Annual Report

SCDOT State Planning & Research Program—Part II: Research

South Carolina Department of Transportation
Research Unit

in cooperation with

U.S. Department of Transportation
Federal Highway Administration

Fiscal Year 2008
(October 1, 2007 to September 30, 2008)

Office of Materials & Research

Office of
Materials & Research

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OVERVIEW

The Research Unit handles the day-to-day operations of the research program. The Unit assists with fulfillment of South Carolina Department of Transportation's (SCDOT's) mission and goals by conducting applicable research, disseminating information, and promoting national research programs. Specific goals established for the Research Unit in FY 2008 were:

- Assist the Department in obtaining its goals included in the Strategic Plan.
- Conduct a Research Topic Solicitation Meeting.

This annual report provides a description of the FY 2008 SPR Research Program that includes the period from October 1, 2007 through September 30, 2008. The report is divided into four parts.

Part 1: Provides a description of the program and project funding, accomplishments regarding emphasis areas established for the Research Unit, and a list of all items included in the FY 2008 Research Program.

Part 2: Gives a description of each study started during FY 2008.

Part 3: Contains project summaries of studies completed during FY 2008.

Part 4: Highlights the results of a recent study.

PART 1

Program / Project Funding

Accomplishments

Research Program Summary

PROGRAM FUNDING

In FY 2008, the SPR Research Program received $2,807,689 in Federal funds. Figure 1 provides a general breakdown of items funded and their amounts, including appropriate matching funds, in FY 2008.

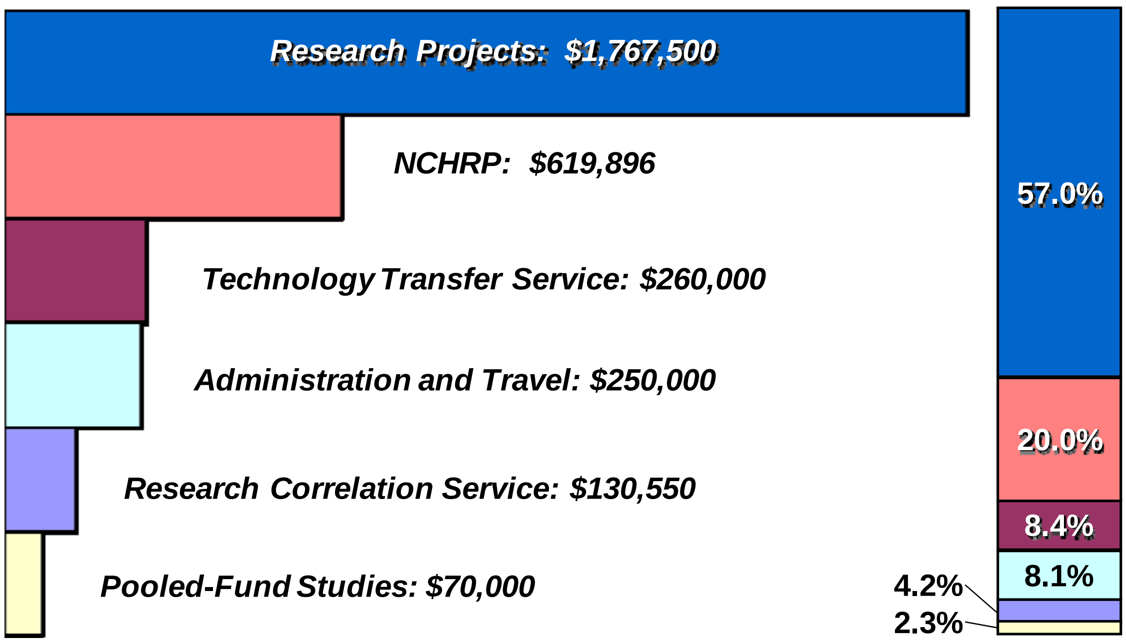

Figure 1. FY 2008 Research Program Funding

PROJECT FUNDING

A total of 21 studies were included in the program. Ten were started during the year, three of which were funded during the previous year. Eleven were carried over from prior-year programs. Three of the studies were completed during FY 2008. Figure 2 shows how the funds obligated for research studies in FY 2008 were distributed by general area and amounts.

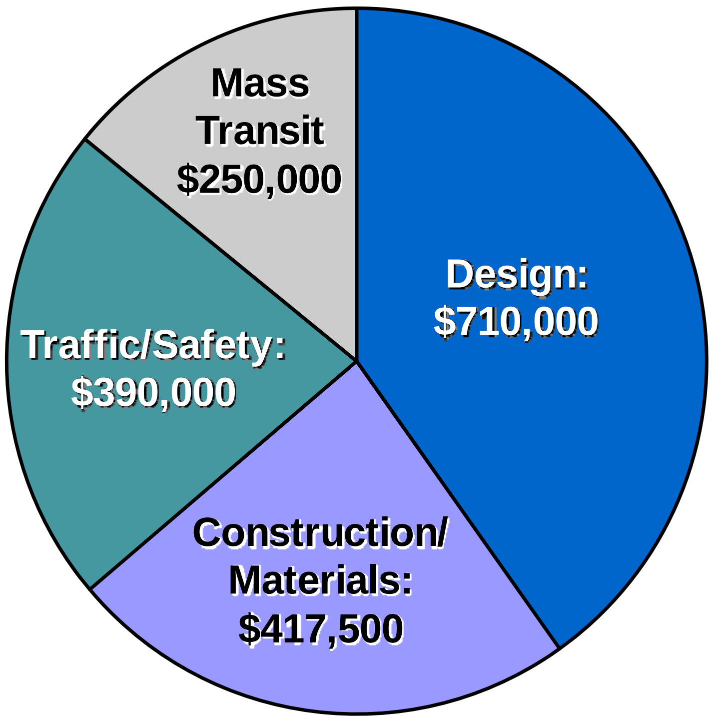

Figure 2. Distribution of FY 2008 Funds Obligated for Research Studies by General Topic Area

ACCOMPLISHMENTS

Emphasis Areas

The Research Unit identified two areas of emphasis for the FY 2008 program.

1. Assist the Department in obtaining its goals included in the Strategic Plan.

All research projects started during FY 2008 support the Department's goal *"to provide adequate, safe and efficient transportation services for the movement of people and goods."*

2. Conduct a research topic solicitation meeting.

The Research Unit held a Research Topic Solicitation Meeting on April 22, 2008 in Columbia, South Carolina. The Transportation Technology Transfer Service (T^3S) at Clemson University, the Department's LTAP Center, provided logistical and administrative support. The purpose of the meeting was to identify and prioritize a wide array of potentially beneficial research topics for consideration by SCDOT's Research and Development Executive Committee (RDEC) for funding as SPR research projects. Approximately 100 people attended including representatives from SCDOT, Federal Highway Administration (FHWA), United States Geological Survey (USGS), academia, and industry.

The meeting began with a plenary session of all participants during which an overview of the SCDOT research program was presented and the purpose and format of the meeting were explained. Each participant then attended one of seven breakout sessions, previously assigned, each on a different subject area of potential research interest for SCDOT. The seven breakout groups included:

- Construction/Materials.
- Maintenance/Bridge Maintenance.
- Traffic/Safety.
- Bridge/Road Design.
- Project Development/Planning.
- Business Operations.
- Hydrology.

Members of the Office of Materials and Research (OMR) staff served as moderators for the breakout groups. Topics were identified, discussed, and prioritized in each group. Also, SCDOT contacts were identified for topics of highest interest in each group. The contacts are responsible for preparing problem statements for their topics for the RDEC's consideration.

RESEARCH PROGRAM SUMMARY

Table 1 lists all items included in the FY 2008 SPR Research Program. The total funding, with amount obligated previously and/or in FY 2008, is given for each item. Also, the percent split between Federal and State funds is shown for money obligated in FY 2008.

Table 1. FY 2008 SPR Program.

SPR No.	Item	Previously Funded	FY 2008 Funds	% Split Fed–State
500	Administration		$250,000	80–20
—	NCHRP		$619,896	100–0
517	Research Correlation Service		$130,550	100–0
642	Frequency and Time–Distribution of Rainfall for Various Regions in South Carolina	$420,007		
647	Development of Improved Rideability Specifications for Rigid Pavements and Bridge Decks	$345,103		
651	Performance of Four Best Management Practices for Highway-Runoff Quality Near Beaufort, SC	$497,500		
654	Rapid Set Concrete Patching Materials for PCC	$190,698		
656	Life Cycle Cost Analysis for Pavement Design	$156,266		
657	An Assessment of SC Road Users to Measure Public Knowledge and Understanding of Traffic Control Measures	$200,719	$80,000	80–20
662	Investigation of the Performance of Class F Self–Consolidating Concrete (SCC)	$198,784		

Continued

Table 1. FY 2008 SPR Program *(continued)*

SPR No.	Item	Previously Funded	FY 2008 Funds	% Split Fed–State
664	Techniques for Estimating Magnitude and Frequency of Floods in Rural Basins in SC	$402,000		
665	AASHTO AssetManager Cooperative Software Development Project	$100,000		
667	Support for the Elimination of Roadside Hazards in an Acceptable Clear Zone through the use of Collision Data	$258,043		
668	Optimal Maintenance Crew Composition and Enhancement of Crew Productivity	$110,520		
669*	Guidelines for Pavement Marking Applications	$220,000		
670*	Geotechnical Materials Database for Highway Design	$235,000		
671*	Mechanistic/Empirical Design Guide Implementation	$195,000		
672	Behavior of Pile to Pile-Cap Connections Subjected to Seismic Forces		$550,000	80–20
673	Field Evaluation of Temperature Differential in HMA Mixtures		$80,000	80–20
674	Synthesis of Optimal Usage of Available Aggregates in Highway Construction and Maintenance		$60,000	80–20
Continued				

Table 1. FY 2008 SPR Program *(continued)*

SPR No.	Item	Previously Funded	FY 2008 Funds	% Split Fed–State
675	Validation of Contractor HMA Testing Data in the Materials Acceptance Process		$277,500	80–20
676	Evaluation of Communication Alternatives for Intelligent Transportation Systems		$310,000	80–20
677	Investigate Simplifying Bridge Expansion Joint Design and Maintenance		$160,000	80–20
678	Feasibility of Establishing a High-Speed Rail Corridor Connecting Florence, Myrtle Beach, and Charleston using Existing Rail Lines		$250,000	80–20
Pooled–Fund Studies Funded in FY 2008				
5(037)	Southeast Superpave Center	$100,000	$20,000	100–0
5(065)	Traffic Control Device (TCD) Consortium	$50,000	$10,000	100–0
5(131)	Underwater Inspection of Bridge Structures Using Underwater Imaging Technology	$20,000	$20,000	100–0
5(141)	Pavement Surface Properties Consortium: A Research Program	$40,000	$20,000	100–0
Continued				

Table 1. FY 2008 SPR Program *(continued)*

SPR No.	Item	Previously Funded	FY 2008 Funds	% Split Fed–State
	Other Projects Funded in FY 2008			
—	Transportation Technology Transfer Service		$260,000**	80–20

* *Funded in FY 2007 with start date in FY 2008*
** *Additional $140,000 funded by LTAP*

SCDOT

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PART 2

Studies Started

During FY 2008

STUDIES STARTED DURING FY 2008

SPR 669: Guidelines for Pavement Marking Applications

Organization: *Clemson University*
Principal Investigator: *Dr. Wayne Sarasua*
Start Date: *02/01/2008* **Completion Date:** *07/31/2010*
Objective: The objective of the project is to develop standardized guidelines for pavement marking applications in South Carolina.

SPR 670: Geotechnical Materials Database for Highway Design

Organization: *University of South Carolina*
Principal Investigator: *Dr. Charles Pierce*
Start Date: *01/01/2008* **Completion Date:** *12/31/2009*
Objective: The objective of the project is to develop a database with design parameters and properties for borrow materials for each county in the state.

SPR 671: Mechanistic/Empirical Design Guide Implementation

Organization: *University of South Carolina*
Principal Investigator: *Dr. Ron Baus*
Start Date: *01/16/2008* **Completion Date:** *09/15/2009*
Objective: The objective of the study is to develop a realistic implementation plan for the Mechanistic/Empirical pavement design model.

SPR 672: Behavior of Pile to Pile–Cap Connections Subjected to Seismic Forces

Organization: *University of South Carolina*
Principal Investigator: *Dr. Paul Ziehl*
Start Date: *01/04/2008* **Completion Date:** *06/30/2011*
Objective: The primary objective of the study is to develop and test potential production details for pile to pile-cap connections subjected to seismic forces to be used on SCDOT bridge projects.

SPR 673: Field Evaluation of Temperature Differential in HMA Mixtures

Organization: *SCDOT*
Principal Investigator: *Mr. Caleb Gunter*
Start Date: *11/15/07* **Completion Date:** *11/14/2009*
Objective: The objective of this project is to determine the magnitude of damage caused by thermal segregation in HMA surface and intermediate courses used by SCDOT.

SPR 674: Synthesis of Optimal Usage of Available Aggregates in Highway Construction and Maintenance

Organization: *Clemson University*
Principal Investigator: *Dr. Bradley Putman*
Start Date: *05/15/2008* **Completion Date:** *05/14/2009*
Objective: The overall objective of the study is to identify possible ways to achieve aggregate mass balance by optimizing existing material specifications and usage to efficiently utilize available aggregate supplies without sacrificing the final product's performance, quality, or expectations.

SPR 675: Validation of Contractor HMA Testing Data in the Materials Acceptance Process

Organization: *Clemson University*
Principal Investigator: *Dr. James Burati*
Start Date: *02/07/2008* **Completion Date:** *02/06/2010*
Objective: The overall objective of the project is to develop new procedures for validating contractor HMA test data that will comply with the regulatory requirements of Title 23 Code of Federal Regulations, Part 637 (23 CFR 637).

SPR 676: Evaluation of Communication Alternatives for Intelligent Transportation Systems (ITS)

Organization: *Clemson University*
Principal Investigator: *Dr. Ronnie Chowdhury*
Start Date: *05/01/2008* **Completion Date:** *01/01/2010*
Objective: The general objective of the study is to conduct a systematic analysis of communication systems for SCDOT to aid in creating both short and long-term plans for technology integration, reliability enhancement, long-term management, and efficient investment to improve statewide mobility.

SPR 677: Investigate Simplifying Bridge Expansion Joint Design and Maintenance

Organization: *University of South Carolina*
Principal Investigator: *Dr. Juan Caicedo*
Start Date: *08/01/2008* **Completion Date:** *07/31/2010*
Objective: The objective of the project is to provide SCDOT with recommendations on the design of cost-effective and durable bridge expansion joints considering the life-cycle of bridges.

SPR 678: Feasibility of Establishing a High–Speed Rail Corridor Connecting Florence, Myrtle Beach, and Charleston Using Existing Rail Lines

Organization: *SCDOT*
Principal Investigator: *Mr. Roy Tolson*
Start Date: *09/15/2008* **Completion Date:** *09/14/2010*
Objective: The objective of this project is to examine the feasibility of identifying a corridor for the purpose of constructing and providing rail service on exisiting rail lines and/or existing right–of–way in the eastern part of South Carolina.

LTAP: Transportation Technology Transfer Service (T^3S)

Organization: *Clemson University*
Principal Investigator: *Dr. James. Burati.*
Start Date: *Conducted on a calendar year basis as per FHWA guidelines*
Purpose: T^3S conducts the Department's Local Technical Assistance Program (LTAP) and assists the Research Unit with selected administrative tasks.

PART 3

Studies Completed

During FY 2008

SPR 654	Rapid Set Concrete Patching Materials

Performing Organization: Clemson University

Authors: Prasada Rangaraju

Report No: *FHWA-SC-07-07*

Date: December 2007

Summary

A wide variety of rapid set patching (repair) materials are available in the concrete industry for use with repairs on concrete pavements, bridges and structures. These materials possess a broad range of physical and mechanical properties. Among the principal reasons for premature failures of concrete repairs is the improper selection of repair materials, without adequate knowledge of the compatibility between the properties of repair material and the substrate concrete. The purpose of this research study is to conduct an experimental program to determine the physical and mechanical properties of selected repair materials from the SCDOT list of approved repair materials for PCC application, and develop a test methodology to assess compatibility of the repair materials with substrate concrete.

Research Program

In this research study, properties of eight different cementitious repair materials and one substrate concrete were investigated in three stages. First, properties of repair materials such as setting time, flow, compressive strength, flexural strength, split tensile strength, slant-shear bond strength, drying shrinkage, freeze-thaw resistance, and permeability, were determined using standard ASTM test procedures. Specific emphasis was placed on determining the bond strength of the repair materials using slant-shear bond strength (ASTM C 882) at different ages. Second, the compatibility between the repair materials and substrate concrete was investigated using a flexure test on a composite beam (consisting of a notched substrate concrete section repaired with a rapid set patching material) under third point loading. Third, correlations between the individual properties of repair materials and the performance of the composite beam under flexural loading were explored to predict the compatibility of the repaired concrete. Based on these studies, a test method is proposed to examine the compatibility between repair material and substrate concrete for future evaluations of repair materials.

Results

Results from this study indicated that although physical and mechanical properties of different repair materials were superior individually, their performance in a composite section such as the slant-shear bond strength test was found to be a function of factors such as relative strengths (both compressive and flexural strengths) between repair materials and substrate concrete and surface texture on the substrate concrete. Based on these findings it was observed that slant-shear bond strength test may not provide a consistent basis to evaluate different repair materials. In its existing procedure, this test method lacks specific guidance on factors such as surface texture to be applied on substrate mortar and compressive strength of the substrate mortar relative to the strength of the repair material. Further, this test method does not simulate realistic stress conditions faced by the repair materials in field conditions. In order to better understand the compatibility between the repair material and substrate concrete in the second stage of this research investigation, composite beams of repair material and substrate concrete were prepared and tested in flexure to simulate tensile stresses in the repaired section. Tensile stresses are generally observed in the negative moment regions of a bridge deck or in cantilevered sections of a concrete structure, where the tension in the concrete repair is induced by imposed loads or due to environmental conditions. In this study, the flexural strength, the failure patterns and the load-deflection curves of the composite beam specimens were determined and compared with the results from tests on a control beam (i.e. substrate concrete alone) to assess the compatibility. In addition, the influence of three curing conditions on the material compatibility was evaluated. Compressive strength, flexural strength, split tensile strength, and drying shrinkage of the repair materials and substrate concrete were investigated to aid in the analysis of the compatibility. In this study, the compatibility of repair material and substrate concrete was found to be a function of (i) flexural strength of composite beam as compared to control, (ii) failure patterns (de-bonding and edge cracking), and (iii) behavior of load-deflection curves. It was observed that significant differences in compressive and flexural strength between the repair material and substrate concrete caused incompatible failures. In addition, high drying shrinkage of the repair materials also caused the incompatible failures. In the third stage of this research, correlation between individual repair material properties such as compressive strength, flexural strength, bond strength, and drying shrinkage, and the performance of the composite beam under flexure loading (compatibility) was investigated. From this study it was observed that no strong correlation exists between the individual repair material properties and the performance of the composite beam under flexural loading.

Conclusions

Based on the findings from this study, it is concluded that although properties of repair materials such as compressive strength, setting time and others are important from an operational standpoint (i.e. opening up the repaired section to traffic), these properties do not correlate well with the long-term field performance of the repaired composite section, and as such do not predict the compatibility of the repair material with substrate concrete. Further, the slant-shear bond strength test was found to be inadequate in properly characterizing the compatibility of the repair material with substrate concrete. The performance of composite beam under flexural loads (i.e.flexural strength, load-deflection behavior, and failure mode) as proposed in this study, has been found to better characterize the compatibility between repair materials and substrate concrete. It is proposed that this test method be further developed into a standard that can be adopted to evaluate compatibility of repair materials, and study the effects of mechanical and environmental factors that affect the long-term performance.

SPR 656	Life Cycle Cost Analysis for Pavement Design

Performing Organization: Clemson University

Author: Prasada Ranaraju

Report No.: *FHWA-SC-08-01*

Date: December 2007

Summary

In the face of scarce funds and limited budgets, transportation officials must constantly choose the most cost effective project alternatives. As transportation agencies consistently rank among the top sectors in public spending, choosing the most cost-effective type and design of pavement while still providing a high quality of service to the traveling public is one of the most important management decisions to be made. Life cycle cost analysis (LCCA) is an essential economic evaluation tool that provides valuable guidance to transportation officials in this process. The LCCA is performed by transportation agencies in the design phase of transportation projects in order to be able to implement more economical strategies, to support decision processes in pavement type selection (flexible or rigid) and also to assess the relative costs of different rehabilitation options within each type of pavement. However, most of the input parameters are inherently uncertain, and a probabilistic approach to ascertain life-cycle costs would be better suited in the decision-making process instead of a deterministic approach.

Background

Transportation agencies using federal funds often must conduct LCCA to justify their planning and design decisions. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) specifically required consideration of “the use of life-cycle costs in the design and engineering of bridges, tunnels, or pavement” in both metropolitan and statewide transportation planning. In addition, the National Highway System Designation Act of 1995 required states to conduct an LCCA for each proposed National Highway System (NHS) project segment costing $25 million or more. The Federal Executive Order 12893, signed by President Clinton in January 1994, required all federal agencies to use a “systematic analysis of expected benefits and costs... appropriately discounted over the full life cycle of each project” in making major infrastructure investment decisions. The 1998 Transportation Equity Act for the 21st Century, TEA-21, has since removed the requirement to conduct LCCA in transportation investment decision making. However, it is still the intent of FHWA to encourage the use of LCCA for National Highway System (NHS) projects.

Research Program

At the present time, South Carolina Department of Transportation (SCDOT) employs a simplistic deterministic approach in the LCCA for pavement type selection process. In order to embrace a comprehensive approach that encompasses the uncertainty of the input parameters in the LCCA for pavement type selection, a research investigation was initiated to study the practices of other states, and through the knowledge gained develop a probabilistic-based LCCA approach that is customized for South Carolina.

Results

This report summarizes the findings from the research investigation and proposes a probabilistic LCCA approach for SCDOT. This investigation was based on analysis of data obtained from a preliminary and a final survey of states across the U.S. and provinces across Canada. The surveys were designed to gauge the level of LCCA activity in different states as well as to solicit information on specific approaches that each state is taking for pavement type selection. The responses obtained from the surveys were analyzed to observe the trends and ranges of various input parameters that feed into the LCCA process. Based on the data from surveys, selected states whose LCCA practices exemplified a progressive and a comprehensive approach were identified and further questioned on specific aspects of their respective LCCA approaches. Based on this analysis, a probabilistic-based LCCA approach for SCDOT is proposed for use with pavement-type selection process. Also, specific recommendations on range of values for different input parameters based on the survey data are made. Where no adequate database exists for certain LCCA input parameters, suggestions for developing a database are offered.

In addition to developing a protocol for a probabilistic LCCA approach, different LCCA software programs such as REALCOST, DARWin and other customized software used by specific states were explored. Amongst these, REALCOST software developed by Federal Highway Administration (FHWA) was found to be widely used by several state agencies and most comprehensive in its treatment of different input parameters. Further, FHWA has been instrumental in providing support to customize the REALCOST software to meet individual state's needs. Based on these findings, REALCOST software was proposed as preferred software for use in conducting LCCA for pavement-type selection.

Conclusions

Based on the considerations elaborated earlier, the Principal Investigators of this study propose a probabilistic based LCCA approach for South Carolina. The intent of the proposed approach is that where possible the input parameters for a probabilistic LCCA approach will be employed from data that is readily available within South Carolina. However, in situations where the relevant data is not readily available, a process would be initiated within SCDOT to determine if reasonable data exists from historic records (i.e. such as through Pavement Management System) and develop a database of values for future use. Meanwhile, data from Maryland will be adopted as seed values for conducting probabilistic LCCA, with due considerations for its relevance to South Carolina operations. It should be noted that even in a probabilistic LCCA approach, certain input parameters will be deterministic in nature. The proposed step-by-step procedure of conducting a probabilistic LCCA approach is based on the methodology outlined by FHWA Technical Bulletin. Considering the simplicity, flexibility of the RealCost software and the user-support offered by FHWA, the principal investigators recommended using RealCost software for conducting the probabilistic LCCA for pavement type selection in South Carolina.

SPR 668	**Optimal Maintenance Crew Composition and Enhancement of Crew Productivity**

Performing Organization: Clemson University

Authors: Lansford Bell

Report No.: *FHWA-SC-08-03*

Date: May 2008

Summary

A research project was conducted by Clemson University for the South Carolina Department of Transportation (SCDOT) to examine the impact of crew composition and other factors on maintenance crew productivity. The research effort included an examination of data from the SCDOT Highway Maintenance Management System in an attempt to rank maintenance crews using a number of performance criteria. The analysis treated urban, rural, and mixed urban and rural counties separately. Although it could not be established with any degree of statistical significance, the data analysis indicated that 6-8 person crews were generally more productive. However, data analysis did depend on precisely how crew “productivity” was defined.

The research effort also included the execution and analysis of a comprehensive questionnaire survey of 382 SCDOT maintenance employees. The survey solicited demographic, experience, and opinion data from the survey respondents. The respondents indicated that in many instances crew size should be increased for optimal productivity. The survey responses also indicated, especially in the more rural areas, that there is the perception that crews with a long history of working together as a cohesive unit are in fact more productive. The crew foremen strongly believed that the work accomplishment goals contained within the SCDOT performance standards were realistic. The survey also indicated that internal policies with respect to equipment utilization were constraining crew productivity.

PART 4

Results of a

Recent Study

SPR 656: Life Cycle Cost Analysis for Pavement Design

SCDOT has long performed life cycle cost analyses in an effort to quantify what is the best pavement investment. These analyses were of the "present value deterministic" type. That is, estimates were made of how much each pavement alternative cost, how long it would last until it needed rehabilitation, and how much future rehabilitation would cost. These future costs would then be converted to a "present value," which corresponded to how much money would have to be invested at a certain interest rate today in order to have the future amount when the time comes. The present value of the future costs would be added to the initial cost to come up with a life cycle cost that represented the overall long-term cost of the alternative. The life cycle costs of each alternative could be compared and used in the pavement selection process.

Unfortunately, when it comes to pavement, things are not quite that simple. Construction costs often vary from the initial estimate. Times to pavement rehabilitation are not consistent. This can be true even on interstate pavements where the lanes going in one direction can be significantly worse than those going in the other, despite having traffic, soils, construction materials, and pavement designs that are supposedly the same. Also, circumstances often dictate that needed rehabilitation gets delayed, changing both the timeline and future costs.

Despite this variability, in a traditional deterministic life cycle cost analysis the analyst has to assume one set of costs, one timeline, and one rehabilitation scenario. The final cost comparison in these situations is often so close that a minor change in assumptions can change the outcome of the cost comparisons. For this reason, SCDOT initiated Research Project 656, "Life Cycle Cost Analysis for Pavement Design," with Professors Prasada Rangaraju and Serji Amirkhanian of Clemson University. The project's Steering and Implementation Committee is shown in Table 2.

Table 2. SPR 656 Steering and Implementation Committee Members

Member	Organization
Danny Shealy, Co-Chair	SCDOT
Robert Pratt, Co-Chair	SCDOT
Stan Bland	SCDOT
Milton Fletcher	SCDOT
Andrew Johnson	SCDOT
Huley Shumpert	SCDOT
Roy Tolson	SCDOT
Merrill Zwanka	SCDOT
David Law	Federal Highway Administration
Steve Page	Parsons Brinckerhoff Construction Services
Wouter Gulden	American Concrete Pavement Association
David Herndon	South Carolina Asphalt Pavement Association

The goals of the research were to establish the current state-of-the-practice by studying the life cycle cost analysis procedures of other state transportation agencies and then make recommendations on how SCDOT could improve its procedures. Their recommendation was that SCDOT should go to a "probabilistic" procedure that objectively considers the potential variability in costs and service life between pavement alternatives. This is done through a process called Monte Carlo Simulation where the various items in the analysis are assigned variability rather than a discrete value. A computer program, developed by the Federal Highway Administration, then takes each item and "rolls the dice" to come up with random values controlled by the assigned variability for each item.

The computer does this process thousands of times and compiles the results as a series of probability curves. So, instead of coming up with a blank-and-white deterministic answer such as, for instance, "Alternative A will cost $3 more than Alternative B," the probabilistic analysis expresses the answer in terms of probability. So, the probabilistic outcome would be that, "Alternative A has a 25% chance of costing the same or less than Alternative B, a 50% chance of costing between $0 and $4 more than Alternative B, and a 25% chance of costing in excess of $4 more than Alternative B."

This gives the analyst a better picture of not only the typical cost difference between alternatives, but of the chances of the costs being more or less than predicted. SCDOT is currently working to develop the appropriate variability values for the analysis and implement the findings of this research. Once fully implemented, the agency should be able to make more informed decisions on where to place its scarce resources most effectively.

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