IN-PLACE PAVEMENT RECYCLING:

GAPS, BARRIERS, AND A PATH FORWARD

Summary of
Workshop Held during the
2014 International and Western States
In-Place Recycling Conference

August 5–7, 2014

Denver, Colorado

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INTRODUCTION

The 2014 International and Western States In-Place Recycling Conference was held in Denver, Colorado, on August 5–7, 2014. The conference was sponsored by the Federal Highway Administration, Asphalt Recycling and Reclaiming Association (ARRA), National Center for Pavement Preservation, Colorado Department of Transportation, and Texas A&M Transportation Institute. Industry associated with in-place recycling sponsored several conference activities including a field trip to view a hot in-place recycling operation and a cold central plant recycling operation. Over 180 participants attended the conference, with 18 states and several foreign countries (Canada, China, the Czech Republic, and Peru) represented. The members of the conference-organizing committee are listed in Appendix A.

This was the seventh In-Place Recycling Conference sponsored by the Federal Highway Administration. Attendance at this conference was greater and more diverse (more states and international participation) than at any of the previous conferences. Representative from the public sector (state departments of transportation, the Federal Highway Administration, and local governments), private sector (contractors, equipment manufacturers, materials suppliers, and consulting engineers), and the academic community attended the conference.

The first two days of the conference provided a summary of the present state of the practice for in-place recycling. Over 37 presentations were given during the conference. The major topics addressed in these presentations included project selection, mixture design, structural design, specifications, performance, life-cycle costs, life-cycle assessment, extent of use, and time required for construction. A copy of the presentations and the video of the conference are available from the National Center for Pavement Preservation website. https://www.pavementpreservation.org/conferences/regional-in-place-recycling-conferences/2014-place-recycling-conference/

Based on the foundation provided by this state-of-the-practice presentation and the collective knowledge of the participants, a significant portion of the third day of the conference was devoted to a workshop session to identify gaps in knowledge and barriers associated with the use of in-place pavement recycling. The purpose of the workshop was to develop a path forward that will result in wider acceptance and use of these pavement rehabilitation/maintenance techniques.

Appendix B contains a copy of the conference program, which consisted of a briefing of all participants, breakout sessions, and a reporting session. A total of 3 hours and 15 minutes was allocated for the workshop. The breakout sessions were established based on three common types of in-place recycling: cold in-place recycling, full-depth reclamation, and hot in-place recycling.

This report presents a summary of the workshop session associated with this conference.

BACKGROUND

Various forms of in-place pavement recycling have been used to rehabilitate and maintain pavements in the United States since the 1930s. The oil embargo of the 1970s created a financial climate, an energy shortage, and high pavement binder costs that stimulated the use and development of in-place recycling. New binder materials, construction equipment, construction operations, mixture design, quality control/quality assurance techniques, and specifications were rapidly developed in the 1970s and early 1980s that improved in-place recycling techniques. Equipment manufacturers concurrently improved their equipment to upgrade and include new technologies in the process.

Since the 1980s, incremental improvements have been made with in-place recycling technology. The use of in-place recycling alternatives for rehabilitation and maintenance of highway and road systems has not increased substantially. In specific public agencies, in-place recycling has declined in use.

In-place recycling and reclaiming, consisting of cold in-place recycling, full-depth reclamation, and hot in-place recycling, are used in a number of regions of North America. Regional use appears to be associated with industry's physical location and marketing and public agency acceptance. As public agency officials and industry change, so does the general acceptance of in-place recycling. The benefits of the various forms of in-place recycling need to be based on their proven economic, engineering, and environmental advantages in the various climate regions of North America. In-place recycling needs to be more of an engineering science than a construction art form.

The definitions of the various forms of in-place recycling are different in various parts of the world. Some definitions are as follows:

- **Cold in-place recycling (CIR) (cold partial-depth in-place recycling):** partial-depth pulverization (2 to 5 inches) of the asphalt bound layers in a pavement, addition of a recycling agent and emulsified asphalt or foamed asphalt, mixing of the recycling agent and pulverized/sized material, laydown, and compaction. Cold central plant recycling, where existing stockpiles of recycled materials are mixed in a stationary recycling unit or a central plant pugmill, is similar to CIR. The only difference is the materials are processed off site rather than on the road. Cold central plant recycling and CIR are often combined and referred to as cold recycling.
- **Full-depth reclamation (FDR) (cold full-depth in-place recycling):** pulverization of the asphalt bound layers (6 to 12 inches) of the pavement and a portion of the underlying materials, with or without the addition of a stabilizer (portland cement, lime, asphalt emulsion, or foamed asphalt), spreading, and compaction.
- **Hot in-place recycling (HIR)—surface recycling:** softening of the asphalt bound surface through heating and scarified (1 to 2 inches) with tines or a milling head. The scarified material is mixed with a rejuvenating agent (recycling agent), placed with standard hot-mix asphalt paver, and compacted.
- **HIR—remixing:** similar to surface recycling, except the scarified/milled material is mixed with a pugmill or mixing drum with new hot-mix asphalt (typically 18 to 25 percent) or aggregate, if desired, and placed as one layer.
- **HIR—repaving:** similar to surface recycling, except a lift of hot-mix asphalt is placed directly on top of the loose surface recycled material and compacted simultaneously as one layer.

PURPOSE OF WORKSHOP

The purposes of the workshop were as follows:

- Provide a forum for public agencies (federal, state, and local government), industry (equipment manufacturers, material manufacturers, and contractors), engineering consultants, and academic/research agencies to discussion in-place recycling.
- Assess what we know today (current state of the knowledge) and identify gaps in knowledge for each form of in-place recycling, including the following:
    - Project selection including evaluation of the existing condition of candidate projects (visual condition survey, falling weight deflectometer, ground-penetrating radar, geometrics, drainage, etc.).
    - Mixture design including assessment of in-place materials, selection of virgin binders, and evaluation for need of new aggregates, binders, and mixtures.
    - Structural design including support contributed from the existing structure and the load-carrying capability of in-place recycled material.
    - Specifications including material selection, mixture design, equipment requirements, construction operations (cure time, traffic control, etc.), quality control/quality assurance, acceptance, warrantees, measurement, payment, etc.
    - Performance including life cycles for typical forms of in-place recycling.
    - Life-cycle cost analysis (LCCA) including first costs, life cycles, and maintenance requirements.
    - Life-cycle assessment (LCA) including energy conservation, emission reduction, natural resources conservation, and costs.
    - Extent of use and typical uses of in-place recycling.
    - Opportunities to reduce time of construction.
- Identify barriers as viewed by public agencies and industry, and provide information to overcome barriers to the implementation of in-place recycling.
- Summarize the discussion during the workshop.
- Identify research, development, and implementation needs, using the following key items:
    - Problem statement.
    - Introduction/background.
    - Scope/objective.
    - Estimated duration/funding level.

SUMMARY OF BREAKOUT SESSIONS

Three breakout sessions were used to address the topics of the workshop, organized by subject area:

- CIR.
- FDR.
- HIR (including the three forms of HIR: surface recycling, remixing, and repaving).

The CIR breakout session had 60 participants, the FDR breakout session had 40 participants, and the HIR breakout session had 30 participants. Notes were captured from the discussion during the more than three hours of the breakout sessions. A summary of the items discussed is briefly presented as follows. The next subsection discusses topics common to all sessions, and the three subsections following discuss information of use primarily to a particular form of in-place recycling.

Topics Common to All Sessions

All breakout sessions were asked to address the following topics: project selection, mixture design, structural design, specifications, performance, LCCA and LCA, construction contracting, barriers and methods to overcome barriers, and research, development, and implementation needs. The time allowed for the breakout sessions was not sufficient to allow for recognition of many of the barriers and approaches to overcome these barriers, and to define research, development, and implementation needs in detail.

Project Selection

All groups identified project selection guidance as a need. This guidance should be incorporated into the various rehabilitation/maintenance alternative decision trees of public-agency pavement management systems and in agency design manual guidance for pavement and materials engineers.

Mixture Design

Mixture design methods are available for all forms of recycling. Improvements and national or regional consistency in these methods are needed.

Structural Design

Structural design layer coefficients are available for all forms of recycling. The basis for these coefficients and variability remains largely undefined. Characterization of in-place recycled materials is needed to provide input into mechanistic empirical design methods. Validated, consistent, and typical recycled mixture-specific structural values are needed.

Specifications

Specifications for the various forms of in-place recycling vary significantly among public agencies. More uniformity and improved specifications are needed. Contractor qualifications, equipment calibration, quality control and quality assurance methods, and criteria are also needed. Sampling techniques for the various operations need attention.

Performance

Performance information over an extended period of time is largely not available. The Colorado Department of Transportation study documenting the performance life of each type of in-place recycled pavement in Colorado needs to be repeated in many of the western states. Material and structural properties over typical design life periods are also needed.

LCCA and LCA

Life cycle cost analysis (LCCA) and life cycle assessment (LCA) are needed for a wider variety of conditions including the type of in-place recycling operation, traffic conditions, and environmental conditions. Few detailed studies are currently available.

Construction Contracting

All groups discussed construction contracting topics. The development of a contractor prequalification system and an incentive/disincentive system was discussed without conclusion.

In-place recycling operations are typically subcontracts in a larger contract. Some participants indicated that the in-place recycling operations should be a separate contract. Speed of construction was recognized as a potential benefit for in-place recycling as compared to the more traditional rehabilitation and maintenance operations. Some contractors would like to see more project information prior to bidding the project. This includes information about the existing pavement structural section, the condition of the pavement, and the properties of the materials to be recycled. Consistent minimum required plan details for project designers are needed for each recycled method.

CIR Discussion
Obtaining high densities or low air voids with CIR operations is difficult. Compaction operations and equipment need to be improved. Compaction chemical aids and optimization of breaking and setting of asphalt emulsions and foamed asphalts are areas of interest. Most CIR operations are used on roadways that require opening to traffic at the end of the work day. Compaction of the recycled material (relatively high liquid content) and opening to traffic without raveling and rutting (relatively low liquid content) must be balanced to obtain the desired early performance and end product.

Uniformity of mix design, additive selection, and specification across public-agency jurisdictions was identified as a need. Improvement in ride quality for CIR was also identified as a need.

Variability in performance of CIR was noted. Short-term and long-term performance was identified as an issue. Project selection, improved recycling processes, and improved recycling agents and other additives were identified as potential area to investigate to help reduce project variability.

Some participants indicated that prequalification of contractors would improve the quality of the operations. In addition, equipment calibration requirements should be considered for inclusion in specifications or for prequalification. Separate contracts for CIR and other project operations were also identified as a potential benefit. Lack of availability of CIR contractors was mentioned in the session.

FDR Discussion
Uniform mixture design methods across public-sector jurisdictions for the use of lime, cement, and asphalt binders in FDR operations were discussed. The mixture design process should contain a process to select the type of stabilizing agent and the optimum stabilizing agent and water contents, as well as to provide information for structural pavement design. At a minimum, improved layer coefficients are needed. Characterization of the recycled materials for use in the mechanistic empirical pavement design methods is also needed (stiffness, elastic modulus, and visco-elastic parameters).

Compaction and obtaining a high density (low air voids) of the recycled mixture were identified as an area of concern. Improvements in compaction equipment, compaction operations, stabilizing agents, and additives or other items are needed.

The number of contractors available to perform FDR projects is limited in some areas of the western states.

HIR Discussion
Project selection was discussed during this breakout session. Projects with high moisture contents in the asphalt pavement, projects that exhibit water susceptibility or stripping problems, projects that contain polymer-modified asphalt binders, and projects with multiple chip seal applications can present problems for this form of recycling. Hardening of the asphalt binder during the HIR operation needs better definition.

Mixture design methods that incorporate the use of rejuvenating agents (rejuvenators) and new asphalt mixture and/or aggregate need improvement.

Density and air-void-content control of the recycled mixture was discussed. These types of problems can be associated with the temperature behind the recycling operation as well as the moisture in the mixture being recycled.

Ride quality and maintenance of the cross slope can be construction problems. Air quality is a concern in some states. The number of contractors available in some regions of the country is limited.

LESSONS LEARNED
During the last session of the conference, the state representatives were asked to identify lessons learned and ideas for moving forward with in-place recycling operations in their states. Appendix C contains a summary of state comments. These comments have not been edited by the states but represent a summary as recorded by staff in attendance.

Topics of interest to the states included project selection and selection of rehabilitation alternatives, specifications, mixture design, structural design coefficients including inputs to mechanistic empirical design, performance information, life-cycle costs, education/workshops/seminars, and LCA. The need for more detailed construction plan information on the project to be recycled was also an item identified. A critical number of projects are needed in a geographic region to ensure the future viability of these recycling technologies.

RESEARCH NEEDS
Appendix D contains a description of individual research projects identified by the workshop participants and the organizing committee for the conference. Research projects are identified for all forms of in-place recycling and for the individual forms of CIR, FDR, and HIR. The titles of the projects are listed in this section. Appendix D provides more detailed information for each project including the following:

1. Title.
2. Introduction/background.
3. Scope/objectives.
4. Estimated cost/duration.

Ten projects are described under the four program areas:

- Program 1.0—In-Place Recycling:
    - Project No. 1.1—Project Evaluation and Alternative Selection.

- Project No. 1.2—Quality Control/Quality Assurance and Specifications.
    - Project No. 1.3—Performance and Life-Cycle Cost Analysis.
    - Project No. 1.4—Life-Cycle Assessment.
    - Project No. 1.5—Implementation/Education.

- Program 2.0—Cold In-Place Recycling (Partial Depth):
    - Project No. 2.1—Mixture Design and Structural Design.
    - Project No. 2.2—Compaction.

- Program 3.0—Full-Depth Reclamation:
    - Project No. 3.1—Mixture Design and Structural Design.
    - Project No. 3.2—Compaction.

- Program 4.0—Hot In-Place Recycling:
    - Project No. 4.1—Mixture Design and Structural Design.

Projects with the highest priority as defined by the organizing committee are:

- Project No. 1.1—Project Evaluation and Alternative Selection.
- Project No. 1.2—Quality Control/Quality Assurance and Specifications.
- Project No. 1.3—Performance and Life-Cycle Cost Analysis.
- Project No. 1.5—Implementation/Education.
- Project No. 3.1—Mixture Design and Structural Design (FDR highest priority).

The details associated with further development and funding for the research and outreach effort have not been identified at this time.

WORKSHOP EVALUATION

A workshop evaluation card was used to assess the workshop. Seventy-four attendees returned the evaluations. Fifty responses were received indicating that the workshop was “very valuable.” Ten attendees responded that the workshop was “somewhat valuable.”

The most significant barriers identified in the survey are:

1. Education/training and marketing (re-branding) of the technologies.
2. Consistency of specifications.
3. Project selection guidelines.
4. Performance.
5. Fear of failure due to lack of understanding of new advancements.

The most important research needs were identified as:

1. Life-cycle costs.
2. Education/training/marketing of the technologies.
3. Consistent specifications.
4. Project selection guidelines.
5. Performance.

Almost all participants indicated that they were able to express their views during the workshop and that they would participate in a follow-up workshop.

APPENDIX A—ORGANIZING COMMITTEE MEMBERS

Lee Gallivan, Federal Highway Administration
Jason Dietz, Federal Highway Administration
Mike Krissoff, ARRA-AEMA-ISSA-PPRA
Larry Galehouse, National Center for Pavement Preservation
Patte Hahn, National Center for Pavement Preservation
Stephen Cross, Oklahoma State University/ARRA
Bill Schiebel, Colorado Department of Transportation
Jay Goldbaum, Colorado Department of Transportation
Scott McDaniel, Colorado Department of Transportation
Dave Johnson, Asphalt Institute
John Rathbun, Cutler Repaving
Patrick Faster, Gallagher Asphalt
Darren Coughlin, Coughlin Company
Michael O'Leary, MeadWestvaco
Everett Crews, MeadWestvaco
Jon Epps, Texas A&M Transportation Institute

APPENDIX B—CONFERENCE PROGRAM

2014 Theme: Revitalizing In-Place Recycling Technologies: Gaps, Barriers, and a Path Forward

TUESDAY, AUGUST 5, 2014

9:00 a.m.–12:30 p.m.	**Registration Desk Open & Exhibitor Setup**
12:30 p.m.–2:00 p.m.	**Opening Session** Moderator—Jason Dietz ARRA Welcome—John Rathbun for Patrick Faster, President, ARRA FHWA Program Support for In-Place Recycling—Butch Waidelich, Associate Administrator for Infrastructure, FHWA Colorado DOT—Scott McDaniel, Acting Chief Engineer, CDOT Summary of FHWA Activities—Lee Gallivan, FHWA ARRA—Stephen Cross, ARRA Activities
2:00 p.m.–2:30 p.m.	**Break & Exhibitor Displays**
2:30 p.m.–4:30 p.m.	**Programmatic Considerations** Moderator—Scott Metcalf Project Selection—Roy Rissky, Kansas Performance/Life-Cycle Costs—Jay Goldbaum, CDOT Sustainability Programs—Everett Crews, MWV
4:30 p.m.–5:30 p.m.	**DOT Roundtable Discussions** Moderator—Tim Aschenbrener What Are You Doing, Why, What Will It Take to Do More
5:30 p.m.–7:00 p.m.	**Reception & Exhibitor Presentations**

WEDNESDAY, AUGUST 6, 2014

7:00 a.m.–7:45 a.m.	**Breakfast & Exhibitor Displays**
7:45 a.m.–8:00 a.m.	**Field Trip Demonstrations Information** Moderator—Stephen Cross **Bus Departs**
8:00 a.m.–1:00 p.m.	**In-Place Recycling (CIR, FDR, & HIR) Field Trip**
12:00–1:00 p.m.	**Lunch on Bus**
1:00–2:30 p.m.	**Technical Considerations** Moderator—Mike O'Leary Structural Design—Joe Leidy, TxDOT Mixture Design—Todd Thomas, Colas
2:30–3:00 p.m.	**Break & Exhibitor Displays**
3:00–5:00 p.m.	**Specifications/Construction Operations** Moderator—Steve Mueller Cold In-Place Recycling—Bill Schiebel, CDOT Full-Depth Recycling—Marco Estrada, PRSI Hot In-Place—Pat Kennedy (City of Denver) & Tim Aschenbrener, FHWA
6:00 pm–7:30 p.m.	**Reception & Exhibitor Displays**

THURSDAY, AUGUST 7, 2014

6:30 a.m.–7:30 a.m.	**Breakfast & Exhibitor Displays**
7:30 a.m.–10:00 a.m.	**International Activities** Moderator—Everett Crews Cold Mixtures Research and Development (Denmark, Finland, Germany, Ireland, Netherlands, and Norway)—Jan Valentin, Czech Technical University South American Perspectives on Cold Recycling—Jorge Escalante, TDM Peru Recycling Directions in People's Republic of China—Stephane Charmot, MWV In-Place Recycling Research—Buzz Powell, NCAT

10:00 a.m.–10:30 a.m.	**Break & Exhibitor Displays** Revitalizing In-Place Recycling Technologies Workshop Session Gaps, Barriers, and a Path Forward—Sponsored by Texas A&M Transportation Institute (TTI)
10:30 a.m.–10:45 a.m.	**Workshop Briefing**—Jon Epps, TTI
10:45 a.m.–12:00 p.m.	**Breakout Session I** Cold In-Place Recycling—Stephen Cross & Scott Metcalf Full-Depth Reclamation—Bill Schiebel & Jason Wielinski Hot In-Place—Surface/Repaving—Tim Aschenbrener & Jay Goldbaum Hot In-Place—Remixing—Dave Johnson & Terri Parker
12:00 p.m.–12:30 p.m.	**Break & Working Lunch**
12:30 p.m.–1:45 p.m.	**Breakout Session II** Cold In-Place Recycling—Stephen Cross & Scott Metcalf Full-Depth Reclamation—Bill Schiebel & Jason Wielinski Hot In-Place—Surface/Repaving—Tim Aschenbrener & Jay Goldbaum Hot In-Place—Remixing—Dave Johnson &Terri Parker
1:45 p.m.–2:15 p.m.	**Break**
2:15 p.m.–2:45 p.m.	**Report Out Summary**—Jon Epps, TTI (Metcalf, Wielinski, Goldbaum, & Parker)
2:45 p.m.–3:45 p.m.	**Agency Lessons Learned**—Lee Gallivan & Jon Epps Notes: Terri Parker How Will States Implement In-Place Recycling? Each State and Local Agency Representative (5 Minutes)
3:45 p.m.–4:00 p.m.	**Conclusion, Summary and Adjournment**—Stephen Cross & Lee Gallivan
4:00 p.m.	**Adjourn**

APPENDIX C—STATE DEPARTMENT OF TRANSPORTATION LESSONS LEARNED AND IMPLEMENTATION

- **New Mexico**—Agree with all that was said today. Need to update our specs; education is needed; pavement decisions are made at the district level, and education is key.
- **Alaska**—Came to learn about hot in-place recycling; will look at other states' specs; will revise and implement in-place recycling.
- **Idaho**—learned a lot from this conference. Idaho is heavily involved in full-depth reclamation world and need to look more into hot and cold areas. Need some guide specs to know how and why these recycling techniques work.
- **Arizona**—Have been doing hot in-place recycling since the late 1980s. We have more positive experience with it than negative. We use cold in-place recycling as well. Issues we have are determination of how to more accurately identify which type of in-place recycling to use. We need more education and training of inspectors.
- **Minnesota**—Importance of doing a mixed design. We have used the National Highway Institute (NHI) web-based course and will continue to use it. HIR field trip: I appreciated knowing the measurable information—how they determine when to conduct in-place recycling and the results.
- **Colorado**—Central plant was something I had not seen before. Heard a lot about quality and long-term performance. The information I learned bolsters my desire to use the recycling technologies. We need mechanistic-empirical properties; FDR; documented structural benefits of stabilizers. We need to develop closer collaboration with industry and encourage growth and new technologies.
- **California**—Specification improvements in all areas—gradation, air voids, and engineering. Need to provide detailed information to contractors for bidding purposes. Education for both agency and contractor crews. Partnering to help ensure projects are positive. Sharing information among all departments of transportation and local agencies so we can learn from each other. Get with Texas Department of Transportation on HIR.
- **Florida**—Education and marketing are needed; need to involve consultants; need to educate districts so staff knows how to find the specs and know what they can use in bidding jobs.
- **Washington**—Collaborate with other states; get FDR specs ready; check out our life-cycle cost data.
- **Montana**—We have had some past successes with FDR. We need to build on the successes that we have and develop goals that are attainable. We have a challenge with the oil patch and are reconstructing a lot of our roads. We can use recycling as part of this process. We need to focus on project selection using each of these recycling processes; how do you choose the right process for the right project? Need to set some goals on using cold central plant recycling. We need to refine process on how we deal with millings. Also need to clarify our expectations within the agency on life-cycle costs and ride so we can measure based on expectations.
- **Georgia**—Will take the NHI courses; want to encourage use of more FDR with higher average daily traffic. The higher-volume roads are in more need of reclamation work. Will look at the CIR specs for the next letting. Will review the HIR specs—currently used only for remixing and resurfacing.

- **Utah**—I have picked up the need to have regular projects with industry and ensure they are properly scoped. In our session on CIR, discussion of the hot-mix industry not always supporting the recycling industry. We need to have discussions to ensure that we do not have our own staff resisting recycling techniques.
- **City of Denver**—For project selection, we need to have better life-cycle costs and analysis.

APPENDIX D—RESEARCH NEEDS

PROGRAM 1.0—IN-PLACE RECYCLING

Project No. 1.1—Project Evaluation and Alternative Selection

Introduction/Background
Pavement and maintenance engineers are making daily decisions on how to best reconstruct, rehabilitate, and maintain pavements. These engineers and supervisors evaluate the condition of the pavement and select from a wide range of rehabilitation and maintenance alternatives based on the dollars available, equipment and crews available, the environmental conditions, the desired performance life of the repaired pavement, the condition of the existing pavement, and other factors.

In-place recycling operations are among the treatment alternatives available to pavement and maintenance engineers for pavement reconstruction, rehabilitation, and maintenance. Individual forms of in-place recycling operations are suitable for certain projects while not suitable for other projects. The suitability of various forms of in-place recycling operations for reconstruction and repair of roadways needs to be defined. The information to be developed needs to be suitable for inclusion into public agency pavement management decision trees for network assessment of system needs, and needs to be available to pavement and maintenance engineers to make decisions at the project level and at the daily maintenance level.

The research effort should identify pavement reconstruction, rehabilitation, and maintenance projects that are both suitable and unsuitable for the various forms of in-place recycling. Pavement evaluation techniques, in-place recycling techniques, and performance and cost estimates for the various alternatives need to be included in this study.

A decision tree suitable for inclusion into a public-agency pavement management system should be a product of this research. In addition, a tool to help make project-level decisions should be developed in a format suitable for use by project engineers and maintenance engineers and supervisors.

Scope/Objectives
1. Define different forms of in-place recycling.
2. Develop a decision tree that describes the suitability of various forms of in-place recycling as a reconstruction, rehabilitation, and maintenance alternative.
3. Develop a tool to assist project-level personnel in selecting suitable in-place recycling alternatives.

Estimated Cost/Duration
$300,000 and 18 months.

Project No. 1.2—Quality Control/Quality Assurance and Specifications

Introduction/Background
Several state departments of transportation and some local government agencies have developed specifications for the various forms of in-place recycling. Some of these specifications vary widely from jurisdiction to jurisdiction. Uniform specifications are needed to more easily allow in-place recycling contractors to operate in these various public agencies. Uniform specifications for all types of in-place recycling operations will be a product of this research effort.

Many existing in-place recycling specifications are method types of specifications with few quality control/quality assurance tests and acceptance criteria. Specifications need to be developed that are more devoted to a quality management type of approach, with specific quality control and quality assurance tests and acceptance limits. Development of more end result specifications and warranty/guarantee types of specifications should be considered. The inclusion of in-place density and ride quality requirements should be considered. Equipment calibration procedures should also be considered for inclusion in specifications.

For each major form of in-place recycling, key control parameters should be identified, and reasonable limiting acceptance criteria should be established from field project-level collected data.

Scope/Objectives

1. Develop uniform guide specifications for all forms of in-place recycling.
2. Establish quality control and quality assurance test methods, sampling plans, and acceptance criteria for all forms of in-place recycling.
3. Develop warranty/guarantee guide specifications for all types of in-place recycling.

Improved specifications and project selection tools will likely reduce the performance variability associated with the various forms of in-place recycling.

Estimated Cost/Duration
$750,000 and 24 months.

Project No. 1.3—Performance and Life-Cycle Cost Analysis

Introduction/Background
Pavement performance information on all forms of in-place recycling operations is limited. A study recently conducted by the Colorado Department of Transportation and an older study conducted for the New Mexico Department of Transportation provide very useful information. These studies need to be expanded to other states that have used in-place recycling operations over a number of years. Many states use only one or two forms of in-place recycling, which are used on a limited basis.

Two approaches should be considered for use. Use of existing state department of transportation pavement management systems will provide useful information relative to performance of in-place recycled pavement sections. However, these data are limited in that they typically do not include information on the condition of the existing pavement prior to recycling, traffic volumes, mixture design, and structural design. It may also be difficult to locate in-place recycling pavement projects from these files. Project locations may need to be obtained from knowledgeable department of transportation staff.

The second and more comprehensive approach will be in the installation of carefully designed, placed, and evaluated test sections at various project locations so that pavement condition, climate, traffic, etc. are known. These types of studies will provide the most reliable performance information but are difficult to establish, manage, and follow over an extended period of time. This second and more comprehensive approach will not be a part of this research effort.

Scope/Objectives

1. Obtain existing reports on performance of in-place recycling projects.
2. Determine the availability of pavement management system information associated with in-place recycling operations in various states.
3. Prepare a report on the performance of in-place recycling operations in various climates, traffic, and pavement conditions.
4. Determine costs/prices associated with different in-place recycling operations.
5. Perform LCCA on typical projects and include comparisons with other forms of rehabilitation and maintenance.

Estimated Cost/Duration
$750,000 and 30 months.

Project No. 1.4—Life-Cycle Assessment

Introduction/Background
LCA, which is a methodology that can be used to define the sustainability of different alternatives for pavement construction, reconstruction, rehabilitation, and maintenance operations, is becoming popular. In-place recycling sustainability as measured by resource conservation, energy consumption, emissions, and greenhouse gases needs better definition than is presently contained in the literature.

The Federal Highway Administration has recently established a contract with the University of Illinois to define energy consumption associated with various forms of in-place recycling. Any research project should be placed on hold until the Federal Highway Administration study is complete.

Scope/Objectives

1. Establish resource conservation, energy consumption, emissions, and greenhouse gas levels associated with various forms of in-place recycling.
2. Perform LCA for various rehabilitation and maintenance alternatives.

Estimated Cost/Duration
$400,000 and 18 months.

Project No. 1.5—Implementation/Education

Introduction/Background

In-place recycling operations are used in a number of regions of North America. Regional use appears to be associated with industry's physical location and marketing and public agency acceptance. As public agency officials and industry change, so does the general acceptance of in-place recycling. The benefits of the various forms of in-place recycling need to be based on their proven economic, engineering, and environmental advantages in the various climate regions of North America. In-place recycling needs to be more of an engineering science than a construction art form.

Current information defining the state of the art and the state of the practice associated with in-place recycling needs to be developed and updated on a continuing basis. The information needs to be placed in documents such as those developed by ARRA and the Federal Highway Administration and NHI training manuals. Documents and presentations are needed that define the key engineering attributes of these in-place operations as well as the engineering and construction steps necessary to produce good projects. Key topics that should be contained in this variety of implementation and education information include project selection, mixture design, structural design, specifications, performance, LCCA and LCA, cost comparison to conventional methods, and potential construction market demand for in-place recycling. Public agencies and the contracting industry, including existing paving industries, should be included in the target audiences to promote the use of in-place recycling and the needed growth in contracting capacity.

Results from the research project identified in this document need to be included in the implementation education effort as they become available. No one document or presentation will satisfy the needs of all audiences. A wide variety of documents, presentations, and delivery systems will be needed to continue the implementation of in-place recycling.

Scope/Objectives

1. Prepare a state-of-the-practice manual on in-place recycling directed to public agencies and containing information on project selection, mixture design, structural design, specifications, performance, LCCA, and LCA.
2. Prepare presentation materials for use in seminars, workshops, and web-based education on in-place recycling operations.
3. Update documents and presentations based on the latest technology.

Estimated Cost/Duration

$250,000 and 18 months.

PROGRAM 2.0—COLD IN-PLACE RECYCLING (PARTIAL DEPTH)

Project No. 2.1—Mixture Design and Structural Design

Introduction/Background

Several different methods are used by public agencies and industry to design CIR mixtures. These methods need to be standardized based on improved engineering information.

Some of the major improvements that need to be made in the mixture design area include the following:

- Characterization of the recycled material.
- Selection of the emulsified asphalt or foamed asphalt together with appropriate additives such as lime or cement.
- A laboratory compaction method.
- Curing and conditioning of laboratory samples to simulate field behavior relative to strength and other engineering property changes with time.
- Engineering property determination—including stiffness or resilient modulus, resistance to permanent deformation, water sensitivity, strength, fatigue, and thermal cracking potential—that can be used not only for mixture design purposes but also pavement thickness design.

Cold in-place recycling is often used in rehabilitation and maintenance operations that require that traffic be placed on the recycled layer soon after construction is completed. Development of improved emulsions and/or additives that will allow for more rapid improvement in engineering properties should be considered as part of this effort.

Scope/Objectives

1. Establish laboratory sample preparation methods that simulate field compaction and engineering property changes with time.
2. Establish methods for obtaining the engineering properties of laboratory- and field-produced materials.
3. Develop improved rejuvenating agent systems that will allow traffic to use the highway facility soon after construction and that will provide desired engineering property improvements.
4. Develop recommended mixture design methods suitable for establishing optimum rejuvenating agent and moisture contents for field compaction and performance.

Estimated Cost/Duration
$1,000,000 and 36 months.

Project No. 2.2—Compaction

Introduction/Background
Typical air void contents in partial-depth in-place recycling operations are in excess of 12 percent. These relatively high air void contents reduce the load-carrying engineering properties of the recycled mixture and allow for movement of water and air into and out of the pavement. Construction equipment and methods, field density measurement, emulsion technology, and additives need to be investigated to provide mixtures that can be compacted to lower air voids in field construction operations and produce the desired engineering properties to ensure early and long-term performance.

Fluid contents (existing asphalt binder in recycled material, asphalt in emulsion, water in emulsion, and added water) are typically relatively high to achieve good mixing and placement characteristics for the recycled mixtures. Lower fluid contents are needed to achieve maximum density during compaction. Loss of moisture is needed to achieve desired engineering property changes prior to the opening of the facility to traffic. The use of improved emulsions and additives that will allow the loss of moisture during field construction operation, during early performance, and during long-term performance needs investigation.

Scope/Objectives

1. Determine if construction operations and equipment changes can improve in-place density.
2. Investigate asphalt emulsion technology and additive technology to determine if compaction and engineering properties of mixtures can be improved.

Estimated Cost/Duration
$500,000 and 30 months.

PROGRAM 3.0—FULL-DEPTH RECLAMATION

Project No. 3.1—Mixture Design and Structural Design

Introduction/Background
Several different methods are used by public agencies and industry to design FDR mixtures. These methods need to be standardized based on improved engineering information.

Some of the major improvements that need to be made in the mixture design area include the following:

- Characterization of the recycled material.
- Selection of stabilizing agents (lime, portland cement, emulsified asphalt, or foamed asphalt together with appropriate additives such as lime or cement).
- A laboratory compaction method.
- Curing and conditioning of laboratory samples to simulate field behavior relative to strength and other engineering property changes with time.
- Engineering property determination including stiffness or resilient modulus, resistance to permanent deformation, water sensitivity, strength, fatigue, and thermal cracking potential that can be used not only for mixture design purposes but also for pavement thickness design.

FDR is often used in rehabilitation and maintenance operations that require that traffic be placed on the recycled layer soon after construction is completed. Development of improved stabilizing agents and/or additives that will allow for more rapid improvement in engineering properties should be considered as part of this effort.

Scope/Objectives

1. Establish laboratory sample preparation methods that simulate field compaction and engineering property changes with time.
2. Establish methods for obtaining the engineering properties of laboratory- and field-produced materials.

3. Develop improved stabilizing agent and additive systems that will allow traffic to use the highway facility soon after construction and that will provide desired engineering property improvements.
4. Develop recommended mixture design methods suitable for establishing optimum stabilizing agent and moisture contents for field compaction and performance.

Estimated Cost/Duration
$1,000,000 and 36 months.

Project No. 3.2—Compaction

Introduction/Background
Typical air void contents in FDR operations are typically 14 to 17 percent. These relatively high air void contents reduce the load-carrying engineering properties of the recycled mixture and allow for movement of water and air into and out of the pavement. Construction equipment and methods, field density measurement, stabilizing agent technology, and additives need to be investigated to provide mixtures that can be compacted to lower air voids in field construction operations and produce the desired engineering properties to ensure early and long-term performance in service.

Fluid contents are typically relatively high to achieve good mixing and placement characteristics for the recycled mixtures. Lower fluid contents are needed to achieve maximum density during compaction. Loss of moisture is needed to achieve desired engineering property changes prior to the opening of the facility to traffic. The use of improved stabilizing agents and additives that allow for the loss of moisture during the field construction operation, during early performance, and during long-term performance needs investigation.

Scope/Objectives
1. Determine if construction operations and equipment changes can improve in-place density.
2. Investigate stabilizing agent technology and additive technology to determine if the compaction and engineering properties of mixtures can be improved.

Estimated Cost/Duration
$600,000 and 30 months.

PROGRAM 4.0—HOT IN-PLACE RECYCLING

Project No. 4.1—Mixture Design and Structural Design

Introduction/Background
Several different methods are used by public agencies and industry to design hot in-place recycled mixtures. These methods need to consider the three different types of hot in-place recycling (surface recycling, remixing, and repaving) and where these materials will be used in the structural section. The mixture design methods need to be standardized based on improved engineering information.

Some of the major improvements that need to be made in the mixture design area include the following:

- Characterization of the recycled material.
- Selection of the rejuvenating agent.
- A laboratory compaction method.
- Curing and conditioning of laboratory samples to simulate field behavior relative to strength and other engineering property changes with time.
- Engineering property determination including stiffness or resilient modulus, resistance to permanent deformation, water sensitivity, strength, fatigue, and thermal cracking potential that can be used not only for mixture design purposes but also for pavement thickness design.

Scope/Objectives

1. Establish laboratory sample preparation methods that simulate field aging and compaction.
2. Establish methods for obtaining engineering properties of laboratory- and field-produced materials.
3. Develop a recommended mixture design method suitable for establishing optimum rejuvenating agent contents for field compaction and performance.

Estimated Cost/Duration

$500,000 and 24 months.