engineering, civil engineering, business

Table 5. Management Plan (continued)

Research Projects	Project Duration (years)	Total Budget	Researcher Hours (at $150/hr.)	Support Staff Hours (at $60/hr.)	Special Equipment/ Other Direct Costs (% of total basis)	Special Facilities	Special Expertise
1-5. Plan Improvements to Mitigate Disruption							
1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process	3	$1,250,000	$1,000,000 (6,667 hrs.)	$125,000 (2,083 hrs.)	$125,000 (10%)	None	Traffic engineering, civil engineering, software engineering
1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development	3	$1,500,000	$1,200,000 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	None	PCC engineer, ACC engineer, structural engineer
1-5.3. Strategic Approaches for Financing Large Renewal Projects	3	$1,000,000	$800,000 (5,333 hrs.)	$100,000 (1,667 hrs.)	$100,000 (10%)	None	Finance, economic analysis, simulation, law
1-6. Improve Customer Relationships							
1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection	3	$2,500,000	$2,000,000 (13,333 hrs.)	$250,000 (4,167 hrs.)	$250,000 (10%)	State partners, private sector partners, visualization software/hardware	Public relations, engineering animation, civil engineering
1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects	4	$1,500,000	$1,200,000 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	None	Public relations, engineering animation, civil engineering
1-6.3. Utilities-DOT Institutional Mitigation Strategies	6	$3,000,000	$2,400,000 (16,000 hrs.)	$300,000 (5,000 hrs.)	$300,000 (10%)	State partners	Utility management, civil engineering, law
1-6.4. Railroad-DOT Institutional Mitigation Strategies	4	$1,750,000	$1,400,000 (9,333 hrs.)	$175,000 (2,917 hrs.)	$175,000 (10%)	State partners	Railroad management, civil engineering, law
1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods	3	$750,000	$600,000 (4,000 hrs.)	$75,000 (1,250 hrs.)	$75,000 (10%)	None	Civil engineering, public relations, law
1-7. Improve Traffic Flow in Work Zone							
1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety	3	$2,000,000	$1,400,000 (9,333 hrs.)	$200,000 (3,333 hrs.)	$400,000 (20%)	State partners, private sector partners, ITS equipment, simulation models	Traffic engineering, ITS engineering (including monitoring), simulation modeling, construction engineering

Table 5. Management Plan (continued)

Research Projects	Project Duration (years)	Total Budget	Researcher Hours (at $150/hr.)	Support Staff Hours (at $60/hr.)	Special Equipment/ Other Direct Costs (% of total basis)	Special Facilities	Special Expertise
1-8. Design and Construct Low-Maintenance Facilities							
1-8.1. Durable Bridge Subsystems	6	$6,000,000	$3,600,000 (24,000 hrs.)	$600,000 (10,000 hrs.)	$1,800,000 (30%)	Laboratory, state partners, test sites, test materials	Structural engineering
1-8.2. Design for Desired Bridge Performance	3	$3,000,000	$2,100,000 (14,000 hrs.)	$300,000 (5,000 hrs.)	$600,000 (20%)	State partners	Structural engineering, software engineering
1-8.3. Composite Pavement Systems	4	$5,000,000	$3,500,000 (23,333 hrs.)	$500,000 (8,333 hrs.)	$1,000,000 (20%)	Laboratory, test materials, state partners	PCC engineering, ACC engineering, construction engineering
1-8.4. Stabilization of the Pavement Working Platform	3	$1,600,000	$960,000 (6,400 hrs.)	$160,000 (2,667 hrs.)	$480,000 (30%)	Laboratory, NDE equipment, stabilization materials	Geotechnical engineering, NDE
1-8.5. Using Existing Pavement in Place and Achieving Long Life	2	$1,000,000	$700,000 (4,667 hrs.)	$100,000 (1,667 hrs.)	$200,000 (20%)	State partners	PCC engineering, ACC engineering
1-9. Monitor In-Service Performance							
1-9.1. NDE Methodology for Unknown Bridge Foundations	2	$1,000,000	$800,000 (5,333 hrs.)	$100,000 (1,667 hrs.)	$100,000 (10%)	State partners	NDE, civil engineering
1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems	6	$4,000,000	$2,800,000 (18,667 hrs.)	$400,000 (6,667 hrs.)	$800,000 (20%)	Pontis source code	Software engineering, structural engineering
1-9.3. Monitoring and Design of Structures for Improved Maintenance and Security	6	$5,000,000	$3,000,000 (20,000 hrs.)	$500,000 (8,333 hrs.)	$1,500,000 (30%)	Test sites, state partners, monitoring equipment	Electrical engineer, structural engineer
1-10. Preserve Facility Life							
1-10.1. Preservation Approaches for High Traffic Volume Roadways	2	$750,000	$600,000 (4,000 hrs.)	$75,000 (1,250 hrs.)	$75,000 (10%)	None	ACC engineer, PCC engineer, structural engineer
1-10.2. Bridge Repair/Strengthening Systems	2	$2,000,000	$1,200,000 (8,000 hrs.)	$200,000 (3,333 hrs.)	$600,000 (30%)	Test sites, state, partners, private industry partners	Structural engineering
1-10.3. Techniques for Retrofitting Bridges with Non-Redundant Structural Members	3	$1,500,000	$1,200,000 (8,000 hrs.)	$150,000 (2,500 hrs.)	$150,000 (10%)	Private industry partners	Structural engineering

SECTION H. IMPLEMENTATION

Implementation is the process for putting research into practice. The implementation can begin at the end of the research phase, but history and experience suggest that a linear approach is slow and cumbersome. The most effective time to begin the implementation is early in the research phase of the program; responsibilities will grow as the research progresses. See Figure 14.

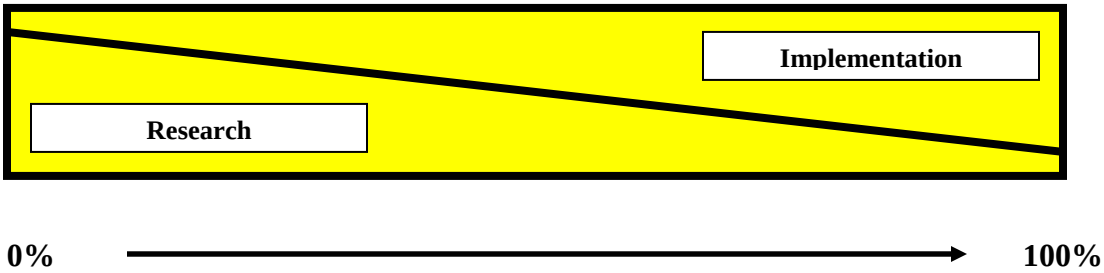


Figure 14. Research Implementation

The implementation process involves four functions:

1. Identify the research results that are of greatest interest and importance to specific DOTs and industry.
2. Show the research throughout in both face-to-face meetings and through media outreach efforts.
3. Evaluate the results within the context of DOT and industry experiences and knowledge.
4. Apply or deploy the technology on a permanent basis.

A small implementation effort at the beginning of the process will ensure that the research statements are clear about the expected outputs and the eventual requirements for implementation at the end of the line. At key junctions, the implementers will help assess the research as to whether the products are actually materializing and are marketable. Also, if the implementers are put in the lead for the outreach and communication effort, they will more effectively communicate to their peers in their language. The team believes this concept is particularly important in the F-SHRP Renewal program for several reasons:

1. Renewal is a new concept—another “R” word to add to restoration, rehabilitation, and reconstruction. It is not a universal word or concept to many elements of the industry. It needs to be understood and marketed early and often.
2. Research proposed in F-SHRP is both technical and procedural. It will involve many more elements of the DOTs—from planning, finance, and design to construction and maintenance. Renewal will require a systems approach to implement most of the research findings.
3. Nearly all of the projects have built-in evaluations as part of research, followed by final completion of the work. Researchers will need to work closely with the DOTs early and often. Implementers can play a key role in this effort.
4. Nearly all DOTs will have extensive experience with many of the research concepts, unlike with SHRP, which was developing something totally new in many cases.
5. Many of the concepts are very challenging to the construction industry and will require constant and open communication.
6. Finally, there will be no need for a learning curve as the implementers have been involved from the start.

One of the most important elements in implementation is the method established to carry it out. Implementers should be intimately involved in the development of at least two mechanisms:

1. A mechanism to assist DOTs with implementation of new approaches and making the necessary changes to organizational behaviors and, in some cases, state laws, in order to achieve the benefits promised by research results

It is envisioned that a "Renewal Clearinghouse" (or some other name) would be a virtual clearinghouse for brokering the talent necessary to advise states and industry on major projects or new processes. This helps achieve the goal of continuous application of new approaches, because the knowledge gained through experience can be transferred to new situations. The brief case examples shown in Section E are just a few of the examples where creative approaches and new technologies have been applied. The clearinghouse would provide awareness, organization, and travel funds to bring the experts into planned projects early in the process. This is the time to discuss the scope of the project, funding mechanisms, application of new rapid technologies, public involvement, railroad and utility issues, etc.

Part of the clearinghouse function would be to apply tools developed by F-SHRP research. The goal is to yield a systematic approach for evaluating new technologies, an expert system to aid in seeing the impacts, and detailed action plans for implementation of different technologies and processes. The clearinghouse would exercise these tools as aids to encouraging acceptance and implementation of new approaches.

A particularly critical element for rapid renewal of roadways is implementation of new rapid-construction bridge technologies. Bridges are often on the critical time path to renewal, so it is vital that rapid-construction bridge technologies be employed in order to achieve the goals of renewal. A special effort to deploy innovative bridge technologies is critical.

2. A mechanism to partner with the public sector to bring products to market to assist industry with implementation

A policy for engaging the private sector in cost-sharing and partnership arrangements to deliver products to market is very important. Many of the products used in the construction industry or by state DOTs are small market items by industrial standards. Good products often do not become commercially available simply due to the small size of the market.

The FHWA has supported development of products by contractors and then has made the designs available to the commercial market. An example is the Maintenance Decision Support System (MDSS), a weather forecasting and deicing distribution package developed by national laboratories for the FHWA. The intent was to develop and field-test the MDSS under contract and then make the software code and technologies available so the private sector could deliver MDSS products.

In some cases, it may be necessary to include a product developer as part of the research team if it is clear at the beginning that development of a product is necessary. Even so, a policy must be in place to allow the designs, specifications, or other products to be acquired by other commercial producers.

The Renewal Clearinghouse could employ an advisory board of manufacturing business leaders, venture capitalists, or other such individuals with experience in bringing products to market. They could advise at the request for proposals stage and at the stage where a prototype is available. The purpose of this group would be to keep commercial implementation in mind throughout the development process and then plan for a successful handoff at the end. This group could develop models for partnering, use existing models, and address patent and proprietary ownership issues.

SECTION I. SCHEDULE AND BUDGET

Project funding estimates are provided for each project in Section F. Table 6 shows budget, priority, estimated duration, and start year. Projects with a high-priority start in Year 1; projects with a medium priority start in later years but are scheduled for completion within the six-year time frame of the F-SHRP program. The annual cash-flow requirements approximate the annual funds anticipated to be available.

Table 6. Project Budget Summary and Schedule
(All Costs Given in $1,000s)

Research Projects	Priority	Years	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Total
1-1. Perform Faster In-Situ Construction									
1-1.1. Utilities Location Technology Advancements	H	5	$400	$1,500	$1,500	$1,000	$600		$5,000
1-1.2. Geotechnical Solutions for Soil Improvement and Rapid Embankment Construction	H	5		$250	$500	$500	$500	$250	$2,000
1-1.3. Replacement of Conventional Materials with High-Performance Materials in Bridge Applications	M	3				$650	$500	$1,000	$2,150
1-1.4. Rapid Rehabilitation Strategies of Specialty Structures	M	6	$1,000	$1,000	$1,000	$500	$250	$250	$4,000
1-1.5. Micropiles for Renewal of Bridge Foundations	H	2	$500	$500					$1,000
1-1.6. Needs Assessment and Implementation Plan for Developing a Comprehensive Intelligent Project Delivery System	M	5	$200	$200	$200	$200	$200		$1,000
1-1.7. Facilitating the Use of Recycled Aggregates	H	3	$500	$1,000	$1,000				$2,500
1-1.8. Identifying and Reducing Worker, Inspector, and Manager Fatigue in Rapid Renewal Environments	H	2	$750	$750					$1,500
1-2. Minimize Field Fabrication Effort									
1-2.1. Modular Bridge Systems for New Construction	H	6	$1,500	$1,000	$1,500	$2,000	$1,500	$2,050	$9,550
1-2.2. Develop Bridge Designs That Take Advantage of Innovative Construction Technology	M	4			$500	$1,500	$1,500	$500	$4,000
1-2.3. Modular Pavement Technology	M	4			$425	$1,000	$950	$125	$2,500
1-3. Perform Faster Inspection and Construction Monitoring									
1-3.1. High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection	H	5	$1,000	$1,000	$1,000	$1,000	$1,000		$5,000
1-4. Facilitate Innovative and Equitable Contracting Environment									
1-4.1. Performance Specifications	H	5	$225	$500	$500	$500	$500		$2,225
1-4.2. Alternate Contracting Strategies for Rapid Renewal	H	4	$250	$750	$750	$250			$2,000
1-4.3. Incentive-Based Specifications to Assure Meeting Rapid Renewal Project Goals	H	3	$750	$500	$250				$1,500
1-4.4. Development and Evaluation of Performance-based Warranties	M	4			$250	$250	$500	$500	$1,500
1-4.5. Risk Manual for Rapid Renewal Contracts	M	3				$250	$250	$500	$1,000
1-4.6. Innovative Project Management Strategies for Large, Complex Projects	H	2	$500	$250					
1-5. Plan Improvements to Mitigate Disruption									
1-5.1. Strategic Approaches at the Corridor and Network Level to Minimize Disruption from the Renewal Process	H	3	$500	$250	$500				$1,250
1-5.2. Integrating the "Mix of Fixes" Strategy into Corridor Development	H	3	$750	$250	$500				$1,500
1-5.3. Strategic Approaches for Financing Large Renewal Projects	H	3	$600	$200	$200				$1,000

$750

Table 6. Project Budget Summary and Schedule (continued)
(All Costs Given in $1,000s)

Research Projects	Priority	Years	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Total
1-6. Improve Customer Relationships									
1-6.1. New Guidelines for Improving Public Involvement in Renewal Strategy Selection	M	3				$500	$1,000	$1,000	$2,500
1-6.2. New Guidelines for Improving Business Relationships and Emergency Response During Renewal Projects	M	4			$250	$250	$250	$750	$1,500
1-6.3. Utilities-DOT Institutional Mitigation Strategies	H	6	$400	$750	$750	$500	$500	$100	$3,000
1-6.4. Railroad-DOT Institutional Mitigation Strategies	H	4	$700	$500	$500	$50			$1,750
1-6.5. Context-Sensitive Designs and Construction Operations to Minimize Impact on Adjacent Neighborhoods	M	3				$200	$200	$350	$750
1-7. Improve Traffic Flow in Work Zone									
1-7.1. Design, Installation, and Maintenance of Work Zones for High Consistency, Visibility, and Safety	H	3	$750	$750	$500				$2,000
1-8. Design and Construct Low Maintenance Facilities									
1-8.1. Durable Bridge Subsystems	H	6	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$6,000
1-8.2. Design for Desired Bridge Performance	M	3				$500	$1,000	$1,500	$3,000
1-8.3. Composite Pavement Systems	M	4			$500	$1,000	$1,000	$2,500	$5,000
1-8.4. Stabilization of the Pavement Working Platform	M	3				$1,000	$300	$300	$1,600
1-8.5. Using Existing Pavement in Place and Achieving Long Life	M	2					$500	$500	$1,000
1-9. Monitor In-Service Performance									
1-9.1. NDE Methodology for Unknown Bridge Foundations	M	2					$500	$500	$1,000
1-9.2. Development of Rapid Renewal Inputs to Bridge Management and Inspection Systems	M	6	$750	$750	$750	$750	$500	$500	$4,000
1-9.3. Monitoring and Design of Roadways and Structures for Improved Maintenance and Security	H	6	$1,250	$1,000	$1,000	$350	$1,000	$400	$5,000
1-10. Preserve Facility Life									
1-10.1. Preservation Approaches for High Traffic Volume Roadways	H	2	$500	$250					$750
1-10.2. Bridge Repair/Strengthening Systems	H	2	$1,000	$1,000					$2,000
1-10.3. Techniques for Retrofitting Bridges with Non-redundant Structural Members	M	3				$500	$500	$500	$1,500
Total			$15,775	$15,900	$15,825	$16,200	$16,500	$15,075	$95,275

SECTION J. RESEARCH PROJECTS NOT INCLUDED IN F-SHRP

During the course of the deliberations leading to the development of the F-SHRP Renewal research plans, a number of commendable research topics were identified that are not included in the final plan. In some cases, these need statements were omitted from the program because their relationship to rapid renewal was not as strong or as obvious as for the projects that were included. In other cases, the research topics were too large scale and beyond the scope of what could be accomplished through F-SHRP. Lastly, some needs were perceived as more incremental, traditional research than desired for F-SHRP. Nonetheless, these research topics have merit. They are included here for the record and in hopes that others might pursue these topics through other means and funding mechanisms.

Project J-1. Accelerate the Deployment of Bridge and Pavement Asset Management Tools

Since the early 1990s the transportation community has recognized the need to find new and innovative ways to do business. With the 21st century transportation agencies at all levels are responding to demands to deliver new and improved services while becoming more efficient and optimizing the use of available funding.

Asset management represents one of the emerging philosophies that make it possible for the 21st century agency to make better investment decisions. Since 1996, FHWA, TRB, AASHTO and other associations have pursued the foundational work to establish asset management in the transportation community.

Although asset management systems have been under development and in use in some areas for a number of years now, the effective integration of these systems as useful decision-making tools by public agencies has not occurred as universally as would be beneficial. Both AASHTO and TRB Asset Management Task Forces continue to provide leadership, education, and identification of future needs for the transportation community. These efforts are highly beneficial and need to continue to accelerate the implementation and deployment of such systems.

Important strides have been made toward implementation of pavement and bridge management systems. However, continued effort is needed to integrate these systems so that trade-off analysis can be conducted across asset categories and for the overall infrastructure system.

To effectively deploy an effective asset management system, several issues need to be addressed. These issues cover a wide array of topics ranging from data integration, better analytical tools, economic analysis, incentive and training programs, and a full array of educational and technology transfer products. Making advances in these areas will enable agencies to effectively utilize asset management principals and make them part of routine business processes.

Objectives

The objectives of this research are to move asset management implementation forward on four fronts:

- **Research.** Research is needed in a number of areas, including the development of analytical tools, trade-off analysis, data integration, and benefit assessment.
- **Outreach.** Outreach is made up of a series of items designed to inform agency professionals of asset management and to assist them in deciding to embrace the concept. Using the recently developed assessment tool (part of the asset management guide), agencies will be asked to submit

their evaluation of their current state of asset management practice. This will assist in defining future direction and provide feedback to each interested agency.

- **Support.** Asset management does not simply happen. Agencies need to learn, develop plans, and take specific steps to make it a reality. A sponsored support mechanism is needed to avoid reinventing asset management implementation in each agency. This mechanism should include support for the use of asset management principles to support future statements of the current and expected condition of the transportation facility.
- **Education.** Professionals in the transportation industry need to better understand the workings of asset management. Education has many elements, including the identification, documentation, and dissemination of best practices and the creation of a master plan for education of future professionals.

Scope

This project will include research and development of asset management tools and practices, as well as educational development, outreach, and ongoing support to promote and assist in implementation.

Tasks

Part A. Research

- Conduct a literature review to identify current research in the area of asset management. The search should cover state and local highway agencies in the United States and internationally.
- Continue interagency cooperation (AASHTO, TRB, and FHWA) to determine future research needs.
- Develop methods to quantify the benefits of implementing asset management.
- Identify, develop, and demonstrate application of analytical tools and techniques to support asset management resource allocation strategies.
- Develop and publish guidance on data needs, including asset inventory, condition, activities, and cost tracking to support decision-making.
- Provide guidance in the development and use of performance measures consistent with agency, political, budgetary, and customer requirements.

Part B. Outreach

- Conduct an outreach program to stakeholders including presentations to illustrate the benefits of asset management.
- Disseminate best practices in asset management.
- Establish a master plan for addressing education and training needs that incorporates the needs of stakeholders, employers, users, politicians, and others.

Part C. Support

- Develop a business process support system to support the following activities: resource allocation, tradeoffs, performance measures, and performance budgeting.
- Develop an incentive and marketing system to promote the use of asset management.
- Link to other initiatives such as the Government Accounting Standards Board Statement 34 (GASB 34), security, etc.

Part D. Education

- Develop training programs to increase organizational competency.
- Identify best practices in asset management.
- Create or enhance an intern program that educates and involves students in asset management and raises the level of awareness in career opportunities.

Products, Benefits, and Implementation

Products

- Guide on data needs
- Business process support system
- Incentive and marketing system
- Training programs to increase organizational competency
- Student intern program

Benefits

- Cost savings and improved, more efficient decision-making
- Better allocation of resources
- An improved level of service for the overall transportation system
- Better customer satisfaction with that system

Implementation

Implementation of the research findings and products will be facilitated through the outreach, educational, and support systems. The student intern program will help to provide a pool of qualified individuals to lead the implementation forward. As AASHTO and TRB have already established task groups on asset management, their support of implementation efforts is assured.

Research Period and Funding Requirement

Part A: $5,000,000
Part B: $500,000
Part C: $1,000,000
Part D: $750,000
Total: $7,250,000

Project J-2. Next Generation Models for Asphalt Pavement Performance

The recent coordinated efforts to develop a performance test for asphalt mixes (NCHRP Project 9-19) and the improvements in asphalt pavement design reflected in the AASHTO *2002 Design Guide* (NCHRP Project 1-37a) mark major improvements in our ability to design asphalt mixtures for known performance and service lives. However, these efforts, particularly the work under NCHRP Project 9-19, were constrained by the fact that they were built on existing models and testing techniques. The models used are mechanistic-empirical. In addition, only three failure distresses were addressed: rutting, fatigue, and thermal cracking. There are other distresses that contribute to the failure of asphalt pavements for which reliable predictive models and tests do not exist; these include reflective cracking, stripping, delamination, and others.

In order to be able to reliably predict the performance of asphalt pavements and the materials that constitute those pavements, it is necessary to have improved performance prediction models that cover the full range of relevant failure mechanisms. This ability to predict the ultimate pavement performance at the design phase is crucial to the goals of renewal. Pavements should be designed for selected design lives and should be able to achieve those design lives reliably. A pavement may be designed to resist rutting under the current practices and models, but if it fails due to reflective cracking and stripping the public is again confronted with a major rehabilitation or replacement. New models that take advantage of improved technologies and more complete, fundamental understanding of a wider range of failure mechanisms will help to ensure that pavements do not fail prematurely and traffic can flow unimpeded by orange barrels.

New, improved performance prediction models can also feed into the asset management system to allow better network-level decisions to be made. Life-cycle cost evaluations will also be improved through more reliable modeling. Work is needed, then, to develop the next generation of advanced, mechanistic predictive models that will improve our predictive capabilities, allowing us to design for specific design lives and incorporate innovative renewal strategies. This development will require a long-range, coordinated research approach that is beyond the capabilities of the existing NCHRP program to fund.

Objective

- Develop improved, integrated performance prediction models for all of the major failure modes of asphalt pavements, including permanent deformation; fatigue, thermal, reflective and top-down cracking; and moisture damage.

Scope

This research will involve extensive laboratory research and development of new test procedures; analytic development of new predictive models; and field evaluations of existing pavements, especially those whose performance has been closely monitored, such as experimental or warranty projects, across the country.

Tasks

Phase I. Develop improved models and test methods

- Review the literature and identify research completed or in progress to develop advanced material characterization and pavement predictive models for a wide range of distress types (including permanent deformation; fatigue, thermal, reflective and top-down cracking; and moisture damage, at a minimum), materials (conventional and porous, SMA, and other HMA types) and pavement structures (full-depth and composite).
- Develop advanced material characterization models, integrating models for different distress types to the extent possible.
- Identify data elements needed in the advanced predictive models and test procedures to obtain that data.
- Conduct a laboratory test program to evaluate, refine, and calibrate characterization and predictive models.
- Conduct a laboratory test program to analyze the sensitivity of the material characterization models to changes in mixture and binder properties.
- Develop advanced pavement performance prediction models for permanent deformation; fatigue, thermal, reflective and top-down cracking; and moisture damage, at a minimum, based on the results of Phase I.
- Develop software as needed to implement the improved models. To the extent possible, models should be modules that can replace or be added to the existing AASHTO 2002 design software.
- Beta-test and debug the new software modules.

Phase II. Validate characterization and performance models

- Identify test sites for field validation of the material characterization and performance models.
- Collect samples of materials from field sites, including both original raw materials and field samples.
- Collect required data elements for validation of the models, including materials and material properties, traffic, environmental factors, pavement structure and layer properties, etc.
- Collect pavement response and performance data, including condition, distress, structural strength (FWD), etc.
- Predict performance of test sites based on material characterization and pavement performance models developed in Phase I.

- Compare actual field performance to predicted performance. Revise or calibrate new models accordingly.

Products, Benefits, and Implementation

Products

- Advanced test methods, in AASHTO format
- Improved performance models for asphalt mixtures and pavements incorporating a wide array of distress types
- Improved pavement design procedures
- More accurate pavement management tools and life-cycle cost analyses
- Training materials
- Guides, software, etc. for using the improved tests and analysis tools

Benefits and Implementation

The benefits of developing and implementing advanced pavement performance models are that they would provide better tools to design a pavement renewal strategy for a particular application to provide a certain service life. This ability would allow designers to take advantage of a "mix of fixes" approach, including rapid techniques, to bring a corridor to a consistent level of service and minimize disruption while also providing for long-lasting pavements. The same tests and models could be used for design, construction quality control and assurance, and performance modeling, as is currently envisioned for the AASHTO *2005 Design Guide*.

Research Period and Funding Requirement

Phase I. 5 years, $7,000,000
Phase II. 3 years, $3,000,000
Total: 8 years, $10,000,000

Project J-3. Validating the AASHTO 2002 Design Guide

The development of the *2002 Guide for the Design of New and Rehabilitated Pavement Structures* is a comprehensive research effort aimed at fulfilling the goal of building facilities of desired performance and service life. After completion of the research efforts some fine-tuning and enhancement of the guide can be anticipated in the near future. This may include evaluating pavement distress models and material models for unbound and bound materials that provide the estimation of the performance life of facilities in the design guide. The implementation of the new design guide is a major task for state highway agencies and needs to be incorporated in national training programs. However, the design guide has been developed mainly for the traditional dense graded asphalt mixtures and conventional concrete pavements. Research is needed to study the impact of asphalt mixtures like stone mastic asphalt and noise reducing open graded friction course mixtures on structural capacity and pavement performance. Additional elements of research may also be needed for less conventional types of PCC pavements, such as porous concrete and ultrathin whitetopping.

The AASHTO *2002 Design Guide*, when implemented, will mark a major improvement in roadway structural design. The guide is being developed to include state-of-the-practice performance models and tests. Its use is expected to provide improved pavement performance and longer lasting pavements. Additional work is needed, however, to take full advantage of the potential improvements. Limited validation of the performance models in the *2002 Design Guide* is being attempted under NCHRP Project 1-37a using data in the LTPP database. NCHRP Project 9-30 is developing an experimental plan and budget to verify the validity of the models using actual materials properties measured using the

recommended test procedures and related to actual field performance. The LTPP database is not sufficient to accomplish this. The plan developed under NCHRP Project 9-30 should be implemented and expanded to include new and innovative renewal techniques developed through the F-SHRP Renewal program, such as modular and composite pavements. This information can then be used to expand and refine the *2002 Design Guide*.

This effort will provide reliable tools to the designer to select and design renewal options that will improve pavement performance and extend service life. By expanding the list of techniques addressed by the guide, it will be possible to include evaluation of pavement preservation and rapid renewal techniques through the same process used for more conventional construction/rehabilitation techniques. This will facilitate the consideration of renewal strategies that are rapid and minimally disruptive, as well as long lasting.

Objective

- Validate the AASHTO *2002 Design Guide* using actual field performance.

Scope

This project will involve field and laboratory testing and data analysis to compare the predictive models to field performance.

Tasks

1. Critically review the research plans developed under NCHRP Project 9-30 for validation of the *2002 Pavement Design Guide*. Refine or expand the plans as necessary. Prepare a detailed draft experimental plan for calibration and validation of the *2002 Pavement Design Guide* models.
2. Following panel review and approval of the plan developed in Task 1, implement the plan as follows:
   - Identify appropriate field-test sites.
   - Collect required samples and data elements (materials and pavement information, properties and performance).
   - Conduct laboratory and field-testing as required.
   - Predict pavement performance using the *2002 Design Guide* models.
   - Compare predicted to actual field performance.
   - Refine or calibrate models as needed to predict actual performance.
   - Modify the *Design Guide* and software as needed to implement refinements.
   - Document the research in a final report.

Coordination with Other Projects

This study is seem as an intermediate step to provide validation of the current 2002 guide pending further refinements and advanced models to be developed under the long-range plan identified in project J-2. The refinements developed under J-2 will be add-ons to the existing guide and will be validated under J-2. This project will help to facilitate the implementation of the *2002 Design Guide* by validating the procedures and will lay the groundwork for validating the expanded and improved guide to be developed under J-2. The long-range research envisioned under J-2 will not provide implementable results for many years, so the *2002 Design Guide* will need validation in the interim.

Products, Benefits, and Implementation

This project will further the implementation of the AASHTO *2002 Design Guide* by providing validation and calibration of the models, giving designers confidence in the ability of the models to predict performance. The benefits of that implementation will include improved pavement performance.

Research Period and Funding Requirement

Task 1: 0.5 years, $75,000
Task 2: 4 years, $2,500,000
Total: 4.5 years, $2,575,000

Project J-4. New and Innovative Materials and Techniques for Rapid Renewal

In order to achieve rapid renewal, a variety of techniques will be needed for different situations. Many situations will include the need for rapid repair of an existing element of the infrastructure to minimize lane closures, accommodate nighttime operations or extend the construction season. These situations, in turn, will require specialized innovative materials that can function despite being applied under less than ideal conditions. Materials are needed that can withstand extreme temperatures, humidity, frost, etc.; are forgiving; are compatible with the existing material; are light weight for certain applications; and are durable.

Many materials are already on the market that purport to have the qualities needed for a variety of rapid renewal applications. The designer of a renewal project, however, is often at a loss to select the best renewal technique for a given situation. The proprietary nature of many of these products makes it difficult to generically specify a material for a particular renewal application. In addition, the way these products are marketed makes it difficult to compare one renewal strategy or material option to another. Guidance is needed on how to select the best renewal strategy and material for a given situation.

The efficient repair and replacement of infrastructure elements requires that repair materials be effectively positioned in a distressed facility and gain sufficient properties that will enable them to provide excellent long-term performance. While we typically request materials with the highest strength, bond, and long-term performance, this is not always achieved and may create additional problems due to incompatibilities with the existing structural system.

Repair materials have typically been designed to provide specific strength and bond properties, but little attention has been paid to the long-term durability and overall performance of the amalgamated system. Frequently, repairs are made using materials that are later found to be incompatible with the existing pavement, structures, and environment, causing these materials to fail prematurely, frequently requiring re-repair. Improvements are needed to develop a framework that will enable long-lasting repair options to be consistently provided when they are needed.

Alternatively, a number of short-term repair strategies may be needed to maintain a facility's serviceability for a few years until global rehabilitation can be performed. These repairs are frequently made using high-cost materials that are designed to provide excellent long-term performance since engineers are familiar with these materials. As a result, when full rehabilitation of the structure is performed the repaired sections have been over-built. Value engineering concepts need to be incorporated to allow engineers to specify specific materials for specific repair needs.

Currently, repair systems are a niche market and specification procedures can vary widely depending on location. As such, many smaller companies provide limited information on their products and test results correspond more appropriately to new construction. To unify the information provided by suppliers and enable selections to be determined, a larger, more comprehensive approach to classify and qualify repair systems is needed.

New and innovative materials tend to be expensive, but are needed for specialized, low-volume applications related to renewal. The benefits of such materials are that they allow us to take advantage of rapid renewal techniques to minimize disruption. You can propose overnight repairs, but unless you have materials that can perform in four-to-six hours, you will not be successful.

Objectives

- Prepare a comprehensive compendium of available techniques and materials to facilitate rapid renewal.
- Identify materials that are needed for certain renewal applications, but are not yet available on the market.
- Develop an expert system to guide designers and specifiers in the selection of materials for a given renewal application, particularly those requiring rapid renewal techniques.

Scope

This research will include such considerations as self-compacting concrete, hybrid technologies, rapid concrete curing techniques, self-inspecting materials, and more. Materials applicable to pavements and bridges will be considered. The project will lead towards an expert system to guide selection of the appropriate repair material and/or techniques for a particular application.

This project will involve reviewing and critiquing existing materials on the marketplace and identifying where materials are needed for particular applications, but are not yet available. This project will not include development of new materials. The missing materials will be made known to industry in hopes of encouraging industry to fill the gaps identified.

Tasks

1. Identify available renewal techniques and materials for bridge and pavement repair, preservation or replacement through Internet and literature searches and surveys of agencies and industry.
2. Investigate the various techniques and materials to determine their best applications, application conditions and requirements, performance, limitations, costs, etc. Compile or develop guide specifications for use of these techniques or materials.
3. Prepare a compendium of available techniques/materials for specific renewal applications.
4. Develop an expert system to guide designers to select the best renewal strategy or options for specific applications, including considerations of type of structure or pavement, traffic, climate, desired closure time, material properties, desired life, cost, and other appropriate parameters.
5. Beta-test and debug the expert system.
6. Provide training materials and conduct a pilot course to train designers on use of the expert system.
7. Identify needed renewal strategies that do not currently exist. Inform industry of the identified gaps through presentations, newsletters, industry associations, and other means to encourage industry to develop the needed materials or techniques.
8. Document the research through a final report.

Products, Benefits, and Implementation

Products

- Expert system to guide designers through selecting a renewal strategy and appropriate material for a given renewal application, such as a bridge repair material that can be opened to traffic in four hours in the winter
- List of materials needed for particular renewal applications but not available, which will encourage industry to develop products for that niche market

Benefits and Implementation

This project will assist designers in choosing an innovative repair strategy and/or material for a particular application, greatly expanding their toolbox of strategies. This, in turn, will lead to wider use of innovative techniques in appropriate applications, faster and longer-lasting repairs, reduced traffic restrictions, and better life-cycle costs. Guide specifications, in AASHTO format, will facilitate implementation.

Research Period and Funding Requirement

Task 1: 6 months, $100,000
Task 2: 9 months, $200,000
Task 3: 6 months, $50,000
Task 4: 9 months, $300,000
Task 5: 6 months, $150,000
Task 6: 6 months, $100,000
Task 7: 6 months, $50,000
Task 8: 6 months, $50,000
(Note: Tasks overlap or occur concurrently.)
Total: 3 years, $1,000,000

Project J-5. Repair and Preservation Systems to Achieve Desired Life

The concept of a “mix of fixes” is central to the effective management of a corridor. Within a given corridor, there will be pavement or bridge segments that need extensive rehabilitation or replacement and other segments that need little or no rehabilitation. Since the ultimate desire is for the entire corridor to perform for a long period of time, it may be prudent to preserve segments of the pavement during the corridor improvements to ensure that those segments last as long as the remainder of the corridor. Pavement preservation techniques may be well suited, in many cases, to ensuring that various segments of the corridor can achieve the desired service life.

Pavement preservation is the preferred terminology for preventive maintenance. The concept is to preserve the pavement and ensure it meets its desired service life by performing selected preventive maintenance measures to prevent distresses and thereby prolong life.

Pavement preservation can impact renewal by providing minimally invasive techniques that can be used to forestall major rehabilitation work. Most pavement preservation can be accomplished very quickly, often in one-pass, under traffic. Thus pavement preservation can help to meet the goals of rapid construction and minimal disruption. In addition, by prolonging the life of the pavement, preservation helps to meet the goal of a long life. This extension may be particularly well suited to corridor operations.

The AASHTO Pavement Preservation Lead State Team took a number of steps to promote the concepts of pavement preservation. They also identified a number of remaining needs. Pavement preservation techniques should be integrated into the asset management system. Guidance is needed on the types of construction and performance data necessary to support the management system. The performance life and life-cycle costs of various pavement preservation techniques for pavements in different states of repair need to be quantified.

Linking pavement preservation to the pavement management system is key. This link is necessary to the efficient allocation of resources to manage pavement conditions and maintain or improve the condition level. Only by incorporating pavement preservation into the pavement management system can rational

decisions be made regarding the need for preventive maintenance, corrective maintenance, rehabilitation or reconstruction. Properly applying pavement preservation can postpone the need for major renewal and thereby forward the goals of renewal.

Objectives

- Integrate pavement preservation into pavement management so that preservation techniques can be used efficiently for renewal.
- Evaluate the performance of existing repair systems.
- Develop new or enhance existing repair systems to achieve the desired performance life and minimize traffic disruption.

Scope

This project will identify and quantify key parameters that should be included pavement management systems to allow pavement preservation to be integrated into the system. Due to the wide variety of pavement management platforms in use across the country, the development of software is not envisioned.

Tasks

1. Conduct literature review and survey, including review of materials from the AASHTO Lead State Team for Pavement Preservation and relevant data from the LTPP database.
2. Identify pavement preservation techniques applicable to specific renewal circumstances, their limitations, benefits, life expectancy under given conditions, etc.
3. Develop of life-cycle cost analysis techniques for pavement preservation.
4. Identify key considerations regarding pavement preservation and development of recommendations for integrating pavement preservation into a pavement management system.
5. Develop guidelines for the use of various pavement preservation strategies and incorporation of those strategies into existing pavement materials systems.
6. Develop training materials to promote the implementation of pavement preservation techniques and their incorporation in pavement management systems. Conduct a pilot course.
7. Document the research effort through a final report, guidelines, training programs, seminars, etc.

Products, Benefits, and Implementation

Products and Benefits

- More widespread use of effective and economical pavement preservation strategies in appropriate applications to provide a high level of service and lower life-cycle costs
- Prediction tools that relate the quality of the repair or preservation technique with performance to provide for better and more cost-effective decision-making
- Training program to facilitate implementation of the findings

Implementation

Implementation will be facilitated by the training program.

Research Period and Funding Requirement

Task 1: 6 months, $150,000
Task 2: 9 months, $300,000
Task 3: 12 months, $350,000
Task 4: 12 months, $150,000
Task 5: 9 months, $100,000
Task 6: 9 months, $150,000

Task 7: 9 months, $50,000
(Note: Tasks overlap or occur concurrently.)
Total: 3 years, $1,250,000

Project J-6. Work Zone Communication Techniques

Improved communication with the public in work zones requires accurate information to maintain public trust and compliance, automated technologies because of the rapidly-changing traffic conditions in work zones, standard symbols that can be instantly recognized, and uniform work zone geometry. This project will investigate the elements of improved communication.

The high level of compliance with regulatory traffic control systems is attributed to the fact that signs and signals reflect actual conditions and police enforcement is always a possibility. In work zones, when no work is underway or traffic information is incorrect, speed limits are unrealistic, or there is no threat of enforcement, motorists pick up the pace, whether or not it is safe. Furthermore, suggesting an alternate route, prior to a work area, due to outdated traffic information with unclear signs and directions causes the public to lose confidence.

Automation is the key for providing accurate, real-time information and enforcement in work zones. Rather than having an operator in a control center relay messages to motorists based on observations of the site, appropriate messages should be automatically displayed on the message boards according to current traffic conditions. Physical enforcement will have to be enhanced with automated enforcement for safety and cost reasons. The most critical information is actual traffic speed downstream. ITS technologies can be installed in work zones to monitor traffic speed and provide that information to approaching motorists in real time. Strengthening this concept to a dynamic speed limit with automated photo-enforcement is the end state of this technology. Reliable detour information with travel-time estimates would also increase public trust in the information. If, for example, a suggested detour is congested an alternate route can immediately be recommended to the drivers. System automation would definitely improve public confidence in the information and consequently encourage speed compliance.

The information presented to motorists prior to or within a work zone may be an advisory speed, a speed limit, a diversion route, and/or a congestion warning message. The information should be presented in an easy-to-understand format that drivers can quickly comprehend. Following successful practices in some European countries, symbols, rather than text, should be used in variable message signs to relay information on a suggested diversion route or a traffic backup.

The symbols could be based on geometric shapes, pictures, or colors. With a recommended diversion route, for example, the symbol is presented on variable message signs at all decision points along the route. Symbols should also be used for congestion, worker presence, incident, and slippery pavement rather than alerting motorists with lengthy text. Research in this area is required to make the variable message signs easy to understand and follow. Involvement of linguistic and human behavior experts is anticipated.

Objectives

- Develop and test a comprehensive list of symbols to replace currently used texts on variable message signs in work zones.
- Develop a standard ITS-based data collection and motorist communication strategy that states can apply in their work zone traffic control strategies.

- Develop consensus standards as needed for work zone ITS technologies following the National Transportation Communications for ITS Protocols (NTCIP) and other standard-setting processes.

Tasks

Phase I. Standard symbol set

1. Conduct a literature review to identify current practices in using symbols to inform motorists in Europe and elsewhere.
2. Develop a comprehensive list of symbols under different categories (e.g., geometric shape, color, and picture).
3. Evaluate the impact of using symbols on variable message signs on drivers' reactions to the provided information. Using a driving simulator, examine the differences between the reactions of a set of selected individuals exposed to symbol and text messages under an identical driving condition.
4. Conduct a public survey to examine the public attitudes toward the use of symbols. Using the survey, the public knowledge and understanding of selected symbols can also be measured.
5. Educate the public through media, billboards, and distribution of brochures and flyers at highway rest stops and elsewhere. Work with local and state legislators to overcome possible opposition to using the symbols.
6. Field-test the most promising symbols at selected urban and rural areas. Compare the results with the simulator outcome.
7. Make recommendations and document in a report.

Phase II

8. Conduct a survey of work zone technologies and practices as a basis for establishing standard ITS work zone practices.
9. Conduct a literature review to identify gaps in current telecommunication and technology “handshake” protocols for work zone traffic control strategies.
10. Form a research focus group consisting of public and private stakeholders to oversee the research. The focus group should include the field researchers, developers, vendors and operators, and other state and local beneficiaries.
11. Identify the most promising universal telecommunication platforms capable of seamlessly connecting the current work zone traffic control strategies. Work with standards-setting organizations and processes like the NTCIP, Institute of Electrical and Electronics Engineers, and American Society for Testing and Materials to establish consensus standards as needed to ensure that implementable products are commercially available.
12. Coordinate efforts of the involved industries and developers to adjust or convert the existing work zone strategies according to the universal telecommunication platforms identified in Task 3.
13. Evaluate the platforms at five work zones with totally different geometries and configurations. Each work zone will include randomly selected traffic control techniques.
14. Make recommendations and document project in the final report.

Products, Benefits, and Implementation

- Standard symbols set for communicating visually with the public
- Standards ITS layouts
- Consensus standards

Research Period and Funding Requirement

Phase I: 2 years, $1,000,000
Phase II: 3 years, $1,500,000
Total: 5 years, $2,500,000

Project J-7. Design for Desired Pavement Performance

Changes in the type and quality of materials used for both the construction of new and renewal of existing pavements necessitate the need for updating the existing pavement design methodologies. With over 170,000 miles of aging interstate and national highways, the United States is facing problems of epidemic proportion as the demand on these structures is rapidly increasing (72 percent over the last two decades) despite only a 1 percent increase in capacity over the same time. The 2001 report card for America's Infrastructure issued by the American Society of Engineers noted that over "one-third of the nation's major roads are in poor or mediocre condition." It is estimated that delays and damage caused by the roads costs the American citizens $5.8 billion a year. Further, poor road conditions and over-congestion contribute to as many as 13,800 highway fatalities annually with over 30 percent of all fatal highway accidents involving outdated and substandard road and bridge design, pavement conditions, and safety features.

One can argue that a considerable amount of the information that is required to determine a strategy for repair and rehabilitation of pavements is already available through various research initiatives on both national and state levels. Most notable of these efforts include the recent development of the AASHTO *2002 Design Guide*, LTPP Program, and various research projects conducted by the FHWA. For example, since over 70 percent of pavement design dollars are spend on rehabilitation, the newly developed AASHTO *2002 Design Guide* for the first time emphasizes rehabilitation design. It uses existing mechanistic-empirical technologies and contains procedures for evaluation of existing pavements, recommendations on rehabilitation treatments, material characterization guidelines, and procedures for life-cycle cost analysis. The research team developing the *AASHTO 2002* Guide will validate the existing pavement performance models using data from the LTPP Program and other sources.

Although all of the above mentioned initiatives will provide many choices for an engineer considering rehabilitation of pavement, no comprehensive set of guidelines is currently available to enable systematic selection among the alternatives. The ultimate goal of the research proposed during this project will be to develop guidelines that will enable selection of repair or rehabilitation strategies based on minimum overall cost and take into account all relevant factors, including existing condition, rate of deterioration, life of the repair, and the residual life of the pavement. Specifically, this project will focus on linking the type and quality of the proposed repair and rehabilitation technique with the required length of service of the pavement. It is envisioned that procedures will be developed for design for varying length of service (from short-term repairs to long-lasting rehabilitations) as appropriate for the existing needs. By considering the efficiency of repair along with the desired length of service of the rehabilitated structure, the proposed approach should result in design procedures that are well suited for a "mix of fixes" approach to maintaining the efficiency of the traffic corridor.

To a large part, designing for renewal is borne from the concepts used in conventional design, however it is essential that we understand new needs that must be addressed to enable the efficient pavement design with predictable, attainable performance. Two of the most important elements that contribute to the performance of concrete pavement over its lifetime are mixture composition and the construction practices used to mix, place, and cure the mixture in the field. All too often we develop short-term, or one time solutions for long-term repeating problems. The drive to accelerated construction practices frequently leads to design, material, and construction modifications that can negatively impact long-term performance. For example, accelerated concrete curing may lead to rapid strength gain which may be desirable for rapid pavement opening, however this rapid development of material properties may influence aspects of the pore system which are responsible for mass transport (e.g., chloride penetrability) negatively. This means that the rules of thumb developed over the last century are less applicable as the

construction and curing windows shorten. Similarly, high early strength materials may be very brittle or susceptible to premature cracking, which has a great impact on long-term performance though it is not frequently, explicitly considered in design.

To overcome these problems designers must have the ability to select material parameters that relate to all aspects of performance and public policy. Conventional concrete pavements, for example, are 'designed' for a thirty-year life however, other than strength, thickness, and support, few of the other essential design choices are in the engineers' hands. Furthermore, other than specification of appropriate traffic loading and fatigue considerations, little is done to quantify that a 30-year life is provided with a 30-year design. Frequently durability one of the key issues that dictates how well a pavement may perform in service, however it is becoming increasingly common to find the infrastructure crumbling due to the use of materials without sufficient durability. Historically, civil engineering focused on strength-based design, using a database of QC/QA testing procedures have been largely developed through experience and observation. As the transportation industry moves forward, we need to develop design procedures that integrate designing for traffic, material selection, exposure conditions, modularity, and public policy. For example, while 60-year pavement designs may require the best sources of aggregate and binder, short-term fixes may take advantage of using marginal or problematic recycled materials. This can provide incentives for using marginal materials. Additionally, material properties need to be considered concurrently with design. Furthermore, several issues like wet weather safety and noise are directly related to construction practices that need to be carefully considered with the use of newer materials.

Clearly, money alone will not solve our infrastructure problems. This development of integrated design procedures for highway renewal is an integral part of a plausible renewal process that will enable efficient designs that incorporate longer lasting, maintenance-free materials. Engineers need to develop design procedures that specifically account for the desired life of the design, traffic, construction speed and quality, durability, environmental impact, and safety.

Objectives

- Build on the existing efforts to introduce the mechanistic-empirical approach to pavement design and rehabilitation.
- Develop a comprehensive pavement design guide that takes into account all factors influencing the performance of the pavement, including existing condition of the pavement, load carrying capacity, rate of deterioration, effect on traffic, life of the repair and the residual life of the pavement.

Scope

The existing information related to repair and rehabilitation strategies used in pavements will be searched and compiled. The search will include detailed information as to materials used, equipment and construction details, and test procedures used for evaluating the condition of existing pavement. Once this information is collected a series of models will be developed that can be used to relate the rate of deterioration to projected service life and local exposure conditions. Next, the set of guidelines will be developed that will help to (1) evaluate the condition of the existing pavement, (2) help to select an appropriate rehabilitation/repair strategy depending on the desired life of the structure, and (3) help to select the type of material that can deliver the desired performance.

The proposed work will be an extension of the approach taken in the AASHTO *2002 Design Guide* where (due to the gaps in the existing knowledge base) mechanistic relationships had to be supplemented by empirical relationships. A considerable amount of information is already available through existing databases, especially in the area of durability. Part of the efforts during this project will include quantification of the effects of durability of materials on the rate of deterioration so this information can

be incorporated in development of models that can tie the material properties and quality of construction with pavement performance.

Tasks

The proposed project will be accomplished in four phases:

- Phase I. Focus on collecting the information and development of a framework for the guide
- Phase II. Development of the working draft of the guidelines, laboratory testing, development of new and refinement of the existing models linking material properties and construction practices with the rate of deterioration and service life
- Phase III. Revision of the guidelines, development of the design software, calibration and fine-tuning of the proposed procedures, preparation of the training material
- Phase IV. Implementation of revisions and modifications; pilot training sessions

Tasks involved in the research effort will include the following:

1. Compile information related to the observed common forms of pavement deterioration and evaluate their effects on pavement performance.
2. Identify and evaluate existing methods of taking deterioration into account in the assessment of pavement performance and planned restoration/repair approach.
3. Develop procedures for field data collection, analysis, and incorporation into design procedures. Specifically it is envisioned that additional testing procedures will be used to obtain more uniform reliable data.
4. Develop of the pavement design procedure that links the quality and cost of the repair with the required service life of the rehabilitated pavement taking into account material properties and local environmental and loading conditions.

Products, Benefits, and Implementation

The information developed as a part of this research effort will be used to develop design procedures for infrastructure renewal that carefully consider all aspects of design that are related to performance. Incorporated in these guidelines will be models accounting for the rate of deterioration that will account for the quality of materials used and the existing condition of the pavement in predicting its expected service life. Linking all of the above elements in a single, comprehensive design procedure will allow for a flexible approach to rehabilitation and repair where quality and type of repair will be directly linked to the length of service. In addition to design guidelines, the product of this research will include training material needed for implementation of the findings as well as suggested field validation and calibration procedures.

Research Period and Funding Requirement

Phase I: 2 years, $1,500,000
Phase II: 1 year, $2,000,000
Phase III: 3 years, $2,000,000
Phase IV: 2 years, $400,000
(Note: Tasks overlap or occur concurrently.)
Total: 5 years, $5,900,000

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