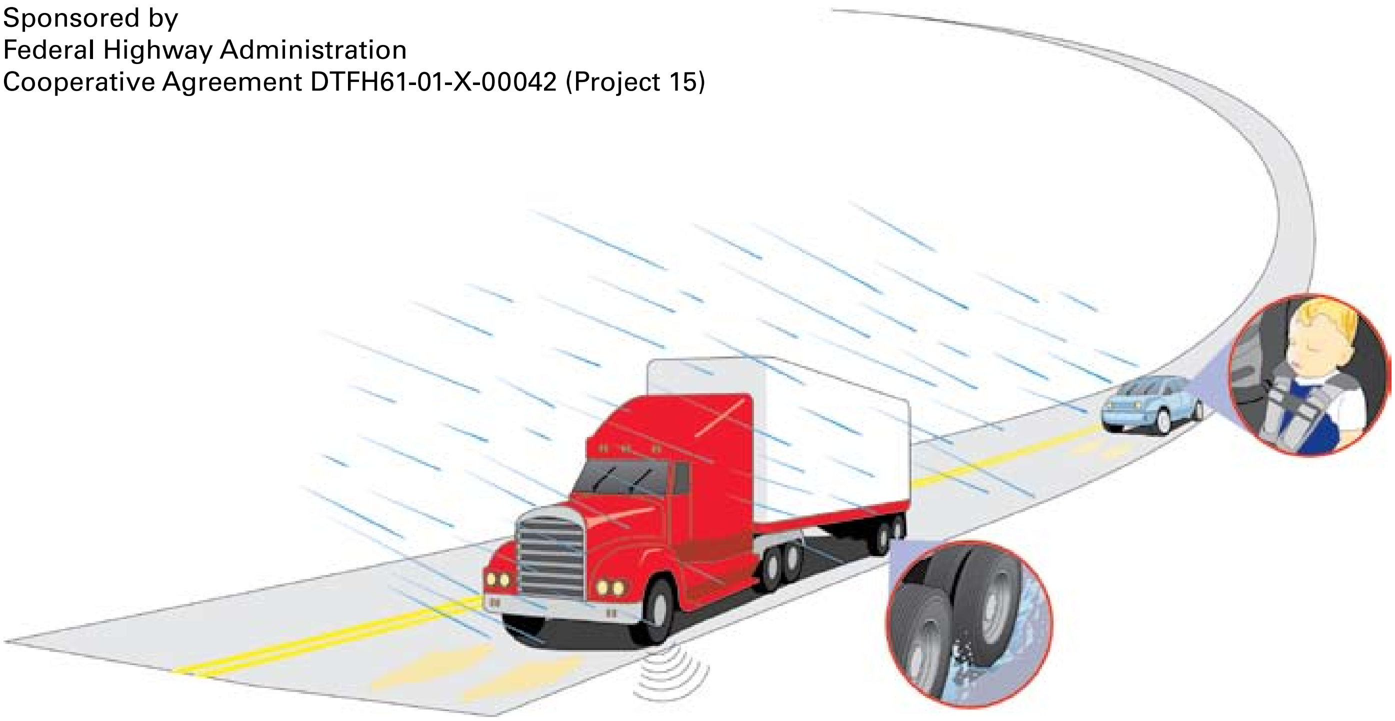
National Concrete Pavement Technology Center

Strategic Plan for Improved Concrete Pavement Surface Characteristics

July 2006

Completed in cooperation with the Federal Highway Administration, American Concrete Pavement Association, and other organizations

Sponsored by
Federal Highway Administration
Cooperative Agreement DTFH61-01-X-00042 (Project 15)



July 2006

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Sponsored by the Federal Highway Administration
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About the National Concrete Pavement Technology Center
The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

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1. Introduction

1.1. NEED FOR A STRATEGIC PLAN

Surface characteristics represent a critical issue facing pavement owners and the concrete paving industry. The traveling public has come to expect smoother, quieter, and better drained pavements, all without compromising safety.

The overall surface characteristics issue is extremely complex since all pavement surface characteristics properties, including texture, noise, friction, splash/spray, rolling resistance, reflectivity/illuminance, and smoothness, are complexly related.

The following needs and gaps related to achieving desired pavement surface characteristics need to be addressed:

- Determine how changes in one surface characteristic (e.g., noise) affect, either beneficially or detrimentally, other characteristics (e.g., friction, splash and spray, or smoothness) of the pavement.
- Determine the long-term surface and acoustic durability of different textures.
- Develop, evaluate, and standardize new data collection and analysis tools.

It is clear that an overall strategic and coordinated research approach to the problem must be developed and pursued to address these needs and gaps.

1.2. PLAN CONTENTS

This strategic plan was developed as one part of a multi-part, long-term Concrete Pavement Surface Characteristics Project sponsored by the Federal Highway Administration (FHWA) and other organizations and conducted through the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University (ISU).

This *Strategic Plan for Improved Concrete Pavement Surface Characteristics* is the result of numerous collaborative activities:

- ISU and FHWA formed a partnership to address surface characteristics (June 2004)
- Stakeholder input to the CP Road Map Surface Characteristics Track (October 2004)
- National stakeholder outreach on surface characteristics (November 2004)
- American Concrete Pavement Association (ACPA) joined the ISU-FHWA partnership to address surface characteristics (April 2005)
- Final outreach event that validated the initial strategic plan (August 2005)
- Draft strategic plan published and widely distributed (September 2005)
- Final strategic plan updated based on ongoing input and new information (July 2006)

This strategic plan provides a 10-year guiding framework for the research, technology transfer, and implementation of the most cost-effective methods of designing, building, measuring, and maintaining optimal concrete pavement surface characteristics.

The plan is organized as follows:

1. Introduction
2. Recent and New Surface Characteristics Research
3. Subtracks and Problem Statements

In Section 3, the plan identifies 40 problem statements representing an investment of between $27 and $56 million in research. The proposed research is organized into seven subtracks and presented in a recommended sequence:

- SC 1. Innovative and Improved Concrete Pavement Surfaces
- SC 2. Tire-Pavement Noise
- SC 3. Concrete Pavement Texture and Friction
- SC 4. Safety and Other Concrete Pavement Surface Characteristics
- SC 5. Concrete Pavement Profile Smoothness
- SC 6. Synthesis and Integration of Concrete Pavement Surface Characteristics
- SC 7. Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research

Each problem statement contained in the plan may correspond to one or more individual projects. The problem statements will need to be developed into research project statements with detailed descriptions of the research to be accomplished, specific budgets, and definite timelines.

The flow chart summary of the plan, including current and proposed research, is presented in Figure 1.1.

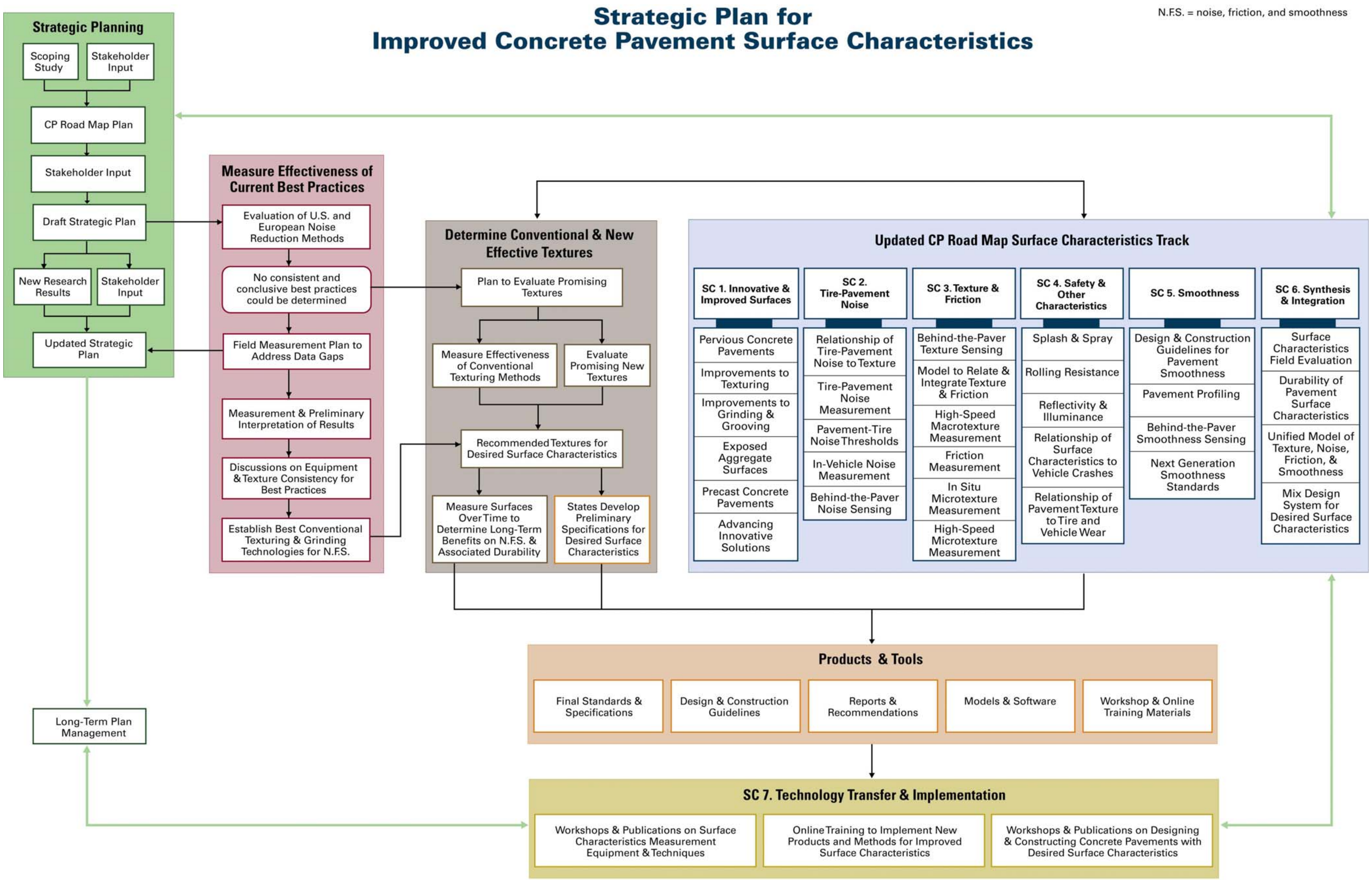

Figure 1.1. Concrete pavement surface characteristics strategic plan flow chart

1.3. OVERVIEW OF THE OVERALL SURFACE CHARACTERISTICS PROBLEM

Surface characteristics are defined as those properties of pavement that impact the non-structural aspects of the pavement—noise, friction, smoothness, drainage, splash/spray, rolling resistance, and reflectivity being the most predominant. The overall surface characteristics issue is extremely complex since all pavement surface properties, including texture, are complexly related. The traveling public has come to expect smoother, quieter, and better drained pavements, all without compromising safety.

One of the most pressing issues facing highway owners is perceived noise by travelers and abutters. While the noise produced from tire-pavement interaction is just one of several noise sources for almost all roads, it becomes the primary source of traffic noise for vehicular speeds over 35 mph (ACPA 2000). In the United States, nearly 70% of the noise on high-speed facilities dominated by automobiles is generated at the tire-pavement interface (as truck traffic volumes increase, truck noise becomes more predominant). Many countries, including most of the European Union, have been working to reduce perceived highway noise for over two decades. Highway noise has recently become a paramount quality-of-life issue in the United States.

Over the last two decades, concrete pavement engineers have focused on improving pavement smoothness without compromising surface friction or surface drainage characteristics. This difficult but important balancing act has led to advancements in smoothness indices, texturing practices, and measurement equipment, among other areas. While smoother concrete pavements are being constructed, additional consideration of noise (and even splash and spray in some conditions) require further study, particularly with regard to fundamental knowledge, interrelationships, variability and durability.

Remaining critical research issues include developing standardized techniques for measuring various surface characteristics, understanding the tire-pavement interaction with various texturing options, facilitating equipment changes to reduce variability, improving construction practices, and predicting the life expectancy of any solution.

The work proposed and underway today on surface characteristics will help pavement engineers better understand fundamental engineering properties to assess noise, friction, and smoothness, isolating better texturing options and tailoring solutions to location, traffic, and renewal requirements. They will also be able to understand the functional and structural performance of various solutions over time, including texture wear and pavement durability. Identifying optimal pavement texture is confounded by the fact that pavement texture does not remain constant over time. Factors such as traffic, weather, and winter maintenance activities eventually wear the surface, reducing friction levels and affecting the tire-pavement noise level (Wenzel, Beckhaus, and Schiessl 2004).

In response to the noise issue, the concrete pavement industry has experimented with new tining patterns, converted to longitudinal tining in some places, and has even used diamond grinding simply to quiet the noise on otherwise acceptable pavement. Some innovative new solutions have also been developed; these innovations require further evaluation to determine their effectiveness, feasibility, long-term performance, and their long-term impact on other surface characteristics.

1.4. STRATEGIC PLAN OBJECTIVES AND CONSIDERATIONS

Surface Characteristics Research Gaps

The following gaps in concrete pavement surface characteristics research need to be addressed:

- Insufficient understanding of the relationship between the design/construction methods and materials and the as-built surface texture
- Insufficient understanding of the relationship between the design/construction material properties and methods and long-term functional performance
- Lack of understanding of unconventional texturing methods (e.g., exposed aggregate and pervious concrete pavements)
- Lack of a mechanistic understanding of the relationships between texture and tire-pavement noise, roadside (pass-by) noise, effective friction, splash, spray, smoothness and other functional indicators and how the changes in one characteristic affect others
- Identification of threshold values for various concrete pavement surface characteristics where the value to the public is exceeded by the cost of achieving the characteristic
- Lack of a validated method that defines a thorough characterization of pavement friction (wet vs. dry, tangent vs. cornering, etc.)
- Insufficient understanding of the relationship between surface texture, wet-weather accidents, and friction demand
- Lack of equipment that efficiently and accurately measures all key surface characteristics on a standard, reproducible scale; insufficient experience with and refinement of new data collection and analysis tools
- Lack of standard protocols for measuring certain critical surface characteristics
- Inadequate information about the long-term surface and acoustic durability of different textures

Strategic Plan Objectives

This strategic plan is designed to provide the principles, framework, and assessment of needs and opportunities necessary to achieve the following objectives:

- Evaluate effectiveness of current best surface characteristics practices and measure effectiveness of conventional and new textures.
- Produce the knowledge needed to specify, design, construct, and measure concrete pavements that provide the traveling public with concrete pavement surfaces that meet or exceed predetermined requirements for tire-pavement noise, friction and safety, smoothness, splay and spray, rolling resistance, light reflectivity, and durability.
- Develop, field-test, and validate concrete pavement designs and construction methods that produce consistent surface characteristics that meet or exceed highway user requirements for friction/safety, tire-pavement noise, smoothness, splash and spray, light reflection, rolling resistance, and durability.
- Determine the design materials and construction methods that produce different levels of surface microtexture, macrotexture, megatexture, and unevenness.
- Determine the relationship between pavement texture levels (microtexture, macrotexture, megatexture, and unevenness) and surface characteristic performance levels (noise, friction, smoothness, splash and spray, rolling resistance, and light reflectivity).

- Evaluate and develop high-speed, continuous measurement equipment and procedures for measuring texture, noise, friction, smoothness, splash and spray, rolling resistance, and other key surface characteristics.
- Identify the critical factors in friction demand, obtain the data necessary to define and quantify the friction demand factors, and develop a standard method for quantifying friction demand.
- Define the material-related factors that control texture and frictional stability, identify tests that quantify these factors, and relate test results to variations in long-term performance.
- Define the relationship between wet-weather crash rates, pavement texture, and friction demand levels.
- Develop design and construction guidelines, measurement protocols, standards and specifications, and associated technology transfer products for desired concrete pavement surface characteristics.

Plan Considerations

The surface characteristics research proposed in this plan is designed to develop answers to the following questions:

What surface characteristics will best serve the public?

Although smooth pavement is known to reduce user cost and is thought to last longer, there is a point of diminishing marginal return. Research must provide the industry with the best target smoothness level, such that a dollar spent on making the pavement smoother always contributes to a dollar saved by the public or an extra dollar's worth of contribution to the pavement life cycle. Safety must not be compromised to improve noise. On the other hand, it is likely that some limit exists where additional texture does not improve safety but does exacerbate noise. This relationship needs to be clearly established. It is also well known that beneath some threshold value, tire-pavement noise is overshadowed by other sound sources.

How can surface properties best be measured?

A systematic understanding of the effect each aspect of pavement surface texture has on noise, safety, and smoothness is required to help optimize the pavement surface. The effect of any surface characteristics on pavement behavior can only be studied properly if the pavement surface and the resulting performance can be measured with a repeatable and reproducible system. Furthermore, the economic viability of innovations can only be evaluated if the benefits are grounded on the useful scale. In other words, the change from marginal to good performance is much more compelling than "a little better." The zone concept presented in this plan provides a framework for understanding results and defining goals.

How can highway owners embrace solutions and the paving industry build them?

The concrete paving industry has a long history of innovating to improve their product as cost effectively as possible. All of the research conducted from this plan should have the goal of demonstrating cost-effective methods for providing desirable surface characteristics. The recommended solutions must be feasibly constructible, achieve desired surface characteristics goals, and demonstrate their cost-effectiveness to the highway owners and the public.

1.5. DEVELOPMENT OF THE STRATEGIC PLAN

Development of this strategic plan is one part of a multi-part, long-term Concrete Pavement Surface Characteristics Project sponsored by the Federal Highway Administration (FHWA) and other organizations and conducted through the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University.

Development of this document, the *Strategic Plan for Improved Concrete Pavement Surface Characteristics*, included the following tasks indicated in the strategic plan flow chart (Figure 1.1) and described below:

- Scoping Study
- CP Road Map Surface Characteristics Track
- Stakeholder Input
- Draft Strategic Plan
- Updated Strategic Plan (this document)

Scoping Study

The CP Tech Center completed a comprehensive compilation of important completed and ongoing research on concrete pavement surface characteristics. This work included studies on the relation of noise and smoothness to friction and spray. The literature search included and extended the *Developing Smooth, Quiet, Safe Portland Cement Concrete Pavements* scoping study (Karamihas and Cable 2004).

CP Road Map Surface Characteristics Track

The Concrete Pavement Surface Characteristics Strategic Plan is built upon and extends the CP Road Map research plan, specifically Track 4 (Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements). Over 400 engineers, contractors, and researchers from academia across the United States contributed to the CP Road Map. This process included identification of research and technology needs and technical and policy gaps; preparation of broad problem statements; and a proposal of ways to share and implement the results.

Stakeholder Input

The plan has been presented for comment in about 50 venues, with ongoing input from federal, state, and local government, private industry, and the research community for over a year. Stakeholder outreach and input events are listed in Table 1.1. Some of the more significant events are described below.

September 2004, FHWA Roadmap to Quieter Pavements Workshop. With sponsorship from the FHWA, Purdue University's Institute for Safe, Quiet and Durable Highways conducted a workshop with the purpose of examining the state of the art to identify the major gaps in technology that would lead to quieter pavement and to develop a plan to fill these gaps. It was considered a requirement that safety not be compromised for noise. In addition, as a design feature, noise was considered for its costs and benefits, in the same terms as durability, smoothness, and other functional performance features of pavement.

October 2004, CP Road Map Final Outreach. The culmination of the CP Road Map's extensive ongoing outreach effort was a major assessment of the final product in October 2004. Nearly 50 engineers, contractors, and academia again reviewed the proposed research in specific details. Each project was discussed, suggestions offered, and the plan updated.

October 2004, Quiet Pavement Scan Implementation Kickoff. While the CP Road Map effort was concluding, the FHWA/AASHTO/NCHRP's International Exchange Scan Program completed a European Quiet Pavement Scan (EQPS) in July 2004. That important scan led to a series of implementation items that added additional momentum to begin work under the strategic plan's noise subtrack.

November 2004, Surface Characteristics Workshop. In Kansas City, over 60 engineers participated in an overall assessment of the plan, focusing critically on noise issues. Attendees reviewed the entire scope of work in surface characteristics and provided focused input on the noise-related issues specifically. It was noted that a comprehensive, integrated approach to noise will be required to find cost-effective solutions. Suggestions were offered to establish a field experiment that concentrates on today's methodologies—texturing and grinding (Part 2 of the ISU-FHWA-ACPA Concrete Pavement Surface Charactertistics Project).

January 2005, ACPA Noise Taskforce Meeting. The research team made a two-hour presentation of the program direction and details to the ACPA Noise Task Force. The team received detailed comments, including significant specific input on grinding issues.

July 2005, TRB ADC40 Noise and Vibration Mid-year Meeting. The team presented the full plan to the over 125 participants, with specific focus on the noise measurement strategies. The approach was validated.

August 2005, International Society for Concrete Pavements Noise Workshops. Iowa State University coordinated and conducted two major workshops at the 8th International Conference on Concrete Pavements. These workshops provided positive feedback on the experiments, especially from international guests.

August 2005, Surface Characteristics Strategic Plan Final Workshop. A final workshop was held in August 2005 in Iowa to help solidify the plan and to begin the process of establishing a management system to govern implementation of the plan. Nine different states were represented, ranging from California to New York.

Table 1.1. Surface characteristics outreach and input events

Date	Group/Meeting
9/14/04	FHWA Roadmap to Quieter Pavements Workshop, Institute for Safe, Quiet, and Durable Highways, Purdue University
9/23/04	Midwest Concrete Consortium Meeting, Detroit, Michigan
10/04	CP Road Map Final Outreach
10/04	Quiet Pavement Scan Implementation Kickoff
11/9/04	Surface Characteristics Workshop, Kansas City
12/3/04	ACPA Annual Convention
1/9/05	TRB Annual Conference
1/18/05	ACPA Noise Taskforce Meeting
1/31/05	Program Review, Des Moines, Iowa
2/28/05	Blastrac Meeting
3/4/05	Iowa DOT, Ames, Iowa
3/8/05	Technical Team Meeting, Alexandria, Virginia
4/20/05	Midwest Concrete Consortium Round Table
5/11/05	WASHTO QP Video Conference
5/13/05	Meeting at Purdue University
5/15/05	NASA Wallops Island Friction and Texture Experiment
5/24/05	ACPA Chapter-State Executives Meeting
6/7/05	International Grinding and Grooving Association Mid-year Meeting
6/14/05	Pavement Preservation Conference, Dallas, Texas
7/13/05	ACPA Mid-year Meeting
7/17/05	TRB ADC40 Noise and Vibration Mid-year Meeting
8/16/05	International Society for Concrete Pavements Noise Workshops
8/22/05	Iowa State University Outreach
8/23/05	Surface Characteristics Strategic Plan Final Workshop
10/5/05	Caltrans Roundtable
10/26/05	MCO/MC2 Iowa Site Tour
11/16/05	New York ACPA Chapter Concrete Conference
11/28/05	ACPA Chapter-State Executives Meeting
12/2/05	Tech Day, ACPA Annual Convention
1/22/06	TRB Noise Workshop
2/1/06	Concrete Equipment Manufacturers
2/2/06	Iowa Concrete Paving Association
2/9/06	Mid-Atlantic Quality Workshop
2/10/06	Wisconsin Concrete Paving Association
2/28/06	Caltrans Roundtable
4/4/06	Missouri/Kansas ACPA Chapter
4/10/06	FHWA Workshop II, Institute for Safe, Quiet, and Durable Highways, Purdue University
4/19/06	Alabama Concrete Conference
5/9/06	ACPA Chapter-State Executives Meeting
5/10/06	Southeast States Pavement Design Conference
5/22/06	NASA Wallops Island Friction and Texture Experiment
5/30/06	Turner-Fairbanks Highway Research Center, Demonstration
6/12/06	Wisconsin DOT Demonstration
7/9/06	TRB ADC40 Noise and Vibration Mid-year Meeting
9/18/06	International Concrete Pavement Symposium, Brussels
12/3/06	InterNoise 2006

Draft Strategic Plan

The information gathered through the literature search, CP Road Map, and outreach and input process was synthesized and integrated into an initial strategic plan (published in September 2005).

Updated Strategic Plan

The draft strategic plan was managed and updated for nearly a year. This task was added to ensure that the contents of the strategic plan were known by those research partners interested in completing surface characteristics research.

During the period between the draft and the updated plan, the project team prepared of status reports; facilitated coordination and tracking of new and active related research; analyzed new results and advancements as they related to plan goals and objectives; received and integrated additional plan input, revisions, and updates; and continued outreach and communication efforts (as indicated in Table 1.1).

In addition, the CP Tech Center developed and implemented a comprehensive program to work with the ACPA and its affiliated chapters/state paving associations on field research to ensure they are fully aware of and understand the initiatives, findings, and ongoing activities.

1.6. COORDINATION AND ACCOMPLISHMENT OF THE PLAN

Overview

The plan contained herein is updated from Track 4 of the Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map). It is recommended that this plan be coordinated and accomplished as a CP Road Map track according to the protocols established by the FHWA and CP Road Map Executive Advisory Committee.

Management Principles

The CP Road Map is a distributed national strategic research program in which projects can be funded by many agencies—federal, state, and industry. Its vision is to bring rapid advancements in concrete pavement products for the ultimate benefit of the public.

The CP Road Map includes a research management plan that outlines a progressive, cooperative approach to managing and conducting the research. Under this plan, organizations identify common interests, partner with one another in executing specific contracts, and, in the end, produce and share a product that is greater than the sum of the parts.

Management Structure

Through the CP Road Map plan development process, a management structure has been recommended to provide leadership and mechanisms for coordinating the complex, numerous activities within the CP Road Map.

The relationships and roles of the CP Road Map Executive Advisory Committee, Track Teams, Administrative Support Group, Sustaining Organizations, and Researchers are illustrated in Figure 1.2 and discussed below.

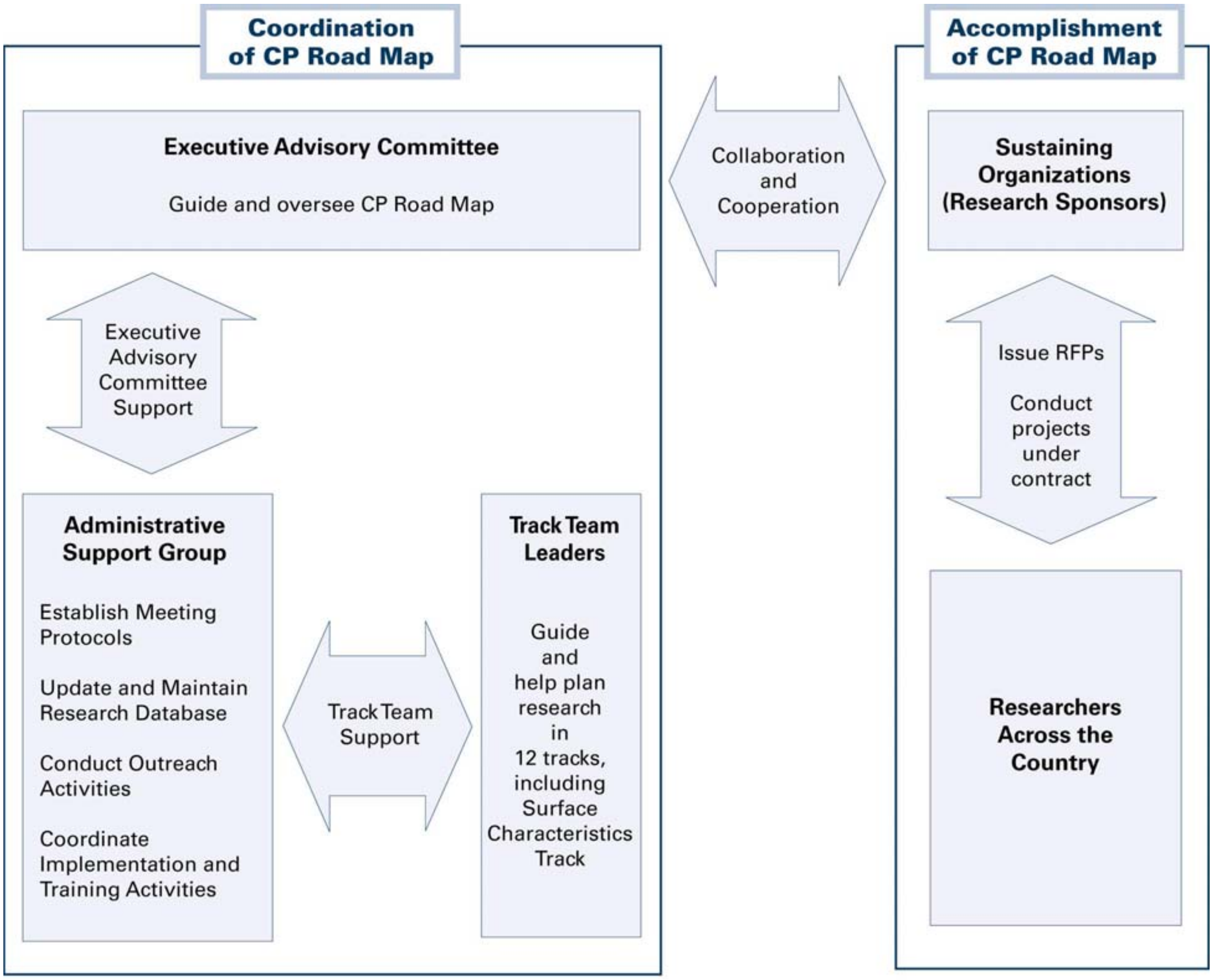

Figure 1.2. Model of CP Road Map coordination and accomplishment

Executive Advisory Committee: Overall management of the CP Road Map will be a cooperative effort undertaken by a partnership of federal, state, and industry representatives who voluntarily choose to work together. The Executive Advisory Committee will provide broad management guidance and oversight to help accomplish the basic goals of the CP Road Map and will consist of managers committed to the vision and goals of the CP Road Map.

Track Teams: Volunteer organizations will also guide the work identified in each research track. These Track Team leaders will include subject matter experts from universities, state departments of transportation, and industry. The general purpose of the Track Teams is to ensure coordination of CP Road Map activities within a track and integration of research across tracks. The Track Teams will provide technical advice and recommendations to the Executive Advisory Committee and will provide guidance for how to advance a particular track in a coordinated manner.

Sustaining Organizations (Research Sponsors): Organizations that fund research have the task of budgeting, procuring, and executing individual research projects. This will not change under the CP Road Map. One of the keys to the success of the CP Road Map is coordination of individual research sponsors so that the CP Road Map program of research is advanced as a coordinated effort. Individual sponsors may choose to sponsor a particular project of interest to them, or they may choose to join with others in pooled fund studies or similar mechanisms. Uniting all the traditional funders of research around the common vision of the Road Map is critical to accomplishing this national plan.

Administrative Support Group: This group's primary function is to be the administrative arm of the Executive Advisory Committee and Track Teams. The Administrative Support Group will steer and coordinate CP Road Map program activities and provide the communication and outreach services recommended by the Executive Advisory Committee and to some extent by the Track Teams.

Next Steps

Federal and state agencies, private industry, and academia have provided input that guided development of the plan. Continued stakeholder support and participation in the plan is critical to its success.

The following next steps are recommended:

1. The Surface Characteristics Track Team should be formally identified and agree to act in this role.
2. A track coordinator should be identified to initiate coordination and administrative management.
3. An initial meeting of the Surface Characteristics Track Team should be organized to discuss funding partnerships, research priorities, and logical partners for developing subtrack frameworks.

1.7. ANTICIPATED BENEFITS

The following products and benefits are anticipated to result from the work outlined in the surface characteristics strategic plan:

- A prioritized, productive, coordinated, and nonduplicative research plan for addressing knowledge gaps and advancing improvements to concrete pavement surface characteristics
- Clearer understanding of the relationship between pavement texture levels (microtexture, macrotexture, megatexture, and unevenness) and surface characteristic performance levels (friction, noise, smoothness, splash and spray, rolling resistance, and light reflectivity)
- Clearer understanding of the relationship between wet-weather accident rates, pavement texture, and friction demand levels

- Reliable, economical, constructible, and maintainable concrete pavement surface characteristics that meet or exceed highway user requirements for all classes of streets, low-volume roads, highways, and special applications
- Fully field-tested and validated concrete pavement designs and construction methods that produce consistent surface characteristics that meet or exceed highway user requirements for friction/safety, tire-pavement noise, smoothness, splash and spray, light reflection, rolling resistance, and durability (longevity).
- Well-documented and applied construction methods that produce specified levels of short- and long-term surface microtexture, macrotexture, megatexture, and unevenness, including design and construction guidelines and technology transfer products
- High-speed, continuous measurement equipment and procedures for measuring texture, friction, noise, smoothness, splash and spray, rolling resistance, and other key surface characteristics

2. Recent and New Surface Characteristics Research

The current project team is aware of numerous surface characteristics projects that have been recently accomplished or are currently in progress. Major studies include those by the FHWA, ACPA, and Purdue's Institute for Safe, Quiet, and Durable Highways. Recently completed ongoing, and newly proposed research related to concrete pavement surface characteristics is summarized in Tables 2.1–2.6. These tables provide a snapshot as of July 2006 and are not intended to be exhaustive.

The projects are grouped by the plan's subtrack topic areas, but it should be noted that as all surface characteristics are interrelated, many research efforts such as Part 2 of the CP Tech Center's Concrete Pavement Surface Characteristics Project cross subtrack lines. Much of this work is being cross-coordinated, with some shared activities and exchange of findings. The work underway will collectively advance the CP Road Map Surface Characteristics Track.

Table 2.1. Recent, new, and proposed innovative surfaces research (Subtrack SC 1)

Project	Sponsors	Summary	More Information
Concrete Pavement Surface Characteristics Project (Part 3): Field Evaluation of Conventional Practices and Innovative Solutions for Desired Concrete Pavement Surface Characteristics	FHWA, ACPA, states, CP Tech Center at Iowa State University	This part of the project includes identifying and evaluating innovative texturing techniques that have the potential to reduce noise by an order of magnitude or more, while also not degrading the other surface characteristics (smoothness, friction, drainage, etc.) of the pavement. Potential innovative solutions include stamping, brushing, and other new texturing techniques; exposed aggregate concrete pavements; pervious concrete pavements; sprinkle treatment; and shot peening.	www.cptechcenter.org
Innovative Methods for Creating Texture on Pavements	FHWA	The objective of this task-ordered project is to develop, test, and evaluate methods/equipment for creating texture consistent with a specified "target texture." Innovative equipment and methods may include stamping, imprinting, brushing techniques, removable inclusions or aggregates with variable wear rates.	

Table 2.2. Recent, new, and proposed noise research (Subtrack SC 2)

Project	Sponsors	Summary	More Information
Caltrans Quiet Pavements Research Program	Caltrans	This work includes developing a database for life-time performance trends; and verifying the operational capability to measure noise/texture values.	
Concrete Pavement Surface Characteristics Project (Part 1, Task 2): Evaluation of Current Methods for Controlling Tire-Pavement Noise Using Concrete Pavements	FHWA, CP Tech Center at Iowa State University	This part of the project included the identification and evaluation of tire-noise reduction methods and results, with a specific focus on European and U.S. practices; development of specifications for the design and construction of exposed aggregate concrete pavements; and development of a detailed pervious concrete pavement research plan.	www.cptechcenter.org
Evaluation of Tire/Pavement and Environmental Traffic Noise	Colorado DOT	The goal of this project is to develop and execute a comprehensive, long-term study to determine if a particular pavement surface type and/or texture can be successfully used in Colorado to help satisfy the FHWA noise mitigation requirements. A data acquisition plan (DAP) will be developed to collect data related to highway traffic noise characteristics and the safety and durability aspects of the associated pavements. The DAP will closely follow the data collection requirements set forth by the FHWA.	http://rip.trb.org/browse/dproject.asp?n=11083
Evaluation using Tire/Pavement Test Apparatus	ACPA	The objective of this research is to examine noise radiation from textured concrete samples using the Purdue University Tire/Pavement Test Apparatus (TPTA). This investigation is a first step in the long-range objective to identify surface texture options than are substantially quieter than current technology. Texturing for the test samples will be achieved by diamond grinding blank samples and by imprinting wet samples with novel surface texture. Phase 1 is directed at grinding experiments, and Phase 2 is directed at imprinting or surface texture casting procedures.	http://www.pavement.com/Downloads/TechTips/2005/GrindingTestUpdate.pdf
Innovatie Programma Geluid (IPG)	Dutch Road and Hydraulic Engineering Institute	A substantial program of noise research, Innovatie Programma Geluid (IPG), has recently been initiated in the Netherlands under the leadership of the Dutch Road and Hydraulic Engineering Institute (DWW) under the Dutch Ministry of Transport. The aim of this project is to further international cooperation and exchange knowledge that is of mutual benefit. Research is being carried out in seven areas: knowledge transfer; clogging of porous pavements; modified bitumen used for porous pavements; raveling of porous pavements; thin silent durable pavements; and CPX noise measurements cost-benefit evaluation.	http://rip.trb.org/browse/dproject.asp?n=11530
Measuring Tire-Pavement Noise at the Source (Project 01-44)	NCHRP	The objectives of this research are to develop rational procedures for measuring tire-pavement noise and to demonstrate applicability of the procedures through testing of in-service pavements.	http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+1-44
Noise Level Adjustments for Highway Pavements	Texas DOT	This project focuses on reducing the chief source of the noise, the tire-pavement interaction. This project will test the candidate quiet pavements and quantify the potential noise reductions over time, which may result in substantial cost reductions and improved community acceptance of highway projects.	http://rip.trb.org/browse/dproject.asp?n=9042
Pavement Noise Intensity Testing in Europe for Comparison to the United States (Project 20-07, Task 204)	NCHRP	This study will develop a comprehensive plan for using quiet pavements in the United States. The study will be guided by the panel for NCHRP Project 1-44, Quiet Pavement Pilot Project Study. Tests on European pavements were conduced by Caltrans; the need for additional tests will be considered based on the plan developed in this study.	http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+20-07
Study of Implementation of Pavement Effects into Traffic Noise Model (TNM)	FHWA	The objective of this project, conducted by the Volpe National Transportation Systems Center, is to evaluate the impact of different pavement types on the results of the FHWA Traffic Noise Model (TNM). An abbreviated study of REMELs (REMELs Light) for current pavements will be conducted to determine if a more comprehensive study of the impact of pavement types is justified.	

Project	Sponsors	Summary	More Information
Test Sections with Noise Reducing Pavements	European Union	This objective of this work is to set up classification and conformity-of-production procedures of road surfaces with respect to their influence on traffic noise; investigate and improve the functional and structural durability of low-noise pavement construction and maintenance techniques; and develop a full life-cycle cost/benefit analysis procedure for traffic noise abatement measures. The final product will be a *European Guidance Manual on the Utilization of Low-Noise Road Surfacings*.	http://rip.trb.org/browse/dproject.asp?n=11344
Tire-Pavement Noise 101 Workshops	FHWA	This effort includes workshops on tire/pavement noise fundamentals to raise the level of awareness of tire/pavement noise for the pavement engineering community and the environmental/noise community.	
Traffic Noise Model (TNM) Technical Support and Distribution	FHWA	The Volpe National Transportation Systems Center provides technical support for the FHWA TNM, which is an entirely new, state-of-the-art computer program used for predicting noise impacts in the vicinity of highways. It uses advances in personal computer hardware and software to improve upon the accuracy and ease of modeling highway noise, including the design of effective, cost-efficient highway noise barriers.	http://www.volpe.dot.gov/acoustics/proj5.html
Truck Noise-Source Mapping (Project 08-56)	NCHRP	The objective of this study is to use acoustic measurement and noise-source mapping techniques to accurately identify, locate, and quantify the noise sources on typical commercial truck and tractor-semitrailer combinations operating in the U.S. roadway environment. Data obtained in this project could directly support a number of ongoing quiet pavement research studies. The data will also yield information that could greatly enhance computer analysis of traffic noise impacts that are a part of environmental impact reports. Information from this project will guide decisions made at both a management level and a project design level.	http://rip.trb.org/browse/dproject.asp?n=10558
Tire/Pavement Noise Research Consortium (TPF-05(135))	Washington DOT	This effort is to provide a forum for states to discuss tire/pavement noise issues and develop a plan for research and data sharing.	http://www.pooledfund.org/projectdetails.asp?id=1104&status=1

Table 2.3. Recent, new, and proposed friction research (Subtrack SC 3)

Project	Sponsors	Summary	More Information
Circular Texture Meter and Dynamic Friction Tester Equipment Loan Program	FHWA	The objective of this project is to provide an opportunity to agencies to evaluate circular texture meter (CTM) and dynamic friction tester (DFT) prior to recommending purchase. Technical assistance with equipment use will also be provided.	
Contribution of Tining to the Skid Resistance in Portland Cement Concrete Pavement	Texas DOT	This project (recently completed by the University of Texas Center for Transportation Research) produced the following conclusions: the tining operation on concrete pavements can have a detrimental effect on moisture loss and abrasion resistance, which can impact the long-term durability and performance of the pavement; tining the surface of a concrete pavement increases skid resistance for wet conditions, but it does not necessarily improve the safety of a road section; and overall, tined or grooved sections present the highest levels of pavement noise, both for the adjacent landowner and for the driver; and the practice of tining concrete pavements results in greater life-cycle costs.	http://rip.trb.org/browse/dproject.asp?n=9149
Guide for Pavement Friction (Project 01-43)	NCHRP	The objective of this research is to develop a guide for pavement friction, for consideration and adoption by AASHTO. The guide will address frictional characteristics and performance of pavement surfaces and consider related tire-pavement noise and other relevant issues. This research is concerned with highway pavements constructed with asphalt and concrete surfaces.	http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+1-43
Texturing of Concrete Pavements (Project 10-67)	NCHRP	The objective of this research is to recommend appropriate methods for texturing concrete pavements for specific applications and ranges of climatic, site, and traffic conditions. These methods shall include tining and other means of texturing fresh and hardened concrete for the purpose of enhancing surface frictional characteristics.	http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+10-67

Table 2.4. Recent, new, and proposed safety and other surface characteristics research (Subtrack SC 4)

Project	Sponsors	Summary	More Information
Wet Pavements Crash Study of Longitudinal and Transverse Tined PCC Pavements	Wisconsin DOT	The objective of this study is to clarify the relative safety characteristics of longitudinal- and transverse-tined pavements through an analysis of crash data from Wisconsin and other states. Expected benefits include evidence that neither type of texture has significant safety advantages over the other, which would allow texture choice based on tire-pavement noise, construction cost and other considerations, resulting in quieter roads.	http://rip.trb.org/browse/dproject.asp?n=11436

Table 2.5. Recent, new, and proposed smoothness research (Subtrack SC 5)

Project	Sponsors	Summary	More Information
Development of a Golden Tire Footprint for Improvement of Profiler Relevance	FHWA	The objective of this project, conducted by the University of Michigan Transportation Research Institute, includes development of sampling strategies or filtering procedures for inertial profiler height sensor data that better represents the how a tire envelopes pavement texture. These procedures will allow more repeatable and reproducible pavement profile data.	
Improving the Quality of Pavement Profiler Measurement (TPF-5(063))	FHWA, states	This project includes development of a sample procurement specification, maintenance guidelines, and profile analysis software program; establishment of criteria for verification centers; and technical review of software.	http://www.pooledfund.org/projectdetails.asp?id=280&status=4
Measuring Pavement Profile at the Slip-Form Paver	Iowa Highway Research Board, FHWA	This recently completed research evaluated equipment and methods to measure profile being produced at the slip-form paver and by each of the various pieces of paving equipment and processes used from the deposit of the pavement concrete to the completion of the curing operation.	http://www.cptechcenter.org/projects/detail.cfm?projectID=-1971648071
Pavement Smoothness Workshops	FHWA	The objective of these workshops is to address the specific needs of targeted states with respect to pavement smoothness numbers. These are typically states with higher traffic volumes and/or older highway systems.	
ProVAL Software Enhancement and Deployment	FHWA	This project includes the continued development of the ProVAL Software to allow for more advanced analysis, improved quality control tools, and harmonization with AASHTO Interim Specifications. An implementation workshop is available through this work.	

Table 2.6. Recent, new, and proposed surface characteristics research synthesis and integration (Subtrack SC 6)

Project	Sponsors	Summary	More Information
Concrete Pavement Surface Characteristics (Part 1): Concrete Pavement Surface Characteristics Strategic Plan	FHWA, CP Tech Center at Iowa State University	Recent work conducted by the CP Tech Center at Iowa State University has provided a framework for coordinating and advancing concrete pavement surface characteristics research in the United States. This strategic plan is described herein.	www.cptechcenter.org
Concrete Pavement Surface Characteristics Project (Part 2): Field Evaluation of the Relationship of Concrete Pavement Surface Textures to Surface Characteristics Properties	FWHA, ACPA, CP Tech Center at Iowa State University	The objective of the initial field evaluation is to measure and analyze conventional texturing variations and grinding techniques and their respective surface characteristics, particularly with respect to tire-pavement noise.	www.cptechcenter.org
Concrete Pavement Surface Characteristics Project (Part 3): Field Evaluation of Conventional Practices and Innovative Solutions for Desired Concrete Pavement Surface Characteristics (TPF-05(139))	FHWA, ACPA, IGGA, states, CP Tech Center at Iowa State University	This part of the project includes identifying and evaluating innovative texturing techniques that have the potential to reduce noise by an order of magnitude or more, while also not degrading the other surface characteristics (smoothness, friction, drainage, etc.) of the pavement. This work also includes a comprehensive analysis of Part 2 data that will in turn lead to building more successful texturing techniques using conventional methods.	www.cptechcenter.org
Pavement Surface Properties Consortium (TPF-05(141))	Virginia DOT	The objective of the pool fund is to establish a research program focused on enhancing the level of service provided by the roadway transportation system through optimized pavement surface texture characteristics. The initial focus of the program will be the application of inertial and laser-based equipment for measuring these properties. An interactive project solicitation process will be used to request feedback from all participants.	http://www.pooledfund.org/projectdetails.asp?id=1042&status=1
Performance Monitoring of Surface Tining Techniques	Kentucky Transportation Cabinet	Interstate 65 in Hardin County is currently being rehabilitated from milepost 97.454 to 102.295. The new pavement will be constructed as an unbonded concrete overlay. The Kentucky Transportation Center will evaluate tining techniques related to surface performance for skid, noise, wear, and any other distresses that may develop during the life of this project.	http://rip.trb.org/browse/dproject.asp?n=11390
PCC Surface Characteristics - Rehabilitation (TPF-05(134))	Minnesota DOT	The objective of this study is to field construct and evaluate concrete pavement grinding strategies and their impact on smoothness, friction/texture, and tire-pavement noise using the MnROAD facility. Strategies used will be developed in cooperation with ACPA and build from research performed at Purdue University.	http://www.pooledfund.org/projectdetails.asp?id=1048&status=1

3. Subtracks and Problem Statements

The plan includes 40 problem statements organized into seven subtracks. The subtracks are summarized below, followed by the plan's problem statements.

3.1. SUBTRACKS

Subtrack SC 1. Innovative and Improved Concrete Pavement Surfaces

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Pervious Concrete Pavements to Provide Desired Surface Characteristics									Guidelines and specifications for the design and construction of pervious concrete surfaces for desired surface characteristics.
	Improvements to Concrete Pavement Texturing									Improved guidelines and specifications for designing and constructing conventionally textured concrete pavement surfaces.
	Improvements to Concrete Pavement Grinding and Grooving									Improved guidelines and specifications for grinding and grooving concrete pavement surfaces.
				Exposed Aggregate Surfaces in Two-Course Paving						Guidelines and specifications for designing and constructing exposed aggregate concrete pavement surfaces.
					Precast Concrete Pavements to Provide Desired Surface Characteristics					Guidelines and specifications for designing and constructing precast concrete pavements for desired surface characteristics.
					Advancing Innovative Concrete Pavement Solutions for Desired Surface Characteristics					Guidelines and specifications for the construction and design of promising new concrete pavement solutions to address one or more surface characteristics demands.

Subtrack SC 2. Tire-Pavement Noise

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Relationship of Tire-Pavement Noise to Texture and Other Factors									A sophisticated model for predicting tire-pavement noise as a function of concrete pavement texture, materials characteristics, and other physical properties.
		Standardized Tire-Pavement Noise Measurement Method								A standardized method or combination of methods for measuring tire-pavement noise; standards and specifications for use of the new tire-pavement measurement method.
			Tire-Pavement Noise Thresholds							Report defining tire-pavement noise thresholds; Guidelines for designing, constructing, and rehabilitating concrete pavements that do not exceed the thresholds.
				In-Vehicle Noise Measurement						A standardized method for measuring in-vehicle noise; Standards and specifications for using the recommended method.
						Behind-the-Paver Tire-Pavement Noise Sensing Equipment				Standards and specifications for using equipment to measure concrete pavement noise and related surface characteristics behind-the-paver.

Subtrack SC 3. Concrete Pavement Texture and Friction

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Behind-the-Paver Texture Sensing Equipment									Standards and specifications for using behind-the-paver texture sensing equipment.
	Model to Relate and Integrate Texture and Friction									A model that relates and integrates texture and friction characterization.
	High-Speed 3D Macrotexture Measurement									Standards and specifications for the use of effective, high-speed 3D macrotexture assessment equipment.
		Multidimensional Friction Measurement Model								Effective method for multidimensional friction measurement; Standards and specifications for use of the method.
			Automated, In Situ 3D Microtexture Measurement							Guidelines, standards, and specifications for the use of in situ 3D microtexture assessment equipment.
					High-Speed 3D Microtexture Measurement					Standards and specifications for the use of effective, high-speed 3D microtexture measurement equipment.

Subtrack SC 4. Safety and Other Concrete Pavement Surface Characteristics

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack (Y1–Y3)										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Splash and Spray (Y2–Y5)									Guidelines and specifications for using splash and spray assessment equipment; Guidance for designing pavement surfaces to minimize splash and spray.
		Rolling Resistance Assessment (Y3–Y6)								Guidelines and specifications for using rolling resistance assessment equipment.
		Reflectivity and Illuminance Assessment (Y3–Y6)								Guidelines and specifications for using reflectivity and illuminance assessment equipment.
		Relationship of Pavement Surface Characteristics to Vehicle Crashes (Y3–Y7)								Evaluation of vehicle crash risks as a function of surface characteristics; Guidance on designing and constructing pavements with reduced crash rates.
				Relationship of Pavement Texture to Tire and Vehicle Wear (Y5–Y8)						Guidelines and specifications for using tire and vehicle wear assessment equipment.

Subtrack SC 5. Concrete Pavement Profile Smoothness

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack (Y1–Y3)										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Design and Construction Guidelines to Improve Pavement Smoothness (Y2–Y4)									Comprehensive and accurate design and construction guidelines to assist stakeholders in improving concrete pavement smoothness.
	High-Speed, High-Resolution 3D Pavement Profiling (Y2–Y5)									An effective method for high-speed, high-resolution 3D pavement profiling; Standards and specifications for use of the method.
		Behind-the-Paver Smoothness Sensing Equipment (Y3–Y6)								Advanced, effective behind-the-paver smoothness sensing equipment with standards and specifications for its use.
				Next Generation Concrete Pavement Smoothness Standards (Y5–Y8)						Recommended refinements to AASHTO provisional standards for pavement profiling and ride quality.

Subtrack SC 6. Synthesis and Integration of Concrete Pavement Surface Characteristics Research

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Comprehen-sive Surface Character-istics Field Evaluation									A rich concrete pavement surface characteristics database available for additional future data analysis; Guidance report with case studies that defines optimum concrete pavement surface characteristics and the methods for achieving them.
			Durability of Concrete Pavement Surface Characteristics							Reports that document the longevity and durability of various surface characteristics; Guidance on effective surfacing methods that provide durable surface characteristics.
				Unified Model of Concrete Pavement Texture, Noise, Friction, and Smoothness						A comprehensive model that unifies texture, noise, friction, smoothness, and other related variables.
							Mix Design System for Desired Surface Characteristics			A mix design system that accounts for the functional demands of the pavement surface layer.

Subtrack SC 7. Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research

Problem Statement Schedule (10 years)										Products
Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	
Framework for Subtrack										A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.
	Workshops and Publications on Concrete Pavement Surface Characteristics Measurement Equipment and Techniques									Workshops and publications on new methods and equipment for measuring concrete pavement surface characteristics.
		Online Training to Implement New Products and Methods for Improved Concrete Pavement Surface Characteristics								A website with web-based modules that train contractors, designers, and owner-agencies in new models, software, and methods for improved surface characteristics.
			Workshops and Publications on Designing and Constructing Concrete Pavements with New and Improved Surface Characteristics							Workshops and publications on designing and constructing concrete pavements with improved concrete pavement surface characteristics.

3.2. PROBLEM STATEMENTS

The plan’s problem statements follow.

SC 1.1. Framework for Innovative and Improved Concrete Pavement Surfaces

Subtrack: Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule: Year 1–Year 3
Estimated Cost: $100k–$250k

Need and Objective

This subtrack will evaluate and advance a variety of new and improved concrete paving solutions for achieving desired pavement surface characteristics. Examples include pervious concrete pavements, exposed aggregate surface courses, precast pavements, and improvements in texturing, grinding, and grooving. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 1.2. Pervious Concrete Pavements to Provide Desired Surface Characteristics

Subtrack: Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule: Year 2–Year 6
Estimated Cost: $1M–$2M

Need and Objective

Pervious concrete pavements have demonstrated an ability to provide surface characteristics similar to those associated with open-graded (pervious) asphalt pavements. However, pervious concrete pavements only perform well if the surface is well maintained. As with porous asphalt surfaces, the pervious concrete pavement surface must be cleaned regularly to prevent debris from clogging the pores that give the surface its beneficial drainage and acoustic properties. Initial experiences with pervious concrete pavement in Belgium showed poor durability in freezing weather; however, these mixtures have since been made more durable with the addition of polymers and additional cement contents. The objective of this research is to further develop effective methods for designing and constructing pervious concrete pavements, especially pervious concrete surface courses.

Potential Scope

- Identify cases in which pervious concrete pavements were used and study how they performed in terms of tire-pavement noise, durability, and other engineering properties.
- Assess how the pervious concrete pavement sections studied were designed and built, identifying relationships between design, construction, and performance.
- Design and build test sections based on the results of previous studies. Thoroughly evaluate the initial and long-term material, structural, and acoustic performance of the test pavements.
- Recommend changes to pervious concrete pavement design and construction practices as necessary.
- Develop final guidelines and specifications to ensure proper design and construction of pervious concrete pavement surfaces.

Products

Guidelines and specifications for the design and construction of pervious concrete surfaces for desired surface characteristics.

Benefits

The guidelines and specifications developed in this research will improve the design, construction, and maintenance of high-quality pervious concrete pavement surfaces.

Coordination

A framework for research on pervious concrete surface courses has been developed through the National Concrete Pavement Technology Center's Concrete Pavement Surface Characteristics Project.

SC 1.3. Improvements to Concrete Pavement Texturing

Subtrack: Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule: Year 2–Year 6
Estimated Cost: $1M–$2M

Need and Objective

The importance of concrete pavement surface texture characteristics for roadway safety has been recognized since the late 1940s, when increases in traffic volumes and vehicle speeds resulted in increased wet-weather accidents and fatalities. Often, appropriate microtexture is sufficient to provide adequate stopping on concrete pavements when vehicles are traveling under 80 km/hr (50 mph). However, when higher vehicle speeds are expected, better microtexture and macrotexture are necessary to provide adequate wet-pavement friction. While increasing macrotexture reduces splash and spray, rougher macrotexture also increases tire-pavement noise. The objective of this research is to refine conventional texturing methods, including tining and drag methods used on fresh concrete pavement surfaces, to maximize surface friction and minimize tire-pavement noise.

Potential Scope

- Identify cases where numerous conventional texturing methods have been evaluated side by side with minimal variation in other parameters. Study the ways these various textures performed in terms of tire-pavement noise, durability, and other engineering properties.
- Assess the design and construction for the sections studied, identifying relationships between design and construction and performance.
- Design and build additional test sections based on the results of previous studies. Thoroughly evaluate the initial and long-term material, structural, and acoustic performance.
- Recommend changes to design and construction practices as necessary.
- Develop final guidelines and specifications to ensure proper design and construction of conventionally textured concrete pavement surfaces.

Products

Improved guidelines and specifications for designing and constructing conventionally textured concrete pavement surfaces.

Benefits

The guidelines and specifications developed in this research will improve the design and construction of conventionally textured concrete pavement surfaces, maximizing surface friction while minimizing tire-pavement noise.

Coordination

The improved texturing techniques developed through this research should take into consideration new knowledge developed in other surface characteristics subtracks (for example, on tire-pavement noise, friction, and other safety characteristics).

SC 1.4. Improvements to Concrete Pavement Grinding and Grooving

Subtrack:	Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule:	Year 2–Year 6
Estimated Cost:	$1M–$2M

Need and Objective

Grinding both newly placed and existing concrete pavements effectively improves surface friction and smoothness while decreasing tire-pavement noise. Grinding improves pavement frictional characteristics by exposing microtexture and creating macrotexture. In addition, grinding increases lateral control for vehicles, especially on transitions and super-elevated curve sections. The objective of this research is to develop effective grinding and grooving methods that will maximize surface friction and minimize tire-pavement noise.

Potential Scope

- Identify cases that evaluated numerous grinding or grooving methods side by side with minimal variation in other parameters. Study ways in which these various textures performed in terms of tire-pavement noise, durability, and other engineering properties.
- Assess the design, construction, and subsequent texturing for these test sections, identifying relationships between design, construction, texturing, and performance.
- Design, build, and texture additional test sections based on the results of the previous studies. Thoroughly evaluate the initial and long-term material, structural, and acoustic performance.
- Recommend changes to design, construction, or grinding practices as necessary.
- Develop final guidelines and specifications to ensure proper design, construction, and grinding of concrete pavement surfaces.

Products

Improved guidelines and specifications for grinding and grooving concrete pavement surfaces.

Benefits

The grinding and grooving methods advanced through this research will maximize surface friction while minimizing tire-pavement noise, improving macrotexture and microtexture.

Coordination

The improved grinding and grooving techniques developed through this research should take into consideration new knowledge developed in other surface characteristics subtracks (for example, on tire-pavement noise, friction, and other safety characteristics).

SC 1.5. Exposed Aggregate Surfaces in Two-Course Concrete Paving

Subtrack:	Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule:	Year 5–Year 9
Estimated Cost:	$500k–$1M

Need and Objective

Though widely used in European countries, exposed aggregate surface techniques have not been widely used in the United States. An experimental U.S. project on I-75 in Detroit did not show the improved surface friction and tire-pavement noise that had been expected. However, the European experience with the exposed aggregate technique illustrates that, when properly designed and constructed, exposed aggregate surfaces perform very well. Characteristics improved with exposed aggregate pavements include low noise, excellent high-speed skidding resistance, good surface durability, and low splash and spray. The objective of this research is to further develop effective methods for designing and constructing exposed aggregate concrete pavement surfaces in two-course concrete paving.

Potential Scope

- Identify cases where exposed aggregate surfaces have been used and study their performance in terms of tire-pavement noise, durability, and other engineering properties.
- Assess the design and construction methods for these cases, identifying relationships between these design and construction and performance.
- Design and build test sections based on the results of previous studies. Thoroughly evaluate the initial and long-term material, structural, and acoustic performance.
- Recommend changes to design and construction practices as necessary.
- Develop final guidelines and specifications to ensure proper design and construction of exposed aggregate concrete pavement surfaces.

Products

Guidelines and specifications for designing and constructing exposed aggregate concrete pavement surfaces.

Benefits

The guidelines and specifications developed in this problem statement will improve the design and construction of exposed aggregate concrete pavement surfaces with low noise, excellent high-speed skidding resistance, good surface durability, and low splash and spray.

Coordination

This research should be closely coordinated with Problem Statement EA 2.4 (Two-Course Concrete Paving) in CP Road Map Track 5.

SC 1.6. Precast Concrete Pavements to Provide Desired Surface Characteristics

Subtrack:	Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule:	Year 6–Year 10
Estimated Cost:	$500k–$1M

Need and Objective

Concrete pavements designed with optimized surface characteristics may not be constructed as designed due to many factors, including contractor inexperience or environmental conditions during construction. Using precast concrete pavement surfaces will minimize these construction variables because construction processes can be better controlled. Precast surfaces with innovative features such as Helmholtz Resonators have already been implemented in Europe; these precast surface technologies may have effective applications in the United States as well. The objective of this research is to develop guidelines and specifications for designing and constructing precast concrete pavements with desired surface characteristics.

Potential Scope

- Identify cases in which precast concrete pavements have been used for noise mitigation and study these pavements’ performance in terms of tire-pavement noise, durability, and other engineering properties.
- Assess the design and construction of these test sections, identifying relationships between design and construction and pavement performance.
- Design and build test sections based on the results of previous studies. Thoroughly evaluate the initial and long-term material, structural, and acoustic performance.
- Recommend changes to design and construction practices as necessary.
- Develop final guidelines and specifications to ensure proper design and construction of precast concrete pavements.

Products

Guidelines and specifications for designing and constructing precast concrete pavements for desired surface characteristics.

Benefits

The guidelines and specifications developed in this research will improve the design and construction of precast concrete pavements with desired surface characteristics and with minimized variations due to construction conditions.

Coordination

This research should be closely coordinated with Problem Statement RC 2.5 (Precast Quiet Pavement Surfaces) in CP Road Map Track 7.

SC 1.7. Advancing Innovative Concrete Pavement Technologies for Desired Surface Characteristics

Subtrack:	Innovative and Improved Concrete Pavement Surfaces
Approx. Schedule:	Year 6–Year 10
Estimated Cost:	$500k–$1M

Need and Objective

Additional concrete pavement products, techniques, and applications not already addressed in the other problem statements in this subtrack need to be identified, evaluated, and advanced to order to fully achieve concrete pavement's potential for providing desired surface characteristics. Concrete pavements are well known for their durability and numerous other characteristics. Inherent with concrete is the ability to use numerous additives and inclusions and to be formed in virtually any geometry. Given the infinite number of permutations, this project exists to capture innovative concrete pavement technologies that might be developed in order to address one or more surface characteristics.

Potential Scope

- Identify innovative concrete pavement technologies that can be used to address the demand for various levels of surface characteristics and that need further evaluation for their advancement.
- Identify contracting mechanisms that would result in the required innovative technologies to be developed and tried.
- Design and build test sections of the innovative concrete pavement technologies. Thoroughly evaluate the initial and long-term material, structural, and functional performance.
- Recommend changes to design and construction practices as necessary.
- Develop final guidelines and specifications to ensure proper design and construction of these innovative concrete pavements.

Products

Guidelines and specifications for the construction and design of promising new concrete pavement solutions to address one or more surface characteristics needs.

Benefits

The innovative concrete pavement products, techniques, and applications advanced through this research will lead to an effective new suite of concrete pavement options that can address a variety of surface characteristics demands.

Coordination

This problem statement serves as a catalyst for creative ideas and innovations, encouraging and expediting solutions that would otherwise take decades, if ever, to advance to implementation.

SC 2.1. Framework for Tire-Pavement Noise

Subtrack:	Tire-Pavement Noise
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack provides a set of research problem statements that will culminate in significantly improved concrete pavement surfaces with respect to tire-pavement noise generation, propagation, and mitigation. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within the subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 2.2. Relationship of Tire-Pavement Noise to Texture and Other Factors

Subtrack:	Tire-Pavement Noise
Approx. Schedule:	Year 2–Year 5
Estimated Cost:	$1M–$2M

Need and Objective

A relationship clearly exists between concrete pavement surface texture and the noise generated by the tire-pavement interface. Other concrete pavement properties such as absorptivity, stiffness, and density also affect tire-pavement noise to varying degrees. Currently, information about the relationships between tire-pavement noise and physical pavement characteristics is empirical at best. The objective of this research is to develop a systematic understanding of the relationship between noise and the way texturing is specified and placed. This work will identify and/or develop improved models to predict the tire-pavement noise for a variety of concrete pavement surfaces. The models will consider various types of directional texturing as well as random textures that may result from advancements in texturing technology.

Potential Scope

- Evaluate and synthesize current models that relate concrete pavement texture and other properties to tire-pavement noise generation, amplification, and propagation.
- Assess whether additional model components need to be developed. Develop and/or enhance model as needed. Provide a recommended unified model that synthesizes the various models.
- Validate the model using controlled experiments with tire-pavement noise measurements or pavement structures with known textures and physical characteristics. The experiments should include both controlled laboratory and field experiments.
- Document the model to allow it to be readily integrated into related work that optimizes pavement texture to minimize the potential for excessive tire-pavement noise.

Products

A sophisticated model for predicting tire-pavement noise as a function of concrete pavement texture, materials characteristics, and other physical properties.

Benefits

The model resulting from this research will provide a rational approach to predicting tire-pavement noise. The results will be useful in writing texturing specifications that deliver the expected noise reduction with adequate friction.

Coordination

This research will build off of models that are at varying stages of development and of varying types (for example, work by the National Concrete Pavement Technology Center and that under various European Union initiatives). Further surface characteristics research will require a better understanding of the relationship between texture, materials characteristics, and tire-pavement noise and will thus rely heavily on the results of this research.

SC 2.3. Standardized Tire-Pavement Noise Measurement Method

Subtrack: Tire-Pavement Noise
Approx. Schedule: Year 3–Year 6
Estimated Cost: $1M–$2M

Need and Objective

Several methods currently measure both vehicle and tire-pavement noise. Traditionally, traffic noise is measured using wayside measures such as statistical pass-by testing, which samples passing vehicles at the roadside, classifying their noise emission by the type of vehicle. Another wayside method, termed controlled pass-by, uses a test vehicle with known tire properties that passes a fixed microphone. This method allows for a detailed assessment of noise generation because many of the dependent variables are known or controlled. In recent years, alternative noise measurement methods called “close proximity,” “source,” or “near-field” testing have become more common. In these methods, various microphones are mounted to a test vehicle near the tire-pavement contact patch. These methods seek to isolate the noise generated at the contact patch from other sources. However, since the pass-by and close-proximity methods do not measure the exact same noise sources, no simple relationship between them can be derived that will work under all circumstances. Furthermore, each variant within these two testing categories results in a different measurement, making comparison between the various methods even more difficult. Because of these compatibility issues, as well as the impact that tire-pavement noise is making on policy in Europe and now in the United States, this research will develop a standardized method for measuring and comparing tire-pavement noise.

Potential Scope

- Identify and synthesize various accepted methods of measuring vehicle noise, particularly those that isolate tire-pavement noise. This should include the current draft specification ISO 11819-2 and ongoing standardization activities for the On-Board Sound Intensity (OBSI) method. Work underway in NCHRP 1-44 should also be considered.
- Conduct a preliminary investigation to determine the best methods for quantifying tire-pavement noise. Confirm that measuring tire-pavement noise will advance the industry and meet the goals for CP Road Map Track 4.
- Identify decision-making criteria for a standard method selection and prioritize the available methods. Where applicable, recommend variations of existing test methods or combinations of test methods. If necessary, develop new methods that can be tested in the field.
- Analyze the candidate methods and/or equipment for accuracy, precision, and ease of use. The measurement systems should be gauged for its repeatability and reproducibility, and should produce results on a relevant scale. The resulting measurements should allow for specification and control or at least monitoring of the construction process. Thus, they should allow for threshold values to be derived. They should also be tied (directly or indirectly) to cost, public satisfaction, and long-term evaluations of functional performance.
- Develop a final recommended method or combination of methods for measuring tire-pavement noise.
- Develop standards and specifications to ensure that proper procedures are followed when the recommended methods are used.

Products

A standardized method or combination of methods for measuring tire-pavement noise; standards and specifications for use of the new tire-pavement measurement method.

Benefits

This research will result in methods that provide for a meaningful, consistent, and reproducible comparison of tire-pavement noise.

Coordination

This research should be closely coordinated with other ongoing and future tire-pavement noise work.

SC 2.4. Tire-Pavement Noise Thresholds

Subtrack:	Tire-Pavement Noise
Approx. Schedule:	Year 4–Year 6
Estimated Cost:	$500k–$1M

Need and Objective

The objective of this research is to define goals for tire-pavement noise levels that are needed to satisfy the public. Noise thresholds should be a factor in pavement optimization. These noise thresholds should characterize tire-pavement noise levels and frequencies, scaling them to include a range of human responses, from mere annoyance to driver and abutter distraction. Research is needed to define these threshold values so that more rational decisions can be made about the tradeoffs between tire-pavement noise and other pavement surface characteristics. Furthermore, it is possible that these same thresholds might be used in policy and the noise models such as the FHWA Traffic Noise Model (TNM) that predict the impacts to abutters. To accomplish this, threshold values will need to be identified for all relevant measurement techniques (e.g., source, in-vehicle, and wayside). This research will answer the question how quiet is quiet enough?

Potential Scope

- Synthesize the current knowledge in this area, drawing from existing work in psychoacoustics.
- Conduct validation surveys on various pavements, assessing the human response to the received noise.
- Define threshold values that can provide a more rational characterization of the human response to both tire-pavement noise level and frequency.
- Provide recommendations for designing, constructing, and rehabilitating concrete pavements that do not exceed the defined threshold values.
- Assess the impact of the thresholds on policy, including the FHWA TNM and other available noise models (e.g., HARMONOISE).

Products

Report defining tire-pavement noise thresholds; Guidelines for designing, constructing, and rehabilitating concrete pavements that do not exceed the thresholds.

Benefits

The rational threshold limits defined in this research will provide guidance in designing, constructing, and rehabilitating concrete pavements with both acceptable friction and tire-pavement noise characteristics.

Coordination

This research will provide noise thresholds that will be used as target values in further surface characteristics research.

SC 2.5. In-Vehicle Noise Measurement

Subtrack:	Tire-Pavement Noise
Approx. Schedule:	Year 5–Year 8
Estimated Cost:	$250k–$500k

Need and Objective

Recent research found that objectionable noise inside the vehicle is identified more with tonal quality (specific frequencies) rather than with total noise level. This objectionable tonal quality is commonly generated by repeating patterns in pavement texture such as transverse tining or even low frequency chatter. It has been recognized that the pavement texture components that affect in-vehicle noise are different than those that affect roadside noise. Previous research revealed that subjective noise ratings of subjects in test vehicles on different surface textures do not correspond with the objective total noise measurements taken outside the vehicle. In order to better understand these and other related issues, standardized in-vehicle noise evaluation procedures are required. The objective of this research is to develop a standardized method or combination of methods for measuring in-vehicle noise. The recommended method will consider the impact that the vehicle itself has on the test results.

Potential Scope

- Identify and analyze accepted and prospective methods of measuring in-vehicle noise. Existing ISO and SAE standards should be considered only as a starting point.
- Conduct a preliminary investigation to determine the best methods for measuring in-vehicle noise. Confirm that more sophisticated noise measurement techniques will advance the industry and meet the goals for CP Road Map Track 4.
- Analyze the candidate methods and/or equipment for accuracy, precision, and ease of use. The measurement system should be gauged for its repeatability and reproducibility and should produce results on a relevant scale. The resulting measurements should allow for specification and control or at least monitoring of the construction process and should allow for threshold values to be derived. They should also be tied (directly or indirectly) to cost, public satisfaction, and long-term evaluations of functional performance.
- After comparing the various methods, recommend methods of measurement that include either an existing method or a combination of methods.
- Develop standards and specifications to ensure proper procedures are followed for the measurement method.

Products

A standardized method for measuring in-vehicle noise; Standards and specifications for using the recommended method.

Benefits

This research will result in an advanced method for measuring in-vehicle noise, allowing for more rational decisions to be made about the influence of noise on the traveling public.

Coordination

This research should be closely linked with other ongoing noise-related work, including the research conducted under the Standardized Tire-Pavement Noise Measurement Method problem statement.

SC 2.6. Behind-the-Paver Tire-Pavement Noise Sensing Equipment

Subtrack: Tire-Pavement Noise
Approx. Schedule: Year 7–Year 10
Estimated Cost: $250k–$500k

Need and Objective

The noise generated by tire-pavement contact is related to the surface texture and other concrete pavement surface properties. Current technology only allows tire-pavement noise levels to be assessed after the pavement has hardened sufficiently to accommodate a test vehicle. If tire-pavement noise is a specification value, and if this value falls outside an acceptable level, costly methods could be required to mitigate the problem. If tire-pavement noise and/or pavement surface texture and other properties (e.g., absorptivity) related to tire-pavement noise could be assessed during placement, improvements could be made in real time while the concrete is still plastic. The objective of this research is to advance effective behind-the-paver noise sensing equipment.

Potential Scope

- Assess the need for and advantages of behind-the-paver tire-pavement noise sensing equipment. The needs should be determined based on the current ability to model noise as a function of more fundamental properties of the pavement including texture.
- Identify currently available behind-the-paver tire-pavement noise sensing equipment. Analyze the equipment for accuracy, precision, and ease of use. Identify the most effective equipment based on cost, technological maturity, and the results of the above analyses. Suggest improvements or modifications to this equipment as needed.
- Develop standards and specifications for the proper use of the equipment for sensing pavement noise, texture, and other concrete properties related to noise.

Products

Standards and specifications for using equipment to measure concrete pavement noise and related surface characteristics behind-the-paver.

Benefits

This research will advance technology to sense tire-pavement noise behind-the-paver.

Coordination

This research should be closely coordinated with the Behind-the-Paver Texture Sensing Equipment problem statement, as well as CP Road Map Problem Statement ND 2.11 (Tire-Pavement Noise Sensing).

SC 3.1. Framework for Concrete Pavement Texture and Friction

Subtrack:	Concrete Pavement Texture and Friction
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack focuses on issues related to texture and friction properties of concrete pavements. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 3.2. Behind-the-Paver Pavement Texture Sensing Equipment

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 2–Year 6
Estimated Cost: $250k–$500k

Need and Objective

Numerous current techniques indicate texture in plastic concrete pavements. However, these techniques are often methods based. Texture is rarely verified due to a lack of testing equipment and expertise. Ideally, texture should be verified in situ and in real time as the paver with texture machine moves. Texture could thus be adjusted in real time, and over- or under-texturing could be minimized. The objective of this research is to advance effective behind-the-paver equipment that measures concrete pavement texture during placement.

Potential Scope

- Identify available behind-the-paver texture sensing equipment or equipment components.
- Analyze the equipment for accuracy, precision, and ease of use.
- Identify the most effective equipment based on cost, maturity, and the results of the above analyses. Suggest improvements or modifications to the equipment as needed.
- Develop standards and specifications for properly using the equipment to measure concrete pavement texture.

Products

Standards and specifications for using behind-the-paver texture sensing equipment.

Benefits

This research will advance technology that can serve as a key component for measuring concrete pavement texture behind the paver, improving the chance that the intended “as designed” texture is actually “as built.” The result is more predictable and consistent surface characteristics including friction and noise.

Coordination

This research should be closely coordinated with CP Road Map problem statement ND 2.10 (Concrete Pavement Texture Sensing).

SC 3.3. Model to Relate and Integrate Concrete Pavement Texture and Friction

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 2–Year 7
Estimated Cost: $1M–$2M

Need and Objective

Research has demonstrated the sensitivity of friction to texture in various wavelength ranges and explained the fundamental mechanisms involved. However, little systematic information currently describes the sensitivity of friction to the specific dimensions of each type of texture, including directionality and variables such as aggregate size or channel width and depth. The objective of this research is to develop a systematic understanding of the relationship between friction and the way texturing is specified and placed. This research will develop a model to relate and integrate texture and friction.

Potential Scope

- Identify and analyze widely used texturing methods.
- Analyze the respective relationships between these methods and pavement friction, tying this characterization to the research conducted under the Multidimensional Concrete Pavement Friction Assessment Methods problem statement as necessary.
- Develop a preliminary model to relate and integrate texture and friction.
- Make adjustments and recommend final model.

Products

A model that relates and integrates texture and friction characterization.

Benefits

This research will result in a model that advances the process of texture selection as it relates to friction, allowing for better prediction of friction resulting from texturing methods.

Coordination

This research should be conducted in conjunction with other research on concrete pavement texture, noise, and friction, including the Multidimensional Concrete Pavement Friction Assessment Method problem statement.

SC 3.4. High-Speed 3D Macrotexture Measurement

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 2–Year 8
Estimated Cost: $1M–$2M

Need and Objective

Measuring pavement macrotexture has been a common practice in Europe for many years. In the United States, the important role that pavement macrotexture plays in providing adequate surface friction is increasingly being recognized. Currently, the mean profile depth (MPD) parameter is used to describe macrotexture, allowing for crude predictions of wet pavement friction. Various spectral metrics are also being standardized. One way of measuring these or any improved metrics will be to use high-speed (for rapid data collection), vehicle-mounted, possibly laser-based measuring devices. This research will build off current equipment advancements to advance effective, high-speed macrotexture measurement equipment that can scan a pavement surface in three dimensions, giving a picture of both longitudinal and transverse variation in macrotexture. This is particularly important as many concrete pavement surface textures are different in both directions and thus will have different texture and friction properties.

Potential Scope

- Synthesize related work and conduct a preliminary investigation to determine the best methods for quantifying macrotexture. Confirm that measuring macrotexture will advance the industry and meet the goals for the CP Road Map Surface Characteristics Track.
- Identify available high-speed 3D equipment options, including laser-based equipment and other technologies as deemed appropriate.
- Analyze the equipment for accuracy, precision, and ease of use. The measurement system should be gauged for its repeatability and reproducibility and should produce results on a relevant scale. The resulting measurements should allow for specification and control or at least monitoring of the construction process. Thus, they should allow for threshold values to be derived. They should also be tied to cost, public satisfaction, and long-term evaluations of functional performance.
- Identify the most effective equipment based on the results of the above analyses. Recommend improvements or modifications to the equipment as needed.
- Develop standards and specifications on the proper use of the recommended equipment.

Products

Standards and specifications for the use of high-speed 3D macrotexture measurement equipment.

Benefits

This research will advance technology that can serve as a key component in assessing concrete pavement macrotexture in three dimensions, thus improving the prediction of wet pavement friction. With this, a more cost-effective characterization of a pavement surface can be made that directly ties to pavement friction, tire-pavement noise, and other functional indicators that are important to the traveling public.

Coordination

The results of this research will be used in the work conducted under the High-Speed 3D Microtexture Measurement problem statement.

SC 3.5. Multidimensional Friction Measurement Method

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 3–Year 9
Estimated Cost: $1M–$2M

Need and Objective

Roadway friction is a complex parameter. It is commonly assessed longitudinally along the direction of travel, essential for determining vehicle stopping distances. This assessment does not address situations in which vehicles slide sideways or diagonally into adjacent lanes, particularly while traversing horizontal curves. Furthermore, friction varies with the presence of water or other lubricating substances on the roadway. This research will capture these and other variables by developing a more effective method for multidimensional friction measurement. The recommended method will measure friction as fundamentally as possible so that the results can be incorporated into mechanistic models capable of optimizing pavement surfaces.

Potential Scope

- Synthesize related work and conduct a preliminary investigation to determine the best methods for quantifying friction. Confirm that more sophisticated friction measurement will advance the industry and meet the goals for the CP Road Map Surface Characteristics Track.
- Identify and analyze existing methods of friction measurement.
- Develop a recommended method for multidimensional friction measurement.
- Develop standards and specifications to ensure proper procedures are followed when using the method.

Products

Effective method for multidimensional friction measurement; Standards and specifications for use of the method.

Benefits

This research will results in safety improvements through a better characterization of how concrete pavement friction can vary depending on the reaction of tire behavior in various directions.

Coordination

This research will build off results from work conducted under the Model to Relate and Integrate Concrete Pavement Texture and Friction problem statement.

SC 3.6. Automated, In Situ 3D Microtexture Measurement

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 4–Year 9
Estimated Cost: $500k–$1M

Need and Objective

Microtexture refers to small-scale pavement roughness, finer than macrotexture, and largely determined by the fine aggregate in concrete mortar. Microtexture affects friction, particularly in dry weather and/or at slow speeds. It also affects tire-pavement noise and other surface characteristics of interest, including tire wear. Fundamentally measuring this property will improve the prediction and optimization of all these surface characteristics. Measuring concrete pavement microtexture is commonly done in the laboratory or estimated in the field using friction measurements. Because of the fine resolution necessary, no automated method for measuring microtexture in situ exists. The objective of this research is to evaluate and advance effective equipment for static, in situ 3D measurement of microtexture.

Potential Scope

- Synthesize related work and conduct a preliminary investigation to determine the best methods for quantifying microtexture in situ. Confirm that measuring microtexture in this way will advance the industry and meet the goals for the CP Road Map Surface Characteristics Track.
- Identify available options for in situ 3D microtexture assessment equipment.
- Analyze the equipment for accuracy, precision, and ease of use. The measurement system should be gauged for its repeatability and reproducibility and should produce results on a relevant scale. The resulting measurements should allow for specification and control or at least monitoring of the construction process. Thus, they should allow for threshold values to be derived. They should also be tied to cost, public satisfaction, and long-term evaluations of functional performance.
- Identify the most effective equipment based on cost, technological maturity, and the results of the above analyses. Recommend improvements or modifications to the equipment as needed.
- Develop standards and specifications on the proper use of in situ 3D microtexture measurement equipment. Develop guidelines that will ensure that the new measurement technologies can be integrated into design and construction control.

Products

Guidelines, standards, and specifications for the use of in situ 3D microtexture measurement equipment.

Benefits

With an automated method for measuring concrete pavement microtexture in situ, a more fundamental measure of its effect on friction and other surface characteristics (e.g., tire wear) can be more accurately gauged.

Coordination

This research should be closely coordinated with conducted under the High-Speed 3D Macrotexture Measurement problem statement. The results will be used in the High-Speed 3D Microtexture Measurement problem statement work.

SC 3.7. High-Speed 3D Microtexture Measurement

Subtrack: Concrete Pavement Texture and Friction
Approx. Schedule: Year 6–Year 10
Estimated Cost: $1M–$2M

Need and Objective

No automated method for measuring concrete pavement microtexture at highway speeds currently exists. However, high-speed 3D equipment is expected to be available for measuring macrotexture at highway speeds. This technology can possibly be adapted and improved (e.g., by increasing laser and computer processing power) to measure concrete pavement microtexture similarly at highway speeds. Other technologies may be available that can accomplish the same objective. The objective of this research is to evaluate and advance effective, high-speed 3D microtexture measurement equipment.

Potential Scope

- Synthesize related work and conduct a preliminary investigation to determine the best methods for quantifying microtexture. Confirm that the high-speed measurement of microtexture will advance the industry and meet the goals for the CP Road Map Surface Characteristics Track.
- Identify the most effective equipment options for measuring concrete pavement macrotexture and microtexture, referring to work conducted under the High-Speed 3D Macrotexture Measurement and In Situ 3D Microtexture Measurement problem statements.
- Modify the equipment or develop additional equipment to measure concrete pavement microtexture at highway speeds.
- Develop standards and specifications on the proper use of the equipment.

Products

Standards and specifications for the use of effective, high-speed 3D microtexture measurement equipment.

Benefits

The fundamental measurement of microtexture will allow for the prediction and optimization of friction, tire-pavement noise, tire wear, and other surface characteristics. High-speed measurement of microtexture will improve efficiency and minimize the problems associated with small samples.

Coordination

This research will build on work conducted under the High-Speed 3D Macrotexture Measurement and Automated, In Situ 3D Microtexture Measurement problem statements.

SC 4.1. Framework for Safety and Other Concrete Pavement Surface Characteristics

Subtrack:	Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack focuses on issues related to other surface characteristics including splay and spray, rolling resistance, reflectivity and illuminance, relationship to vehicle crashes, and relationship to tire and vehicle wear. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 4.2. Splash and Spray

Subtrack: Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule: Year 2–Year 5
Estimated Cost: $1M–$2M

Need and Objective

Tires rolling on a pavement with standing water commonly produce splash and spray, which occurs when the vehicle tires on the pavement surface pick up water and eject it as small droplets into the air. The airborne water can then reduce visibility, particularly for vehicles traveling next to or closely behind other vehicles. Research suggests that 10% of wet weather accidents are caused by poor visibility due to splash and spray. While macrotexture is a primary contributor to splash and spray, little is known about the quantitative relationship between macrotexture and splash and spray. The objectives of this research are to expand understanding of these relationships, evaluate splash and spray assessment equipment, and develop guidelines for reducing splash and spray. Testing with the equipment could measure the effectiveness of a given pavement in meeting reasonable splash and spray limits, thus increasing safety.

Potential Scope

- Research the role that splash and spray has on the overall functional performance of the pavement. For example, identify its link to safety, and thus the benefits that can be gained by improving this property.
- Research the relationships between pavement texture and splash and spray. Identify existing relationships and/or derive new relationships. For the latter, relationships with a fundamental basis are preferred in order to minimize the expense of model validation.
- Identify and evaluate existing equipment or new equipment as needed to assess splash and spray.
- Develop a model that explains and verifies meaningful and quantifiable relationships between macrotexture and splash and spray, if applicable.
- Develop guidelines and specifications on the proper use of the equipment and the proper interpretation of the relationships between macrotexture and splash and spray.
- Produce a guidance document for designing concrete pavement surfaces to minimize splash and spray.

Products

Model to relate texture to splash and spray; Guidelines and specifications for using splash and spray assessment equipment; Guidance for designing pavement surfaces to minimize splash and spray.

Benefits

Understanding the relationship between texture and splash and spray will help engineers optimize pavements for this property. The equipment advanced through this research will quantify this effect. The public will benefit from improved safety and improved perception of pavements.

Coordination

This research should be related to the work being conducted under the High-Speed 3D Macrotexture Measurement problem statement.

SC 4.3. Rolling Resistance Assessment

Subtrack: Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule: Year 3–Year 6
Estimated Cost: $1M–$2M

Need and Objective

Megatexture and concrete pavement roughness characteristics contribute to rolling resistance. Excessive rolling resistance can cause vehicles to work harder and thus increase user costs through increased fuel consumption and vehicle wear. The objectives of this research are to better understand these relationships and to advance effective rolling resistance assessment equipment, allowing the effects of rolling resistance to be measured directly. This equipment will also allow the relationship between this surface characteristic, texture, and other physical concrete pavement properties to be better understood. The effects of rolling resistance related to the pavement will be clearly separated from those due to the environment, vehicle, and/or other factors that are not a function of the pavement surface.

Potential Scope

- Research the role that rolling resistance has on the overall functional performance of the pavement. For example, identify its link to the user cost and thus the benefits that can be gained by improving this property.
- Research the relationships between pavement texture and rolling resistance. Identify existing relationships and/or derive new relationships. For the latter, relationships with a fundamental basis are preferred in order to minimize the expense of model validation.
- Identify existing or new concepts for rolling resistance assessment equipment.
- Analyze the equipment for accuracy, precision, and ease of use.
- Identify the most effective equipment based on cost, technological maturity, and the results of the above analyses. Recommend improvements or modifications to the equipment as needed.
- Develop and verify meaningful and quantifiable relationships between megatexture/roughness and rolling resistance, if applicable.
- Develop guidelines and specifications for properly using the equipment and properly interpreting relationships.

Products

Guidelines and specifications for using rolling resistance assessment equipment.

Benefits

This research will advance equipment that directly measures rolling resistance. This work will lead to reduced rolling resistance, resulting in reduced user costs through decreased fuel consumption and vehicle wear.

Coordination

This research may benefit from other ongoing advancements in equipment that measures various concrete pavement surface characteristics.

SC 4.4. Reflectivity and Illuminance Assessment Equipment

Subtrack: Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule: Year 3–Year 6
Estimated Cost: $1M–$2M

Need and Objective

Different concrete pavement materials and textures can affect reflectivity/illuminance characteristics. Some reflectivity and illuminance can be beneficial (e.g., reflection that aids nighttime driving), but too much can be distracting (e.g., sunlight reflected during daylight hours, particularly at dawn or dusk). This research will advance effective reflectivity and illuminance assessment equipment. This equipment will allow optimum materials and textures to be selected to provide the ideal level of reflectivity and illuminance.

Potential Scope

- Research the role that reflectivity and illuminance has on the overall functional performance of the pavement. For example, identify its link to safety, and thus the benefits that can be gained by improving this property.
- Research the relationships between pavement texture, concrete properties, and reflectivity and illuminance. Identify existing relationships and/or derive new relationships. For the latter, relationships with a fundamental basis are preferred in order to minimize the expense of model validation.
- Identify available reflectivity and illuminance assessment equipment.
- Analyze the equipment for accuracy, precision, and ease of use.
- Identify the most effective equipment based on cost, technological maturity, and the results of the above analyses. Recommend improvements or modifications to the equipment as needed.
- Develop guidelines and specifications to ensure the proper use of the equipment.

Products

Guidelines and specifications for using reflectivity and illuminance assessment equipment.

Benefits

This research will advance equipment that assesses concrete pavement reflectivity and illuminance, allowing the level of reflectivity/illuminance to be optimized and thus improved ride safety.

Coordination

This research may benefit from other ongoing advancements in equipment that measures various concrete pavement surface characteristics.

SC 4.5. Relationship of Pavement Surface Characteristics to Vehicle Crashes

Subtrack: Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule: Year 3–Year 7
Estimated Cost: $1M–$2M

Need and Objective

Because safety is important, the traveling public demands it and the highway community must respond to this demand by designing and building roads that minimize the acceptable risks of vehicle crashes. Pavement surface characteristics, including texture, friction, splash and spray, and illuminance and reflectivity, can impact crash potential. However, little is known about the relationship between pavement surface characteristics and the increased crash rate. Because numerous variables impact the overall crash rate, quantifying the crash risks from any single factor proves difficult. The objective of this research is to methodically evaluate numerous existing concrete pavements, assessing the relevant pavement surface characteristics and collecting crash rate statistics categorized by the likely contributors to the crashes.

Potential Scope

- Investigate the exposure to liability that the results of the research might incur, and take measures to formulate and execute the research so that this exposure is mitigated.
- Identify the pavement surface characteristics most likely to contribute to vehicle crashes and prioritize these characteristics for subsequent consideration in this research.
- Develop and execute a plan for collecting data on pavement surface characteristics and crash rates nationwide. Ensure the methods are statistically sound and enough data are collected to make reliable conclusions.
- Analyze the data and report the relationship found between pavement surface characteristics and vehicle crash rates.
- Develop general guidance related to designing and constructing concrete pavements with reduced crash rates.

Products

Evaluation of vehicle crash risks as a function of the types and magnitudes of pavement surface characteristics; Guidance on designing and constructing concrete pavements with reduced crash rates.

Benefits

This research will result in improved methods for designing and constructing concrete pavements to minimize crash rates.

Coordination

This research should consider the methods and results of other related roadway safety and vehicle crash research.

SC 4.6. Relationship of Pavement Texture to Tire and Vehicle Wear

Subtrack: Safety and Other Concrete Pavement Surface Characteristics
Approx. Schedule: Year 5–Year 8
Estimated Cost: $1M–$2M

Need and Objective

Tire and vehicle wear relate directly to user costs. Microtexture is a primary factor that contributes to tire wear, while megatexture and roughness contribute to rolling resistance, which contributes to vehicle wear. The objective of this research is to advance effective tire and vehicle wear assessment equipment. This equipment will allow the relationship between texture and vehicle and tire wear to be better understood.

Potential Scope

- Identify the importance of tire and vehicle wear (for example, its link to user costs) and the potential benefits that can be gained by modifying pavement surface properties to minimize tire and vehicle wear.
- Research known relationships between pavement texture and vehicle and tire wear.
- Identify necessary equipment for assessing tire and vehicle wear. Recommend improvements or modifications as needed.
- Using effective microtexture and megatexture/roughness assessment equipment (note work conducted under the Automated, In Situ 3D Microtexture Measurement and High-Speed 3D Microtexture Measurement problem statements) and the tire and vehicle wear assessment equipment, develop improved relationships between texture and tire and vehicle wear.
- Develop guidelines and specifications on proper use of the equipment and interpretation of the results.

Products

Guidelines and specifications for using tire and vehicle wear assessment equipment.

Benefits

This research will lead to the reduced user costs associated with minimizing tire and vehicle wear.

Coordination

This research should be closely coordinated with the Rolling Resistance Assessment problem statement.

SC 5.1. Framework for Concrete Pavement Profile Smoothness

Subtrack:	Concrete Pavement Profile Smoothness
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack focuses on issues related to concrete pavement smoothness. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 5.2. Design and Construction Guidelines to Improve Concrete Pavement Smoothness

Subtrack: Concrete Pavement Profile Smoothness
Approx. Schedule: Year 2–Year 4
Estimated Cost: $500k–$1M

Need and Objective

To provide smooth pavements, most state departments of transportation have implemented smoothness specifications that offer incentives for very smooth pavements and impose penalties for unacceptably rough pavements. However, little specific guidance assists contractors in improving smoothness during pavement construction. Similarly, little guidance is provided to pavement designers to achieve smoothness goals. The objective of this research is to develop such guidance.

Potential Scope

- Develop an initial draft of smoothness guidelines by synthesizing existing best practices for design and construction of smooth concrete pavements.
- Validate the draft guidelines by contacting agencies to identify recently constructed pavements of varying smoothness levels. Assess the ways in which the pavements were designed and built and determine whether the draft guidelines are valid under the varying situations.
- Based on this validation, identify the need for additional test sections to assist in refining the guidelines. Execute this validation work if necessary.
- Develop a final set of design and construction guidelines to improve concrete pavement smoothness.

Products

Comprehensive and accurate design and construction guidelines to assist stakeholders in improving concrete pavement smoothness.

Benefits

This research will result in guidelines that advance design and construction practices to achieve pavement smoothness goals.

Coordination

The design and construction guidelines for concrete pavement smoothness should be closely coordinated with work conducted under the High-Speed, High-Resolution 3D Pavement Profiling problem statement and may need to be modified and updated upon completion of the Next Generation Concrete Pavement Smoothness Standards problem statement.

SC 5.3. High-Speed, High-Resolution 3D Pavement Profiling

Subtrack: Concrete Pavement Profile Smoothness
Approx. Schedule: Year 2–Year 5
Estimated Cost: $2M–$5M

Need and Objective

Current concrete pavement profiling technology commonly differentiates two categories of profiles: longitudinal and lateral. Longitudinal profiles are measured for an assessment of concrete pavement roughness and some forms of texture. Lateral profiles are measured for an assessment of rutting (e.g., from studded tire damage), cross slope, lane separation, and localized damage. While combining these two profiles can be beneficial, such combinations are rare because piecing the two together is laborious and the resulting complete profile is often questionable. Ideal concrete pavement profiles would include methods for 3D measurement, which allow pavement distresses and directional features in the pavement surface to be readily detected and quantified. The objective of this research is to develop an effective method for high-speed (for rapid data collection), high-resolution 3D pavement profiling.

Potential Scope

- Synthesize related work and conduct a preliminary investigation to determine the best methods for profiling concrete pavements. Confirm that more sophisticated pavement profiling techniques will advance the industry and meet the goals for the CP Road Map Surface Characteristics Track.
- Identify and analyze existing methods for 3D pavement profiling.
- Develop additional methods as needed for higher speed and higher resolution performance.
- Analyze the methods and/or equipment for accuracy, precision, and ease of use. The measurement systems should be gauged for their repeatability and reproducibility, and should produce results on a relevant scale. Recommend a method that allows for specification and control or at least monitoring of the construction process. The recommended method should allow for threshold values to be derived and should be tied to cost, public satisfaction, and long-term evaluations of functional performance.
- Develop standards and specifications to ensure proper procedures are followed for the method.

Products

An effective method for high-speed, high-resolution 3D pavement profiling; Standards and specifications for use of the method.

Benefits

High-speed, high-resolution 3D pavement profiling will allow for an efficient and simultaneous assessment of a multitude of structural and functional parameters of the pavement, including ride quality, joint condition, localized damage and roughness, and cross slope. The result will be a cost savings and a more accurate representation of the true condition of the roadway.

Coordination

This research should be closely coordinated with work conducted under the High-Speed 3D Macrotexture Measurement problem statement.

SC 5.4. Behind-the-Paver Smoothness Sensing Equipment

Subtrack:	Concrete Pavement Profile Smoothness
Approx. Schedule:	Year 3–Year 6
Estimated Cost:	$500k–$1M

Need and Objective

Concrete pavement smoothness is usually assessed after the pavement has gained enough strength for pavement profilers to traverse the surface without damage. In this scenario, a pavement that does not meet the minimum required smoothness level would require costly remedial methods or, worse, rejection of the pavement. The frequency of these consequential actions can be minimized if pavement smoothness is assessed during paving. The smoothness level would thus be reported to interested parties while the concrete is still plastic. Furthermore, with an integrated expert system, various artifacts of the concrete paving process that introduce roughness can be readily identified so that corrective action can be taken. The research in this problem statement will develop effective and advanced behind-the-paver smoothness sensing system capable of assessing pavement smoothness during paving, and identifying construction-related artifacts.

Potential Scope

- Identify available behind-the-paver smoothness sensing equipment.
- Analyze the equipment for accuracy, precision, and ease of use.
- Identify the most effective equipment based on cost, technological maturity, and the results of the above analyses, improving this equipment or developing new equipment as needed.
- Develop standards and specifications on the proper use of the equipment for sensing pavement smoothness.

Products

Advanced, effective behind-the-paver smoothness sensing equipment with standards and specifications for its use.

Benefits

Behind-the-paver technology that serves as a key component in sensing pavement smoothness, providing real-time information that can immediately correct paving operations.

Coordination

The research in this problem statement will be closely coordinated with problem statement ND 2.9 (Concrete Pavement Smoothness Sensing).

SC 5.5. Next Generation Concrete Pavement Smoothness Standards

Subtrack: Concrete Pavement Profile Smoothness
Approx. Schedule: Year 5–Year 8
Estimated Cost: $1M–$2M

Need and Objective

Four AASHTO provisional standards exist for assessing concrete pavement smoothness. These standards provide an excellent resource for implementing a smoothness quality assurance program, but must be reviewed and revised continuously as more is learned about pavement smoothness measurement and interpretation. Research is needed in various other aspects of pavement smoothness to ensure that these specifications continue to provide smooth pavements at a reasonable and rational cost. The objective of this research is to refine the AASHTO standards based on the results of research and development efforts both currently underway and conducted under this and other research programs.

Potential Scope

- Seek appropriate inputs to determine a reasonable answer to the question "how smooth is smooth enough?" Identify the threshold beneath which the public is very likely to be satisfied, the threshold beneath which on-board vibration sources (tire imbalance, engine vibrations) eclipse road-induced vibrations, and the threshold beneath which automobile and truck suspensions become less effective in isolating the vehicle. It should be noted that there is a continuum for each of these qualities. Gauge existing smoothness specifications using the criteria established. The economic side of this issue should be explored simultaneously, including the additional expected service life and decreased user cost for incremental improvements in smoothness and a way to weigh that against the cost of achieving the smoothness initially.
- Review, identify, and analyze accurate and repeatable profiling methods and smoothness metrics. These should be as relevant as possible to the comfort of vehicle occupants.
- Explore alternate smoothness and/or profiling specifications as needed. Suggested methods must provide relevant, understandable output and minimize the sensitivity of the process to measurement errors.
- Suggest refinements to the specifications for smoothness pay factors, rationalizing the factors based on the costs involved with ride quality degradation.
- After formal peer review, advance these specification refinements to AASHTO for consideration.

Products

Recommended refinements to AASHTO provisional standards for pavement profiling and ride quality.

Benefits

The project will produce the criteria for smoothness targets that will ensure user satisfaction and mitigation of truck dynamic loading. Specification refinements that advance the construction and evaluation of pavement smoothness will be advanced, ultimately enhancing ride quality for the traveling public.

Coordination

This research will be closely coordinated with earlier research conducted under this subtrack.

SC 6.1. Framework for Synthesis and Integration of Concrete Pavement Surface Characteristics Research

Subtrack:	Synthesis and Integration of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack focuses on validating and integrating the various surface characteristics research findings and innovations. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 6.2. Comprehensive Concrete Pavement Surface Characteristics Field Evaluation

Subtrack: Synthesis and Integration of Concrete Pavement Surface Characteristics Research
Approx. Schedule: Year 2–Year 3
Estimated Cost: $1M–$2M

Need and Objective

Researching designs, construction records, and past performance reports is often insufficient to understand the advantages or disadvantages of certain concrete surface pavement characteristics. Performing a comprehensive field evaluation is therefore necessary. The objective of this research is to perform a field study of pavement surface characteristics to define the surface characteristics that maximize friction and smoothness while minimizing noise. Additional characteristics may also be included in the field evaluation as needed.

Potential Scope

- Identify the numerous variables to be included in the field evaluation through a thorough synthesis and outreach effort. The controlled variables should be selected based on their known or anticipated sensitivity to the various surface characteristics being investigated. Develop a formal plan for the field evaluation.
- Conduct the field evaluation. Measurement of surface characteristics should employ the latest techniques and technologies available. If standardized equipment has not been identified, numerous measurement devices should be included.
- Reduce and analyze the data from the field evaluation to define the variables affecting the measured characteristics and the ways the characteristics are affected. Shortcomings in the study should also be identified so that additional field studies can address them.
- Develop surface characteristics guidance that feeds into other work, including the Design and Construction Guidelines to Improve Concrete Pavement Smoothness problem statement, and can be used immediately to improve current practices.

Products

A rich concrete pavement surface characteristics database available for additional future data analysis; Guidance report with case studies that defines optimum concrete pavement surface characteristics and the methods for achieving them.

Benefits

This research will result in guidance and an understanding of how to design and construct concrete pavements for desired surface characteristics.

Coordination

This research will supplement and support research conducted across the Surface Characteristics Track. The National Concrete Pavement Technology Center is currently conducting a portion of this work.

SC 6.3. Durability of Concrete Pavement Surface Characteristics

Subtrack:	Synthesis and Integration of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 4–Year 10
Estimated Cost:	$500k–$1M

Need and Objective

The objective of this research is to evaluate the time stability of certain pavement surface characteristics and the impacts that various surfacing methods might have on durability. A limited number of studies on the subject suggest the effect of pavement wear on noise may be significant over time. One study observed a decrease in noise on concrete pavements over the first seven years, then an increase afterward (Chalupnik 1992).

Potential Scope

- Identify existing and newly constructed pavements that possess a certain range of materials and surface characteristics. The selected pavements should cover a broad spectrum of climatic conditions and traffic levels.
- Monitor the selected pavements over time, using carefully selected and thoroughly documented evaluation methods. The research should evaluate the measures of tire-pavement noise, friction, and smoothness. Additional surface characteristics should be included as necessary.
- Periodically assess and publish findings and related guidance on the longevity of the studied surface characteristics, including pavement durability and performance.

Products

Reports that document the longevity and durability of various concrete pavement surface characteristics; Guidance on effective surfacing methods that provide durable surface characteristics.

Benefits

This research will provide improved methods for designing and constructing more durable concrete pavement surfaces with desired surface characteristics.

Coordination

This research should be closely coordinated with the work conducted under the Comprehensive Concrete Pavement Surface Characteristics Field Evaluation problem statement and research underway by the National Concrete Pavement Technology Center.

SC 6.4. Unified Model of Concrete Pavement Texture, Noise, Friction, and Smoothness

Subtrack: Synthesis and Integration of Concrete Pavement Surface Characteristics Research
Approx. Schedule: Year 5–Year 9
Estimated Cost: $1M–$2M

Need and Objective

Concrete pavement texture, friction, noise, and smoothness are all related to each other in a complex system. Empirical evidence shows that certain types of texture that provide good friction will increase noise and decrease smoothness. Since ideal, as-built texture provides good friction while minimizing noise and maximizing smoothness, a more thorough understanding of the relationships between texture, noise, friction, and smoothness is necessary. The objective of this research is to develop a comprehensive model that integrates texture, noise, friction, and smoothness to define optimal texture. This model should consider numerous other variables, including pavement materials properties and tire properties. A possible outcome may be a unified surface characteristics index or a set of indices that can gauge the overall functional condition of the pavement.

Potential Scope

- Synthesize existing and improve or develop new models of the relationships between texture, noise, friction, smoothness, and other important variables.
- Evaluate these models using existing data sets and identify the need for additional data.
- Release interim versions of the unified model as they become available so they can be used in other related research. Peer review of the model should be integrated throughout the process.
- Consider the benefits and feasibility of a unified index or indices that can rate the functional condition of the pavement.

Products

A comprehensive model that unifies texture, noise, friction, smoothness, and other related variables.

Benefits

This research will result in a model that will allow the industry to relate the complex nature of concrete pavement texture to the various pavement surface characteristics.

Coordination

This research will rely on the findings of earlier surface characteristics research and provide important inputs to future work.

SC 6.5. Concrete Pavement Mix Design System for Desired Surface Characteristics

Subtrack: Synthesis and Integration of Concrete Pavement Surface Characteristics Research
Approx. Schedule: Year 8–Year 10
Estimated Cost: $500k–$1M

Need and Objective

Concrete pavement and materials engineering decisions are often driven by functional requirements established at the highest levels. These requirements commonly respond to a perceived public need, such as driver and abutter demands for quieter, safer, and smoother pavements. While concrete pavements can meet these functional demands, pavements must be designed appropriately to do so. The objective of this research is to develop a concrete mix design system that will consider the effects of concrete materials and mixture on functional demands related to the pavement surface.

Potential Scope

- Assemble the requisite mix design models for the system.
- Identify the requisite laboratory mix design test procedures and ensure standardized reporting for input to the mix design system.
- Develop a beta version of the system and initiate peer review.
- Develop a final version of the system and prepare it for training and implementation.

Products

A mix design system that accounts for the functional demands of the pavement surface layer.

Benefits

With a better understanding of the relationships between concrete materials and mixtures and pavement functional requirements, improved mix design techniques can be developed to meet pavement functional requirements such as noise and ride quality.

Coordination

This research should be closely coordinated with CP Road Map Problem Statement MD 1.4 (PCC Pavement Mix Design System Integration Stage 4: Functionally Based Mix Design). These mix design procedures will allow innovative solutions such as two-lift pavements to be optimally designed for a given set of functional demands.

SC 7.1. Framework for Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research

Subtrack:	Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 1–Year 3
Estimated Cost:	$100k–$250k

Need and Objective

This subtrack includes implementation activities related to concrete pavement surface characteristics. The objective of this initial effort is to develop a framework and detailed, sequenced plan for the research within this subtrack to be accomplished in a coordinated, strategic way.

Potential Scope

- Examine the problem statements within the subtrack, modify as appropriate, and divide them into specific, manageable contracts.
- Arrange the contracts in a carefully sequenced plan that reflects a logical progress of research and available funding.
- Expand each of the broad research problem statements included in the subtrack into a detailed research plan with specific objectives, tasks, and funding recommendations.
- Review and provide direction for the various research contracts underway to ensure that they fulfill their objectives and allow future contracts to use their results. Guide the additional work required if a contract fails to achieve its objectives and additional work is necessary.

Products

A detailed, sequenced, and validated framework for the research to be conducted in this subtrack.

Benefits

This initial effort will provide the organizing framework for a coordinated, productive, and effective research program.

Coordination

This initial effort will provide the organization and validation essential for the success of this subtrack. Implementation of this problem statement will set the stage for the rest of the problem statements in the subtrack.

SC 7.2. Workshops and Publications on Concrete Pavement Surface Characteristics Measurement Equipment and Techniques

Subtrack:	Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 2–Year 10
Estimated Cost:	$1M–$2M

Need and Objective

While new methods and equipment for measuring concrete pavement surface characteristics are being developed on an ongoing basis, transportation agencies are often slow to adopt them due to unfamiliarity with these new technologies and a lack of research resources. Workshops provide an ideal environment for familiarizing and training agencies in new methods and equipment for measuring concrete pavement surface characteristics. The workshops and workshop materials developed will provide technology transfer of methods and equipment for measuring concrete pavement surface characteristics.

Potential Scope

- Identify states or industry representatives willing to host workshops and conferences on methods and equipment for measuring concrete pavement surface characteristics.
- Assemble pertinent information on these measurement techniques and equipment.
- Conduct workshops, presenting information and hands-on training for these measurement methods and equipment. Make associated publications available.

Products

Workshops and publications on methods and equipment for measuring concrete pavement surface characteristics.

Benefits

The technology transfer of methods and equipment that measure concrete pavement surface characteristics will help move promising research findings and innovations into practice.

Coordination

The workshop content will be based on research findings from completed and ongoing Surface Characteristics Track work.

SC 7.3. Online Training to Implement New Products and Methods for Improved Concrete Pavement Surface Characteristics

Subtrack:	Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 3–Year 10
Estimated Cost:	$500k–$1M

Need and Objective

While many new research products and technologies are developed and ready for implementation every year, transportation agencies often implement and use the new research inadequately. Workshops offer contractors and owner-agencies the opportunity to learn about new research products and technologies, but often agencies cannot afford to send employees to workshops or may be restricted from traveling to a workshop outside the home state. With web-based training, contractors, designers, and owner-agencies can explore new research products and technologies from a computer with internet access. Online, on-demand training can include documentation, case studies, software applications, and other resources to make recent research on concrete pavement surface characteristics accessible to the concrete paving community.

Potential Scope

- Compile information on new equipment, procedures, and applicable software related to concrete pavement surface characteristics, including thorough documentation, case studies, downloadable software applications, photos, and video.
- Develop web-based training modules that train contractors, designers, and owner-agencies on the concrete pavement surface characteristics software and equipment.
- Develop a website allowing contractors, designers, and owner-agencies to access the training modules. Maintain the website with updates on new research products or refinements to existing products. Consider the supplemental need for materials available on CD-ROM.

Products

A website with web-based modules that train contractors, designers, and owner-agencies in new models, software, and methods for improved concrete pavement surface characteristics.

Benefits

The web-based training provided through this problem statement will allow contractors, designers, and owner-agencies from any computer with internet access to access recent research. This training mechanism will rapidly facilitate implementation of new research products for concrete pavement surface characteristics to previously under-reached users.

Coordination

The online training content provided through this problem statement will be based on research findings from completed and ongoing Surface Characteristics Track work.

SC 7.4. Workshops and Publications on Designing and Constructing Concrete Pavements with Desired Surface Characteristics

Subtrack:	Technology Transfer and Implementation of Concrete Pavement Surface Characteristics Research
Approx. Schedule:	Year 4–Year 10
Estimated Cost:	$1M–$2M

Need and Objective

While new products and techniques for improving concrete pavement surface characteristics are being developed, transportation agencies are often slow to adopt them due to unfamiliarity with the new technologies and a lack of research resources. Workshops provide an ideal environment for familiarizing and training agencies in innovations for improving concrete pavement surface characteristics. The workshops developed will provide technology transfer opportunities for the new and improved surfacing techniques for desired concrete pavement surface characteristics. The training materials should include incremental lessons-learned such as improved techniques to control conventional concrete pavement texture.

Potential Scope

- Identify states and industry representatives willing to host workshops and conferences devoted to new and improved surface types for achieving desired surface characteristics.
- Assemble pertinent information on the new concrete pavement surface designs and construction methods to be discussed at the workshops.
- Conduct workshops, presenting information on these products and methods and providing hands-on training.

Products

Workshops and publications on designing and constructing concrete pavements with improved concrete pavement surface characteristics.

Benefits

The training provided through this problem statement will facilitate implementation of improved design and construction methods for desired concrete pavement surface characteristics.

Coordination

The online training content provided through this problem statement will be based on research findings from completed and ongoing Surface Characteristics Track work.

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