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 2022
October 1, 2021 to September 30, 2022

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RESEARCH CONTACTS

Address: **Office of Materials and Research**
1406 Shop Road
Columbia, South Carolina 29201
Phone: (803) 737-6681
Fax: (803) 737-6649

Merrill E. Zwanka, P.E.
Materials and Research Engineer
Phone: (803) 737-6681
E-mail: ZwankaME@scdot.org

Terry L. Swygert
Research Engineer
Phone: (803) 737-6691
Email: SwygertTL@scdot.org

Jade E. Watford
Research Program Manager
Phone: (803) 737-6697
E-mail: WatfordJE@scdot.org

Daniel C. Cook
Research Innovation Manager
Phone: (803) 737-6627
E-mail: CookDC@scdot.org

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. Goals established and achieved for the Research Unit in FFY 2022 were:

- Began Research Topic Solicitation Process for FY 23-24
- Developed Research Projects Approved by the Research and Development Executive Committee (RDEC)
- Hired Two Employees to the Research Unit
- Earned Two Awards for Research Project SPR 741
- Produced Two Videos to Market Recently Completed SPR High Value Research Projects

This annual report provides a description of the FFY 2022 SPR Research Program that includes the period from October 1, 2021, through September 30, 2022. The report is divided into four parts.

Part 1: Provides a description of the program and project funding and a summary of all items included in the FFY 2022 Research Program.

Part 2: Provides a summary of the Research Unit's accomplishments.

Part 3: Gives a description of each study started during the year.

Part 4: Contains project summaries of studies completed during FFY 2022.

Research Program/ Project Funding and Research Program Summary

PART I

PROGRAM FUNDING

In FFY 2022, the SPR Research Program received $4,159,254.00 in Federal funds. Figure 1 provides a general breakdown all items funded and amounts in FFY 2022 including appropriate matching funds and corresponding carry-over funds from previous fiscal years.

- Research Projects $2,553,027.00
- NCHRP $797,399.00
- Pooled-Fund Studies $861,500.00
- Transportation Technology Transfer Service (LTAP Center) $861,500.00
- TRB Core Program $143,363.00
- AASHTOWare Project Data Analytics™ System Cooperative Software Development $187,500.00
- AASHTO Technical Services Programs $116,000.00

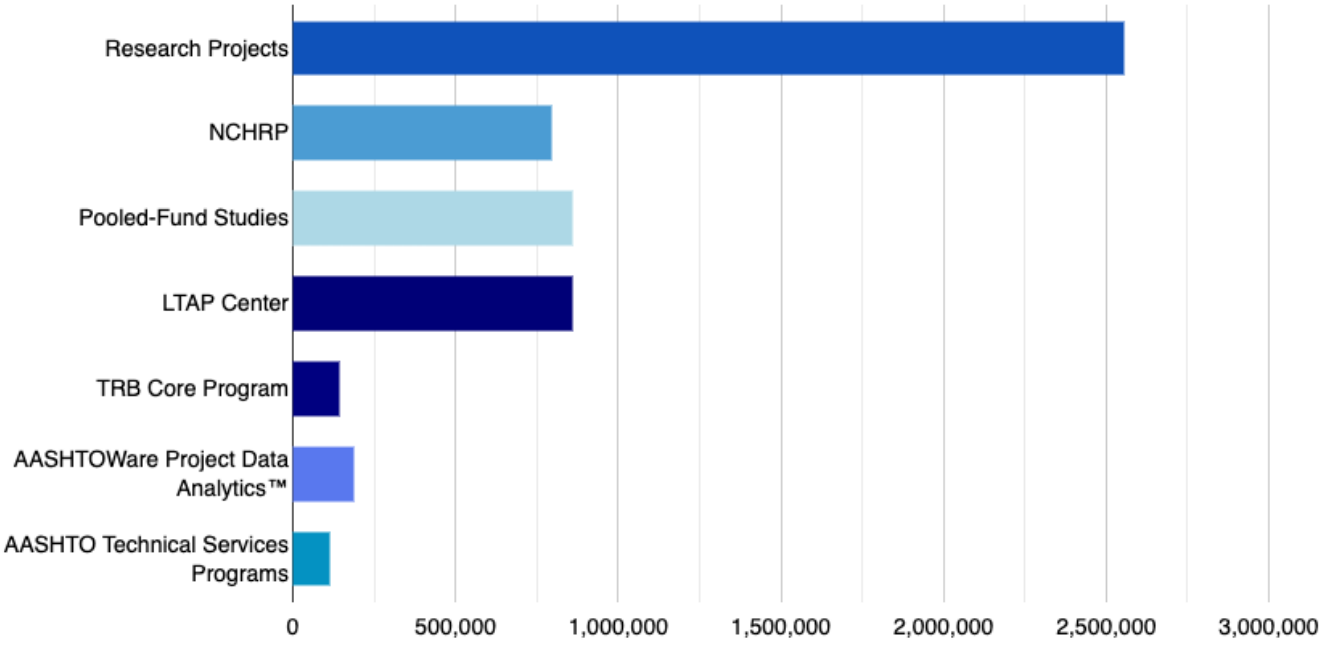

Figure 1. FFY 2022 Research Program Funding

PROJECT FUNDING

A total of twenty-two (22) projects were included in the program. Seven (7) research projects were initiated in FFY2022. Six (6) studies were completed during the year. Figure 2 shows how the funds obligated for research projects in FFY 2022 were distributed by general area and amounts.

• Bridge Maintenance	$960,000.00
• Design/Build	$300,000.00
• Environmental	$442,281.00
• Project Development	$300,045.00
• Traffic Safety	$550,701.00

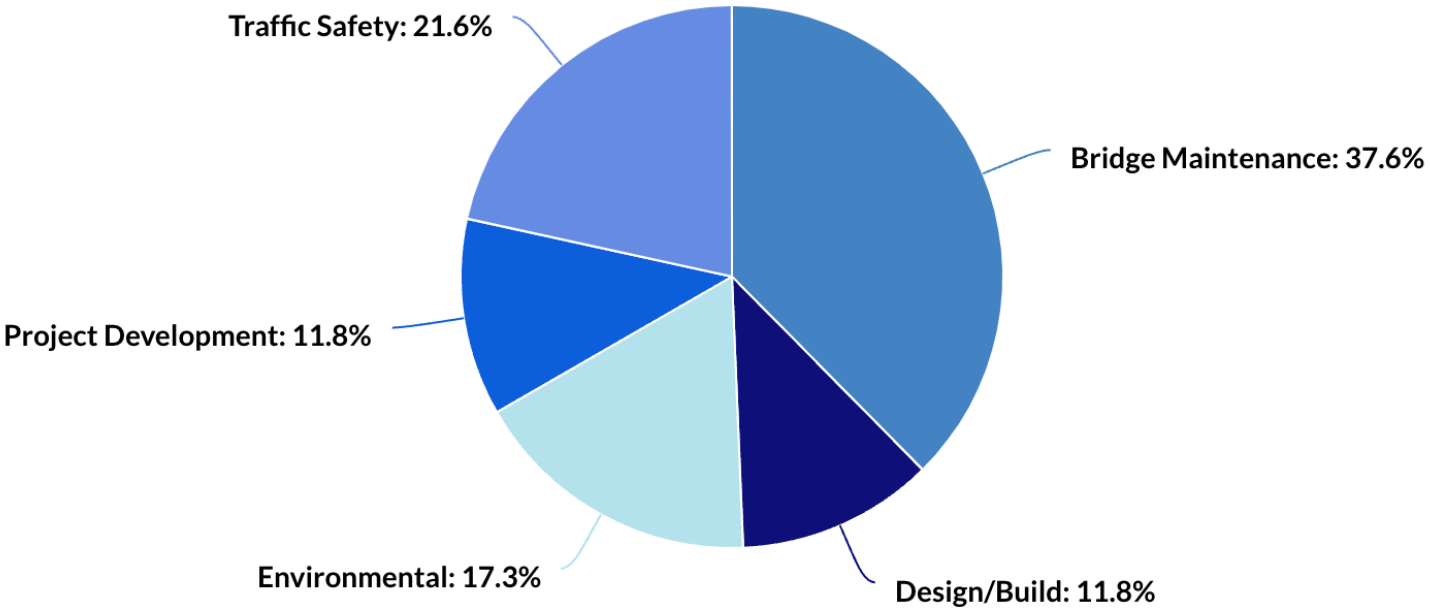

Figure 2. FFY 2022 Research Project Funding

RESEARCH PROGRAM SUMMARY

Table 1 below lists all items included in the FFY 2022 SPR Research Program. The total funding, with amount obligated previously and/or during the year, is given for each item. Also, the percent split between Federal and State funds is shown for money obligated in FFY 2022.

SPR No.	Item	Previously Funded	FFY 2022 Funds	% Split Fed-State
732	Calibration of the AASHTO Pavement Design Guide to SC Conditions - Phase II	$1,762,300.00		80-20
733	Updating Techniques for Estimating Magnitude and Frequency of Floods for Rural Basins in the Southeastern United States	$493,612.00		80-20
741	Improving SCDOT Project Delivery Through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process	$640,678.00		80-20
742	Automatic Extraction of Vehicle, Motorcycle, Bicycle, and Pedestrian Traffic from Video Data	$148,890.00		80-20
743	Pavement Performance Curves - Modeling Pavement Deterioration for SCDOT	$251,371.00		80-20
745	Update to SCENARIO_PC	$1,274,033.00		80-20
746	SC Flood Inundation Mapping	$255,000.00		80-20
747	Evaluating the Construction Cost and Schedule Impacts of SCDOT's Traffic Control Restrictions	$149,966.00		80-20
750	Risk-Based Inspection Program	$291,360.05		80-20
751	SC StreamStats Phase II: Additional Tools and Layers for Enhanced Workflow and Efficiency	$972,522.00		80-20
752	Safe and Cost-Effective Reduction of Load Postings for South Carolina Bridges	$487,882.00		80-20
753	SCDOT Scope of Services Template	$387,051.00		80-20
754	Optimization of Cement Modified Recycle Base (CMRB) Mixture Design	$320,999.00		80-20
755	Investigation and Assessment of Effective Patching Materials for Concrete Bridge Decks	$286,493.00		80-20
756	Impact of Utility Delays on Project Delivery	$414,996.00		80-20

SPR No.	Item	Previously Funded	FFY 2022 Funds	% Split Fed-State
757	A Preliminary Cost Estimating Model for Transportation Projects		$149,996.00	80-20
758	Field Trials for Cost-Effective Strengthening of SC Load Posted Bridges		$960,000.00	80-20
759	Best Practices on Collecting Asset Information from the Construction Stage		$150,049.00	80-20
760	Reducing Crash Risk at Work Zones in South Carolina		$250,879.00	80-20
761	Streamlining Permitting and Mitigation Processes to Improve SCDOT Project Delivery		$442,281.00	80-20
762	Ultra-High-Performance Concrete (UHPC) Used as a High Friction Surface Treatment (HFST) on Pavements & Bridges		$299,822.00	80-20
763	Does Design-Build Always Expedite Project Delivery: Insights from SCDOT's Historical Data from the Past Decade		$300,000.00	80-20

Pooled-Fund Studies and Other Items Funded in FFY 2022

TPF No.	Item	FFY 2022 Funds	% Split Fed-State
5(375)	National Partnership to Determine the Life Extending Benefit Curves of Pavement Preservation Techniques (MnROAD/NCAT Joint Study - Phase II)	$50,000.00	100-0
5(385)	Pavement Structural Evaluation with Traffic Speed Deflection Devices	$300,000.00	100-0
5(430)	Midwest Roadside Safety Process Fund Program	$67,000.00	100-0
5(437)	Technology Transfer Concrete Consortium (FY20-FY-24)	$12,000.00	100-0
5(441)	No Boundaries Transportation Maintenance Innovations	$10,000.00	100-0
5(446)	High Performance Computational Fluid Dynamics (CFD) Modeling Services for Highway Hydraulics	$80,000.00	100-0
5(447)	Traffic Control Device (TCD) Consortium	$10,000.00	100-0
5(449)	Robust Wireless Skin Sensor Networks for Long-term Fatigue Crack Monitoring or Bridges	$30,000.00	100-0
5(463)	Pavement Surface Properties Consortium: Phase III – Managing the Pavement Properties for Improved Safety	$20,000.00	100-0
5(464)	Hydrologic and Hydraulic Software Enhancements (SMS, WMS, Hydraulic Toolbox, and HY-8)	$10,000.00	100-0
5(465)	Consortium for Asphalt Pavement Research and Implementation (CAPRI)	$107,500.00	100-0
5(469)	NCAT Pavement Test Track 2021	$100,000.00	100-0
5(480)	Building Information Modeling (BIM) for Infrastructure	$30,000.00	100-0
5(485)	Consequences-Based Analysis of Undrained Shear Behavior of Soils and Liquefaction Hazards, Phase 1: Filling the Data Gaps	$20,000.00	100-0
5(488)	Southeast Transportation Consortium - Phase II	$15,000.00	100-0

Other Items Funded in FFY 2022

TPF No.	Item	FFY 2022 Funds	% Split Fed-State
5(420)	NCHRP - FY 22	$797,399.00	100-0
5(450)	TRB Core Program Services	$143,363.00	100-0
-	AASHTO Engineering Technical Service Programs (FY21)	$116,000.00	100-0
-	AASHTOWare Project Data Analytics™ System Cooperative Software Development (FY21)	$187,500.00	100-0
-	* Transportation Technology Transfer (T3) Service (LTAP Center) (FY21)	$351,038.00	80-20

* Additional $150,000.00 funded by LTAP

Accomplishments

PART II

ACCOMPLISHMENTS

The Research Unit established and achieved the following goals in the FFY 2022 program.

1. Began Research Topic Solicitation Process for FY 23-24

Every two years, the SCDOT solicits research topics from within the Department, the U.S. Geological Survey, other State and Federal agencies, in-state institutions of higher education, and in-state trade organizations. The purposes for doing this are two- fold: (1) to identify a wide array of potentially beneficial research topics for consideration by the SCDOT Research and Development Executive Committee (RDEC) for funding as SPR research projects; and (2) as a condition for FHWA Part B funding pursuant to 23 CFR § 420.209.

At the August RDEC meeting, the Research Unit proposed a timeline of deadlines for the submission and review of topics, which was approved. On August 25, 2022, announcement emails were sent encouraging research topics submission using an online form. Seventy four (74) topics were submitted by the September 29, 2022, deadline. The submissions were reviewed by the Research Unit, separated by subject matter, and forwarded to the appropriate Director and/or Deputy Secretary for their review and consideration. The Directors and/or Deputy Secretaries are asked to eliminate any topics unsuitable for further consideration that are deemed to be not beneficial for the Department. Given the number of topics received and the limited number that can be funded as projects, eliminating those that are obviously not suitable for research will provide more time for meaningful discussion and consideration of viable topics. This review also helps the Director and/or Deputy Secretary in identifying participants for the upcoming meetings from the units they supervise.

The Research Topic Solicitation Forum was held on November 10, 2022. The morning session for each category was attended by topic submitters and interested invitees, where each topic was presented and discussed in detail. The afternoon session was attended by SCDOT and FHWA personal, who voted to identify the higher priority topics and appoint a SCDOT Champion who will then submit a problem statement for consideration for funding by the RDEC at their winter meeting.

2. Developed Research Projects Approved by the Research and Development Executive Committee (RDEC)

The Research Staff continued development of the twelve (12) projects from the 2020 Research Topic Solicitation Forums that were approved and prioritized by the RDEC on February 9, 2021. During FFY 2022, agreements were signed on four (4) projects, and four (4) others are in the development stage.

3. Hired Two Employees to the Research Unit

During the month of August, two new employees were hired to be a part of the Research Unit.

Jade Watford was hired to fulfill the role of Research Program Manager. The Research Program Manager provides program management to the Research Engineer with development, administration, and implementation of the SPR Research Program including establishing and revising policies and procedures to ensure compliance with State and Federal requirements. They also schedule and host all SPR projects, New Product Committee, and In-House Investigations Committee meetings and prepare detailed meeting minutes. They manage accounting processes for the Department's SPR Research Program involving budget items, invoices, etc. and act as the liaison for contracts and accounting personnel for universities and consultants conducting studies.

A new position was created to manage the Department's innovation related duties. Daniel Cook was hired to fulfill the role of Innovation Manager. The Innovation Manager serves as the Department's representative for a variety of innovation related committees to help identify and track opportunities for innovation. The Innovation Manager also assists with the New Products program and the SPR In-House Research programs.

4. Received Two Awards for Research Project SPR 741

Each year, AASHTO's Research Advisory Committee's (RAC) Value of Research Task Force solicits projects for consideration as high value research projects. Each of the four RAC regions selects its top four projects from the submittals to form the "AASHTO High Value Research Awards." SCDOT was awarded a High Value Research award for recently completed SPR 741, "Improving SCDOT Project Delivery through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process". The project also won the 2022 Technical Contribution of the Year Award by the American Society of Civil Engineers South Carolina Section.

5. Produced Two Videos to Market Recently Completed SPR High Value Research Projects

One of the main goals of the Research Unit this year was to find better ways to market SPR research within SCDOT, to our partners, and the general public. SCDOT contracted 9/8 Central Studios in Greenville, SC to create two videos showcasing recently completed projects.

The first video produced highlights the findings and deliverables for the award winning project mentioned above- SPR 741 "Improving SCDOT Project Delivery through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process". The video highlights the research, researchers and application of the project.

Link: https://www.youtube.com/watch?v=13YtVjKElsk

A video was also produced to highlight the accomplishments of the project SPR 748 "Utilization of Traffic Speed Deflectometer (TSD) for Pavement Management". The video gives insight to the issues that inspired the project and how its application has improved South Carolina's roads.

Link: https://www.youtube.com/watch?v=HzJTUXZKLb8

Description of the Studies Initiated in FFY 2022

PART III

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Part III: Description of the Studies Initiated in FFY 2022

SPR 757	A Preliminary Cost Estimating Model for Transportation Projects
SPR 758	Field Trials for Cost-Effective Strengthening of SC Load Posted Bridges
SPR 759	Best Practices on Collecting Asset Information from the Construction Stage
SPR 760	Reducing Crash Risk at Work Zones in South Carolina
SPR 761	Streamlining Permitting and Mitigation Processes to Improve SCDOT Project Delivery (Phase 2)
SPR 762	Ultra-High Performance Concrete (UHPC) Used as a High Friction Surface Treatment (HFST) on Pavement and Bridges
SPR 763	Does Design-Build Always Expedite Project Delivery: Insights from SCDOT's Historical Data from the Past Decade

SPR 757	A Preliminary Cost Estimating Model for Transportation Projects	CLEMSON UNIVERSITY

Organization: Clemson University
PI: Dr. Kalyan Piratla
Start Date: 01/01/2022
Completion Date: 06/30/2023

Objective

The South Carolina Department of Transportation (SCDOT) is responsible for the systematic planning, construction, maintenance, and operation of the fourth largest state highway system in the U.S. SCDOT invests hundreds of millions of dollars annually in maintenance, rehabilitation, and new construction of its statewide transportation infrastructure. As with any state highway agency (SHA), the construction needs exceed the budget limitations, which mandates that SCDOT prioritizes transportation project needs based on benefit/cost considerations. An early stage cost estimate is imperative for evaluating the feasibility of large construction projects. Early cost estimates are typically prepared during the planning phase of the project development when minimal scope and design details are available thereby making accurate cost estimates impossible as many design details are unknown. Cost estimates are likely to change as the design is completed and the construction timeline becomes more tangible. The time taken for many projects to mature from the planning phase through the letting phase can be multiple years, and this warrants the consideration of the risks associated with differed market conditions and price inflation. If the project is considerably underestimated, there would be significant cost overruns in the later phases of the project development thereby delaying or limiting the investment into other prioritized projects. It is also possible that the project may lose support for further advancement at the stage of design completion due to lower benefit to cost ratio. It is therefore imperative to use a sophisticated estimating approach to systematically develop conceptual or preliminary estimates during the planning phase by rationally assigning contingency costs to account for the unknowns. SCDOT does not currently have an established agency-wide procedure for rapidly developing preliminary cost estimates for the variety of construction projects they plan and manage.

The proposed project will develop a statistical cost estimating model based on the empirical cost databases maintained by SCDOT. These data sources offer valuable historical insights that will need to be effectively channeled to develop risk-based preliminary cost estimates for future projects. This project also aims at identifying South Carolina's Highway Construction Cost Index, an indicator of construction price inflation in the current market. The developed cost estimating model will predict the range of total project cost based on a broadly defined scope with limited specifics identified. The research work will mainly entail: (a) classifying construction projects into meaningful categories; (b) collecting appropriate empirical cost data from past projects as well as national average unit costs; and (c) developing and validating a robust statistical model that will ultimately be made into a user-friendly tool for SCDOT to use.

SPR 758	Field Trials for Cost-Effective Strengthening of SC Load Posted Bridges	

Organization: University of South Carolina
PI: Dr. Paul Ziehl
Start Date: 10/15/21
Completion Date: 04/14/26

Objective

The South Carolina Department of Transportation is currently conducting a multiyear effort to load rate its inventory of approximately 9,500 bridges. Initial findings from the effort have identified both precast flat slab panels and skinny leg channels (referred to as channels hereafter) as problematic bridge types. Many precast flat slab panels and channel bridges are understrength compared to rating vehicles and will require intervention in the form of posting, strengthening, or replacement. The proposed research project will focus on field trials of strengthening methods for understrength precast flat slab panels and channel bridges. Successful completion of the project will result in design and installation guidelines for cost-effective strengthening schemes that are applicable to thousands of South Carolina's bridges. By developing improved approaches to better understand the strength of existing bridges and cost-effective strengthening strategies, the project has the potential to remove many postings and to minimize or forestall costly replacements. These outcomes represent significant indirect and direct cost savings for the state of South Carolina.

SPR 759	Best Practices on Collecting Asset Information from the Construction Stage	CLEMSON UNIVERSITY

Organization: Clemson University
PI: Dr. Tuyen Le
Start Date: 03/01/2022
Completion Date: 02/29/2024

Objective

The objectives of this project are to: (1) identify the best practices regarding the acquisition of transportation asset information from the data captured during the construction phase; and (2) provide SCDOT with guidance and a reliable tool for quickly migrating construction data into asset data repositories. Anticipated benefits include significant reduction in the duplication of data collection in the O&M stage by directly leveraging digital as-built project data and assist SCDOT's highway maintenance staff obtain accurate and more complete data for making maintenance and rehabilitation decisions.

SPR 760	Reducing Crash Risk at Work Zones in South Carolina	U of SC

Organization: University of South Carolina
PI: Dr. Nathan Huynh
Start Date: 01/07/2022
Completion Date: 06/30/2024

Objective

To help provide a safer work environment for its workers and contractors, the SCDOT is interested in understanding the factors that contribute to crashes at and within the influence area of work zones, and exploring the appropriate countermeasures to reduce the frequency and severity of crashes at or influenced by work zones. The objectives of this research project are to: (i) review work zone related crash reports to verify the reported information, (ii) identify factors that contribute to work zone related crashes in SC, (iii) identify countermeasures based on factors identified in objective (ii), (iv) understand the impact of the presence of law enforcement at work zones, and (v) develop a predictive work zone risk assessment tool to proactively assess the risk at the beginning/during the lifespan of a project.

SPR 761	Streamlining Permitting and Mitigation Processes to Improve SCDOT Project Delivery (Phase 2)	

Organization: University of South Carolina
PI: Dr. Nathan Huynh
Start Date: 01/03/2022
Completion Date: 01/25/2025

Objective

In SPR 741 titled "Improving SCDOT Project Delivery Through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process," the project team developed web apps and forms to help streamline the mitigation and permitting processes to expedite project delivery. In this follow-up project (Phase 2), the project team will enhance those tools that have been created in Phase 1 and create new web apps and forms to support other processes. It seeks to build on the success of Phase 1 where the created apps and associated processes have been adopted and implemented by the SCDOT staff, leading to cost savings ranging from $5,000 to complete a full JD package for a bridge replacement project in-house to $25,000 to complete a JD package for a rural safety corridor project that is less than 10 miles long.

SPR 762	Ultra-High-Performance Concrete (UHPC) Used as a High Friction Surface Treatment (HFST) on Pavements and Bridges	

Organization: Clemson University
PI: Dr. Prasad Rangaraju
Start Date: 01/01/2022
Completion Date: 12/31/2024

Objective

The objective of this research is to review current High Friction Surface Treatment (HFST) usage practices for pavements and bridges by DOTs around the country and explore the use of Ultra-High-Performance Concrete (UHPC) produced using local materials as a potential HFST that is economical and durable. The research will investigate the laboratory and field performance of local aggregates, the UHPC produced with the local aggregates, and then compare against the performance requirements of existing specifications for traditional HFST that require the imported calcined bauxite.

SPR 763	Does Design-Build Always Expedite Project Delivery: Insights from SCDOT's Historical Data from the Past Decade	

Organization: Georgia Institute of Technology
PI: Dr. Baabak Ashuri
Start Date: 02/23/2022
Completion Date: 08/24/2024

Objective

The purpose of this research is to improve the Department's current understanding of cost and schedule growth on both design-build delivery and design-bid-build delivery methods for highway transportation projects. The project objectives are to: (1) systematically analyze SCDOT's cost and schedule data, cost and schedule change order data, along with other historic data using statistical methods to extract insightful comparisons regarding cost and schedule growth, and project intensity; (2) articulate the critical causes and predictors of cost and schedule growth; (3) articulate the effect that critical causes have on cost and schedule growth for both design-build and design-bid-build projects; and (4) develop mitigation strategies for same.

Summaries of SPR Studies Completed in FFY 2022

PART IV

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Part IV: Summaries of SPR Studies Completed in FFY 2022

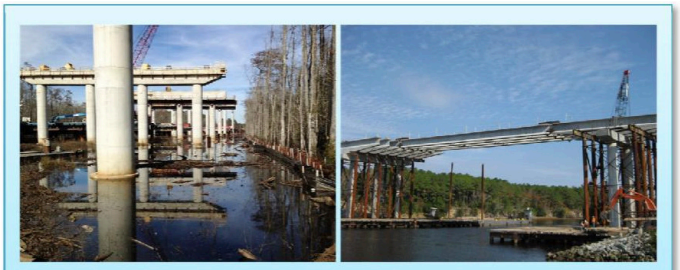
SPR 741	Improving SCDOT Project Delivery through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process
SPR 742	Automatic Extraction of Vehicle, Motorcycle, Bicycle, and Pedestrian Traffic from Video Data
SPR 743	Pavement Performance Curves - Modeling Pavement Deterioration for SCDOT
SPR 746	SC Flood Inundation Mapping
SPR 747	Evaluating the Construction Cost and Schedule Impacts of SCDOT's Traffic Control Restrictions
SPR 750	Risk-Based Inspection Program

SPR 741	Improving SCDOT Project Delivery Through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process	

Organization: University of South Carolina
PI: Dr. Nathan Huynh
Report No.: FHWA-SC-21-06
Date: December 2021

Problem

The South Carolina Department of Transportation (SCDOT) identified three areas that have significant effect on its ability to deliver projects on time and on budget: 1) inconsistent permit application submittals among consultants that led to delay in approval by the U.S. Army Corp of Engineers (USACE), 2) inability to consistently identify "red flags" early in the project development process, and 3) lack of mitigation credit coverage.



These projects have impact on freshwater wetlands and streams, and thereby require Section 404 permits and mitigation. These projects may also affect threatened and endangered species, essential fish habitat, and/or Section 106 properties, which if not identified early in the project development process could delay their completion.

Objectives

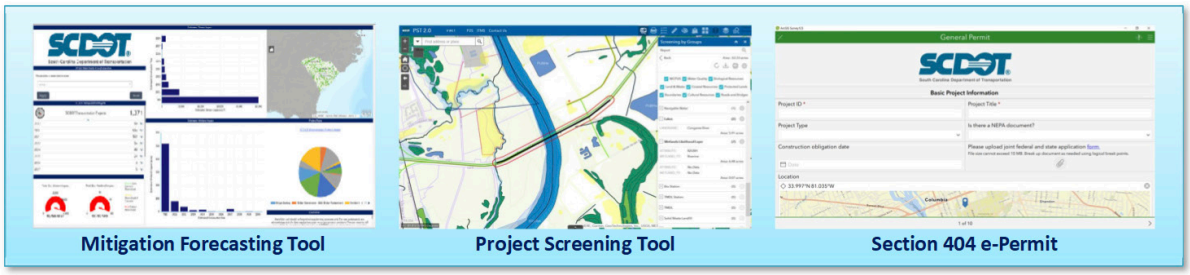
The objectives of this research project were to: 1) review existing mitigation and conservation assessment models/tools used in the U.S. and use the gathered information to develop GIS-based applications that are implementable by the Environmental Services Office (ESO) to provide a sustainable statewide mitigation program, and 2) review existing Section 404 permit application processes and tools used in the U.S. and use the gathered information to develop web-based, interactive applications that are implementable by ESO staff and consultants to streamline the submittal process for Section 404 permit applications submitted to the U.S. Army Corps of Engineers (USACE).

Research

The findings from the literature review indicated that no other state DOT has developed an electronic permitting application for Section 404 general permits and a few agencies have developed mitigation tools and project screening tools (PST). None of the off-the-shelf products and other agencies' in-house applications can be easily tailored to the SCDOT's practice. As a result, the project steering committee directed the project team to develop applications that address SCDOT specific needs. Extensive research was conducted by the project team to determine the most suitable platforms and development tools to use to develop the webapps and smart forms for the SCDOT.

Products

Three web applications (webapps) and two web-based smart forms were developed for the SCDOT's ESO: 1) the Mitigation Forecasting Tool (MFT) aims to reduce the number of projects at risk due to the lack of wetland and stream mitigation bank credit coverage and the number of projects at risk due to low wetland and stream credit availability; 2) the Project Screening Tool (PST 2.0) aims to ensure that SCDOT projects are developed in a way that avoids, minimizes, and mitigates impacts to South Carolina's natural and human environment; 3) the Jurisdictional Determination (JD) webapp aims to facilitate the creation of maps for the JD application; 4) the JD smart form works in conjunction with the JD webapp to produce the JD application package; and 5) the Section 404 e-permit aims to standardize permit submittals in terms of what information to include, how the documents should be presented, where in the package each document should be placed, and how permit drawings should be presented.



Recommendations

It is recommended that the SCDOT consider adopting and utilizing the developed applications in its day-to-day operations. Results from actual use and beta testing of these applications indicate the following tangible benefits for the SCDOT:

- The external MFT webapp has strengthened the relationship between the SCDOT and the mitigation banking community. As a result, the mitigation risk in South Carolina has been significantly reduced and will continue to be reduced with the increase in the number of approved banks across the state, with more on the horizon, pending approvals.
- The use of the PST 2.0 webapp is expected to save ESO staff 20 to 25 hours per month based on a monthly average of one feasibility report and four to five project screenings.
- The use of the e-permit smart form is expected to save SCDOT money by reducing consultants on contract by 30 to 40 hours per month based on a monthly average of two general permits.
- The average USACE reTechnology Transfer and Implementation Planthe developed e-permit smart form, the majority of the general permits will be approved within 2 months.

Technology Transfer and Implementation Plan

The developed applications have been transferred to the SCDOT IT. Several initiatives have been implemented and several more are being planned to assist SCDOT staff, consultants, and partners in using the developed tools. Training was provided to SCDOT superusers throughout the project duration, and these superusers in turn have produced video tutorials for their colleagues and consultants. The SCDOT superusers have also shown the mitigation bankers how to use the external MFT webapp. Current initiatives to further assist with the implementation of the tools include working with the SCDOT video production office to produce shorter how-to video tutorials, a workshop for select consultants in March of 2022, a workshop for all consultants that do business with SCDOT ESO in May of 2022, and demonstration of the tools at the 2022 SC Highway Engineers Conference. Lastly, a promotional YouTube video is being put together to showcase the tools developed in this project for the benefit of SCDOT peers.

SPR 742	Automatic Extraction of Vehicle, Bicycle and Pedestrian Traffic	

Organization: University of South Carolina
PI: Dr. Nathan Huynh
Report No.: FHWA-SC-21-09
Date: December 2021

Problem

Currently, the primary method being used by the SCDOT to collect 48-hour traffic data at short-duration count stations is the MetroCount Counter with pneumatic tubes as shown in Figure 1a. This method is considered 'intrusive' because its use requires placing the rubber tubes across the roadway. This intrusive method is problematic on high-volume roads. Specifically, it is not safe for the data collection crew to be in the roadways, it is difficult to secure tubes on roads with multiple lanes, and high-volume roads tend to have a higher percentage of classification errors due to multiple vehicles passing the tubes at the same time.

Figure 1. Methods to collect traffic data: (a) intrusive - using pneumatic tubes, (b) non-intrusive – using thermal camera and trailer

Objectives

This project investigated the use of traffic cameras to count and classify vehicles. The intent is to provide an alternative approach to pneumatic tubes for collecting traffic data at high volume locations and to eliminate safety risks to SCDOT personnel and contractors. The objectives of this research were to:
1) develop image processing algorithmsto automatically extract vehicle counts and classifications as well as counts of motorcycles, bicycles, and pedestrians from videos, and
2) incorporate the developed algorithms into a stand- alone application with an easy-to-use interface to enable the SCDOT staff to process traffic videos in house.

Research

Background subtraction and foreground detection algorithms were implemented to detect moving vehicles, and a Convolutional Neural Network (CNN) model was developed to classify vehicles. To overcome the issue of poor image quality at night with the traditional visible traffic camera, the FLIR TrafiSense2 Dual (visible and thermal) camera was purchased and custom-built to allow for recording of thermal images to an external drive. To power the thermal camera, the SCDOT solicited bids for a portable solar trailer with specific power requirements, height of crank up mast, and storage capacity. Figure 1b shows the deployment setup of the trailer and thermal camera.

To overcome false detection of vehicles due to either camera motion or erratic light reflection from the pavement surface, an algorithm was developed to keep track of each vehicle's trajectory and the vehicle trajectories were used to determine the presence of an actual vehicle. Figure 2a shows a sample set of vehicle trajectories. A Windows-based application, named DECAF (detection and classification by functional class) shown in Figure 2b was developed to enable users to easily specify the folder containing the video files to be processed, specify the region for which traffic should be analyzed, specify the time interval for which the data should be aggregated, and view the detection and classification results in either PDF or CSV formats. DECAF usesthe thermal CNN model to classify each vehicle at every frame of a running video while the vehicles are within the user- specified region of interest.

Figure 2. DECAF functionalities: (a) vehicle tracks, (b) vehicle detection and classification

Results

The thermal CNN model, when used within DECAF, yielded a counting and classification accuracy of at least 95%, which was the aim of this project. Compared to MetroCount, DECAF produced higher classification accuracy and comparable count accuracy, when deployed in recommended conditions. Table 1 shows the validation results of DECAF/thermal CNN model using an independent test dataset, not previously used to train the model. The results on the test data were comparable to the training data which indicate that the CNN model was not overfitted to the training data. The one instance with high classification error (11%) was due to breezy and gusty wind conditions during that deployment. Compared to MetroCount, DECAF produced higher classification accuracy and comparable count accuracy, when deployed in recommended conditions.

Table 1. Model validation results using independent test datasets

Location	Counting Error	Classification Error
Old Dunbar Road	1%	6%
Pineview Road	5%	5%
Rosewood Drive	4%	4%
Boston Avenue	2%	11%

Recommendations

Based on this project's findings, it is recommended that the SCDOT consider using the purchased solar-powered trailer and thermal camera to collect traffic data on high-volume roads and using the developed Windows application, DECAF, to obtain vehicle counts by categories. There are two situations where the use of the thermal camera and DECAF are not recommended: 1) breezy conditions (over 15 MPH) with gusts over 30 MPH for portions of the 48-hour period, and 2) extreme heat with temperatures above 90 °F for portions of the 48-hour period. Cloudy days do not pose any power problem for the thermal camera.

Value and Benefit

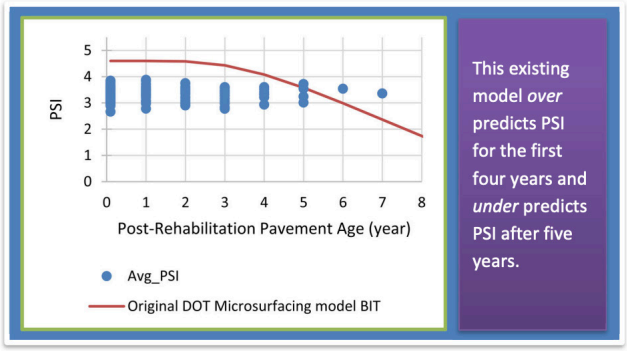
Deploying the trailer and thermal camera on the side of the road will be safer for the SCDOT personnel than deploying MetroCount's pneumatic tubes across multiple lanes. The level of effort required for deploying the trailer and thermal camera is similar to that of deploying the Miovision Scout which the SCDOT has done in the past. The advantage of using the in-house equipment and software is that it will save the SCDOT the video processing cost, approximately $500.00 per 48-hour count.

SPR 743	Pavement Performance Curves: Modeling Pavement Deterioration for SCDOT	

Organization: University of South Carolina
PI: Dr. Nathan Huynh
Report No.: FHWA-SC-22-01
Date: February 2022

Problem

The South Carolina Department of Transportation (SCDOT) pavement management system relies on pavement performance models to estimate future pavement conditions. Their prediction accuracy is critical to the SCDOT in optimizing the scheduling of maintenance activities and budgeting for these activities to achieve a predetermined level of performance. The pavement performance models being used by the SCDOT were formulated in 1989 by Stantec with assistance from SCDOT personnel, and they were based on engineering experience of pavement performance in South Carolina. Since their initial development, the parameters of the adopted sigmoidal, or S- shaped, function have not been updated. The original model parameters may no longer reflect current pavement degradation trends due to changes in materials, construction practices, and traffic loads, as well as changes in the technology being used to collect pavement roughness and distress data. Figure 1 shows the difference between the projected PSI over time from an existing performance model compared to calculated PSI from IRI data collected between 2000 to 2020.



Objectives

The objectives of this research project were to: 1) validate and, if necessary, update the SCDOT existing PSI and PDI prediction modelsfor new construction, existing pavements, and treatment types most frequently utilized by the SCDOT to preserve or rehabilitate pavements on the interstates and primary routes, and 2) supplement the Highway Pavement Maintenance Application (HMPA) with a search of paper records to determine when and what preservation or rehabilitation treatments were applied to the pavements.

Research

This project focused on evaluating those models that are associated with the top five maintenance activities performed on the interstates and the top five activities performed on primary routes in the last ten years in South Carolina

There are seven different combinations of treatment and pavement types for interstates as shown in Table 1 and there is a separate model for PSI and PDI; thus, a total of 14 interstate models were evaluated using pavement roughness and distress data collected from 2000 to 2020 on 117 road sections that span 953 lane-miles. For primary routes, consisting of only asphalt pavements, a total of ten models (five for PSI and five for PDI) were evaluated using pavement roughness and distress data collected from 294 road sections that span 1,116 lane-miles.

To evaluate the PSI and PDI models and parameters, their predicted values were compared against measured data for the applicable treatment type and pavement type. The difference was quantified using the metric Mean Absolute Percentage Error (MAPE). To develop new parameter values for each model, MATLAB's built-in curve fitting function and constrained optimization function were used. The robustness of these parameters which were developed as part of this project was validated by comparing the mean squared error (MSE) of the model when applied to training data and test data.

Results

Among the seven proposed interstate PSI models (Table 1), the relative improvement over existing models ranges between 36.74% and 75.80%, and among the seven proposed interstate PDI models (Table 1), the relative improvement ranges between 7.76% and 80.72%. Among the five proposed primary route PSI models (Table 2), the relative improvement over existing models ranges between 72.79% and 85.25%, and among the five primary route PDI models (Table 2), the relative improvement ranges between 51.69% and 75.11%. The MSE results showed that the proposed models were not overfitted to training data.

Table 1. Performance of proposed interstate models compared to existing models

Treatment / Pavement Type	Mean Absolute Percentage Error (%)				Relative Improvement	
	Current PSI model	Proposed PSI model	Current PDI model	Proposed PDI model	PSI (%)	PDI (%)
GR CON	10.20	5.23	17.46	12.33	48.71	29.35
GR CRC	11.19	7.08	9.53	7.16	36.74	24.85
OC CON	26.64	14.44	34.80	28.91	45.78	16.91
MR 2-4"+200 PSY BIT	12.71	3.74	10.35	4.85	70.56	53.12
MR 2-4"+200 PSY BOC	10.28	3.09	8.08	7.41	69.94	8.32
MR 1-2"+400 PSY BIT	12.78	3.09	87.68	16.90	75.80	80.72
MR 1-2"+400 PSY BOC	8.89	2.57	12.68	11.69	71.06	7.76

Table 2. Performance of proposed interstate models compared to existing models

Treatment / Pavement Type		Mean Absolute Percentage Error (%)				Relative Improvement	
		Current PSI	Proposed PSI	Current PDI	Proposed PDI	PSI (%)	PDI (%)
MR 1-2" BIT		32.70	7.22	14.33	6.60	77.92	53.97
MR 1-2" + 200 PSY BIT		28.06	7.63	37.18	14.60	72.79	60.73
Crack Seal	Crack Seal BIT	32.13	7.84	60.50	22.77	75.61	62.37
	US/SC default	40.70	7.84	91.49	22.77	80.75	75.11
OL 100-200 PSY BIT		29.39	4.34	11.51	5.56	85.25	51.69
Micro-surfacing BIT		36.29	6.34	38.92	16.76	82.54	56.95

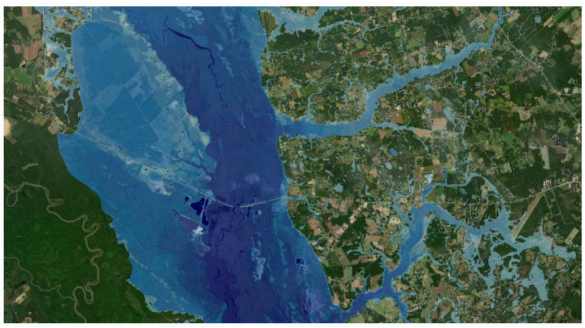
Recommendations

From the findings in this project, it is recommended that the SCDOT consider updating the parameters of the 14 interstate models and 10 primary route models. Overall, the recommended PSI and PDI model parameters show a slower degradation rate compared to the current values for the first 10 years after receiving treatment. Therefore, adopting the recommended parameter values will enable the SCDOT to better identify those pavement candidates that are truly in need of repair and avoid making repairs to those that still have sufficient remaining service life.

SPR 746	SC Flood Inundation Mapping	

Organization: South Carolina Department of Natural Resources (SCDNR)
PI: Maria Cox Lamm
Report No.: FHWA-SC-SC-21-08
Date: November 2021

In recent years, South Carolina has experienced large and small scale flood events. At the time of these events, there was no easy access to predicted inundation mapping for flooding. This Research Grant developed and quality-controlled flood inundation libraries that contain 10 flood frequency scenarios for both the Little Pee Dee and the Lumber Hydrologic Unit Code (HUC 8) Watersheds. The information produced augments the SC Flood IMPACT website and assists in providing state and local officials, as well as the public, with a reliable and accessible resource to communicate flood hazards and identify areas at risk of flooding. An example of a 2,000 year storm event (or 0.05% annual exceedance probability) is shown in the figure below.



0.05% Annual Exceedance Probability Flood Map in the Little Pee Dee Watershed

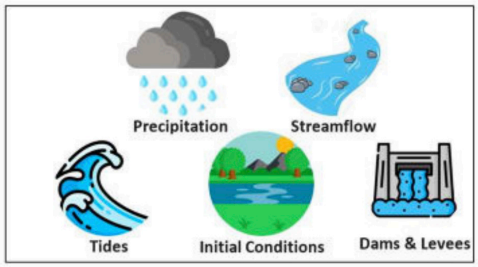
Problem

The State of South Carolina has recently experienced severe storm events resulting in devastating floods. Specifically, the flooding that resulted from Hurricane Matthew in 2016 highlighted the need to produce inundation maps to be used by multiple government agencies and partners for emergency response. As part of SCDNR's inundation mapping efforts for Hurricane Florence, the two-dimensional (2D) hydraulic modeling approach was identified as an efficient and effective method for delivering inundation mapping for large magnitude events. The previous extreme weather events have emphasized several critical needs for the State, including:

- Increase public awareness of flood hazards by identifying areas that may experience flooding,
- Provide a publicly available flood alert system, and
- The need for more resilient mitigation planning and emergency management.

Research

SC Flood IMPACT (Inundation and Mapping for Action) analyzes major factors that contribute to flooding such as precipitation, streamflow, tidal influence, initial model conditions, and dam releases. From each of these factors, the website continuously analyzes data multiple times each day. The end goal is for the website to choose an event from the library to display. By default, a flooding scenario from the library will not display until an event is triggered. Events are triggered using precipitation data produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) and Southeast River Forecast Center (SERFC) gauge information. The forecast is updated every three hours.



SC Flood IMPACT Input Components

All 2D models were created using Hydrologic Engineering Center - River Analysis System (HEC-RAS). HEC-RAS is a software program that models the hydraulics of water flow through natural rivers and other channels. It is designed to perform one-dimensional (1D) and 2D hydraulic calculations. The software allows simulating flow in natural or artificial channels to calculate the water level for performing flood studies and determining the areas that are likely to flood. Various input data was inserted into the model such as Light Detection and Ranging (LiDAR), soil and land use data, and precipitation data. The models were evaluated using established data sets, methodologies, and acceptable tolerances. This includes utilizing flood data from the Federal Emergency Management Agency (FEMA), historical events, high water marks, and photographs. Historical gauge data was analyzed to ensure that timing, magnitude, and volume of the riverine flows were reasonable. SC Flood IMPACT is a unique project which paved the way for an innovative approach to predicting flood events. As a result, many specialized procedures were developed and utilized. These alternative procedures were explored and investigated to ensure that the mostinformed path was taken.
Two key findings:

- 2D Modeling is a viable approach for creating flood inundation raster libraries, and
- There are numerous data sources that must be considered when creating an inundation raster library

Results

The funding for this research project provided for the creation of 10 flood frequency scenarios for both the Little Pee Dee and the Lumber Hydrologic Unit Code (HUC 8) Watersheds in the form of flood inundation libraries. The library information was produced in the form of depth rasters. The depth rasters were loaded into the SC Flood IMPACT website library repository. The repository is programed to display the appropriate depth raster that corresponds to the forecasted event. The website will automatically update as the forecast is refined and once the rainfall event has ended, the site updates based on precipitation data and gauge information.

Value and Benefit

SC Flood IMPACT is the proposed solution to address critical needs as the State will benefit greatly from instantaneous forecasts, accessible flood information, and an alert system. This website provides state and local officials, as well as the public, with a reliable and accessible resource to communicate flood hazards and identify areas at risk of flooding. One of the main benefits of using rain-ongrid 2D modeling is that it identifies all areas that are at risk of flooding, as opposed to 1D modeling which focuses only on a single stream. As a result, SC Flood IMPACT differentiates itself in this regard compared to similar websites that only display flooding within a mile upstream or downstream of a stream that has a U.S. Geological Survey (USGS) gauge.
For SCDOT, additional benefits could include:

- Inundation scenarios that will identify areas that are at risk for flooding prior to the storm arriving,
- Ability to create and distribute maps of areas forecasted to flood, and
- Utilize potential flood impacts to determine where to stage resources.

SPR 747	Evaluating the Construction Cost and Schedule Impacts of SCDOT's Traffic Control Restrictions	CLEMSON UNIVERSITY

Organization: Clemson University
PI: Dr. Kalyan R. Piratla
Report No.: FHWA-SC-SC-21-08
Date: November 2021

This study empirically evaluated the influence of lane closure restrictions on project cost and schedule considering pay item and daily work report data for over 58 past interstate projects. The queue length implications of lane closures are investigated using a simulation-based prediction approach. While the queue length was found to be significantly dependent on the lane closure restriction specification, the empirical analysis using linear regression modeling did not reveal significant influence of lane closure specifications on project cost and productivity of critical work items. To validate these insights, four transportation contractors were invited to submit hypothetical bids and production estimates for a set of critical work items considering nine daily lane closure restriction scenarios. Contractor inputs for four projects revealed that: (a) the currently used 9am-4pm daytime construction window is not necessarily better than the nighttime-only construction window, (b) the contractors prefer extended nighttime (i.e., 7pm-7am) construction windows, as informed by lower cost and higher production rate estimates in the hypothetical bids, and (c) the project costs and production may not be highly influenced by lane closure restrictions alone. A queue length prediction model is developed for SCDOT to consider specifying lane closure restrictions based on a chosen threshold.

Project Hypothesis: Relaxing the lane closure restrictions would expedite transportation project delivery and make them less costly

Problem

State transportation agencies allow lane closures for making work zones safer to both workers as well as travelers. Lane closures however result in higher road user costs as the work zone capacity shrinks and are therefore restricted in crucial times of the day. These restrictions could lead to longer project schedules and higher cost. The tradeoff between project cost, schedule, and user costs is under explored in the context of traffic control planning for work zones. This study focused on evaluating that tradeoff primarily using empirical data from past and current SCDOT projects.

Research

This study empirically evaluated the influence of lane closure restrictions on project cost and schedule considering pay item and daily work report data for over 58 interstate projects. The queue length implications of lane closures are investigated using a simulation-based prediction approach. Regarding cost, total project cost, unit project cost, and itemized costs for various critical pay items were statistically analyzed for their dependence on both the traffic threshold volume for lane closure restriction specification and the weekly daytime construction window hours. Further, regression models were developed to predict the project cost as dependent on the lane closure restriction specification considering preservation/re-surfacing and re-construction/full-depth patching project categories.

Finally, contractors were invited to submit hypothetical bids for a few projects considering nine different lane closure restriction specifications. Contractors' inputs for four projects were assessed to validate the insights from the prior empirical analysis. The schedule impact assessment followed a similar approach focusing on production rates for various critical work items in the past projects. Contractors' inputs were also sought for production rates for a few projects considering nine lane closure restriction specifications. For queue length prediction, parametric and non-parametric models were developed in this study. Three statistical models namely, multiple linear regression, quantile regression, and ridge regression, and four machine learning models namely, decision trees, k-nearest neighbor, random forest, and extreme gradient boost were leveraged. The framework is demonstrated for 2-to-1 (as in closure of one lane on a 2-lane freeway), 3-to-1, and 3-to-2 lane closure scenarios. In addition, the study also investigated making the models transferable to any freeway of South Carolina (SC) to avoid the necessity for developing models for each new network.

Results

Based on the empirical analysis, traffic threshold volume or weekly daytime construction window hours were not found to be statistically significant for predicting project cost or production rates of critical payitems. The contractor bidding exercise revealed that: (a) 9am-4pm is not a long enough daytime construction window to result in cost and schedule benefits; and (b) extended nighttime construction windows (i.e., 7pm-7am) may be beneficial to contractors to result in slight cost and schedule benefits. The summary of aggregated itemized costs for a hypothetical bid received from a contractor is presented below. Production rate estimates from a contractor for a couple of payitems is also presented below.

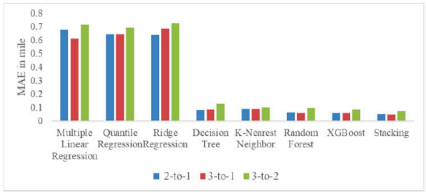
Construction Window	Project #2
Payitem % Cost Contribution	50.25%
9pm-7am both ways	$6,898,933
7pm-7am & 9pm-7am	$6,897,090
9pm-7am &7pm-7am	$6,897,090
7pm-7am both ways	$6,897,090
9am-4pm both ways	$8,583,116
9am-7pm & 9am-4pm	$7,874,640
9am-4pm & 9am-7pm	$7,874,640
9am-7pm both ways	$6,631,858
24 hrs	$6,641,685

Aggregated itemized costs from a contractor's hypothetical bid

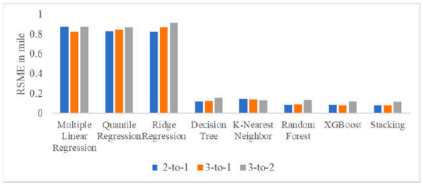
Construction Window	Production/10-hr shift	
Payitem # →	3100310	4030310
Quantity →	102980 Ton	45772 Ton
9pm-7am both ways	1000	1000
7pm-7am & 9pm-7am	1100	1100
9pm-7am &7pm-7am	1100	1100
7pm-7am both ways	1200	1200
9am-4pm both ways	700	700
9am-7pm & 9am-4pm	850	850
9am-4pm & 9am-7pm	850	850
9am-7pm both ways	1000	1000
24 hrs	1200	1200

Production rate estimates for a couple of payitems from a contractor's hypothetical bid

As can be observed from the below plots, the developed queue length prediction models revealed that the machine learning models performed better than the statistical ones with extreme gradient (XG) boost model being the best. The XGBoost model performed best for transferability evaluation too. These transferable models can be used to estimate queue length of any freeway without having to develop new models. A userfriendly Microsoft Excel-based computational tool was developed to run the regression models to predict queue length based on several work zone and lane closure restriction specification characteristics.



Comparison of mean absolute error (MAE) for various queue length prediction models



Comparison of root mean square (RMSE) for various queue length prediction models

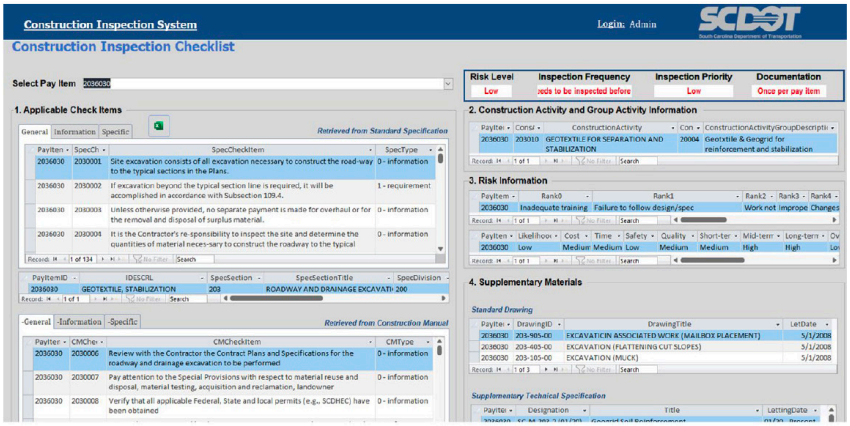
Value and Benefit

The analysis undertaken in this project did not support the hypothesis that relaxing lane closure restrictions would lead to considerable cost and schedule benefits. It is however recommended that nighttime construction windows be extended by a couple of hours, where possible, to provide contractors longer production windows. There is evidence to suggest this would result in production rate improvement and slight reduction in cost. Contractors are concerned with getting trucks in and out of job sites during daytime due to congestion with lane closures. They also opined that inconsistent and shorter daytime construction windows prevent from scheduling daytime work.

SPR 750	Risk-Based Inspection Program	PURDUE UNIVERSITY

Organization: Purdue University
PI: Dr. Hubo Cai
Report No.: FHWA-SC-22-03
Date: August 2022

Construction inspection is a critical component of the quality assurance/quality control (QA/QC) program at the South Carolina Department of Transportation (SCDOT). A pressing challenge SCDOT has been facing is to balance the increasing demand to rebuild the statewide transportation systems with declining resources available for inspection. This project aims to address this critical issue by developing a risk-based inspection program that includes (1) the identification and assessment of risks associated with construction activities at SCDOT, (2) the development of inspection strategies that correspond to the level of risk, (3) the identification of quality requirements and inspection activities that are applicable to pay items, and (4) the design and implementation of a digital, risk-based inspection system.



Intelligent Inspection Database System

Problem

Construction inspection is a critical component at the SCDOT to ensure the quality and long-term performance of the resulting infrastructures (e.g., roads and bridges). In the current practice, SCDOT has been facing the challenge of balancing the inspection resource shortage (attributed to staff downsizing and the retirement of experienced construction inspectors) with the increasing demand for rebuilding and maintaining the statewide infrastructures. The growing number of transportation projects and complexities in modern construction projects further aggravate the challenges. Therefore, there is still a critical need for SCDOT to seek alternative strategies to more effectively allocate its limited inspection resources to ensure the construction quality and life cycle performance of infrastructure

Research

In order to assist SCDOT in effectively allocating limited resources to the most critical areas, this research aims to develop a risk-based inspection program by focusing mainly on risks associated with SCDOT's current construction activities. This research consists of four objectives: (1) identification and assessment of risks associated with construction activities at SCDOT, (2) the development of inspection strategies that correspond to the risk level, (3) identification of quality requirements and inspection activities associated with construction activities, and (4) the design and implementation of a digital, risk-based inspection system. This project consists of eight tasks.

Task 1 aims to identify construction activities and requirements at SCDOT by identifying pay items associated with construction activities, developing a work breakdown structure (WBS), and linking pay items to applicable sections and divisions in related construction documents (e.g., standard specification). Task 2 aims to understand the current inspection practices at SCDOT by conducting surveys and aligning pay items with construction processes. Task 3 aims to identify the availability and cost of inspection resources at SCDOT by conducting surveys and analyzing materials provided by the SCDOT. Task 4 aims to identify risks associated with construction activities and assess corresponding risk levels by compiling a list of risks, developing risk breakdown structure (RBS) and risk breakdown matrix (RBM), determining the risk likelihood and consequence severity, and computing the composite risk score based on risk assessment matrix (RAM). Task 5 aims to determine inspection priority, inspection frequency, and documentation requirements for construction activities based on the risk level. Task 6 aims to identify critical inspection information from construction documents and develop a digital inspection system by retrieving quality requirements from construction documents (e.g., standard specification) using deep learning approaches. Task 7 aims to summarize a list of inspection requirements. Task 8 aims to develop a toolbox to accompany the inspection system designed in Task 6.

Results

Task 1 Identification of construction activities and construction requirements at SCDOT:
- A total of 7,024 pay items were found to be associated with the construction activities at SCDOT.
- The 7,024 pay items can be organized into the developed WBS in which the hierarchical structure consists of 1,276 construction activities, 142 activity groups, and 7 construction areas.
- For each construction activity, construction requirements were identified.

Task 2 Current inspection practice at SCDOT:
- The focus of the construction inspection at SCDOT is on 6 areas (asphalt, earthwork, concrete, traffic control, structures, and erosion control and survey).
- The SCDOT inspection process consists of 4 steps [(1) notification, (2) requirements retrieval and planning, (3) inspection, and (4) documentation], and a significant amount of time is spent on requirements retrieval, inspection, and documentation.

Task 3 Availability and cost of inspection Resources:
- In the current inspection practice, SCDOT mainly uses in-house staff and CE&I contracts.
- CE&I contracts have relatively higher average hourly rates on all the positions compared with in-house staff.

Task 4 Risk identification and assessment for construction activity:
- The RBM, which was developed based on WBS and RBS in this research, can be used to identify risks for construction areas, construction activity groups, or even construction activities.
- The risk level for each of the 142 construction activity groups and the overall risk level of the 7 construction areas were assessed.

Task 5 Recommendation of inspection priority, inspection frequency, and documentation based on risk:
- Three levels of inspection priority were designed: high, medium, and low.
- Three levels of inspection frequency were proposed: full-time, intermittent, and end of production
- Three levels of documentation were developed: daily/per segment, per pay item, and once per pay item.

Task 6 Inspection documentation for database:
- The sentence classifier can correctly classify requirements in standard specifications with an average accuracy of 91% and those in the construction manual with an average accuracy of 90%.

Task 7 Inspection summary:
- The inspection summary containing inspection objectives and inspection activities at the section level was developed.

Task 8 Toolbox for inspectors:
- The intelligent inspection database system can (1) automatically generate applicable check items for the selected pay item from standard specification and construction manual, (2) retrieve corresponding construction activity and group, (3) display associated risk information, (4) retrieve applicable supplementary materials and (5) generate inspection forms as a checklist format.

Value and Benefit

SCDOT can make risk-informed decisions based on inspection information (e.g., risk factors). For example, within the project, SCDOT can prioritize construction activities based on risk level and organize limited inspection resources accordingly. Also, inspection frequency (e.g., continuous and intermittent) can be set based on the varying risk level of construction activities and used for efficient inspection. As such, this research can facilitate the efficient allocation of available inspection resources, reduce the workload of construction inspectors, ensure consistency in the QA/QC practice, and support the documentation of construction inspection.

2022 SCDOT SPR Program
Part II: Research