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 2019
October 1, 2018 to September 30, 2019
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Contacts</td>
<td>1</td>
</tr>
<tr>
<td>Overview</td>
<td>2</td>
</tr>
<tr>
<td>Part I: Research Program/Project Funding and Research Project Summary</td>
<td>3</td>
</tr>
<tr>
<td>Program Funding</td>
<td>4</td>
</tr>
<tr>
<td>Project Funding</td>
<td>5</td>
</tr>
<tr>
<td>Research Program Summary</td>
<td>6</td>
</tr>
<tr>
<td>Part II: Accomplishments</td>
<td>9</td>
</tr>
<tr>
<td>Conducted a Research Topic Solicitation Meeting</td>
<td>10</td>
</tr>
<tr>
<td>Balloted the Research and Development Executive Committee (RDEC) for approval and prioritization of topics for development as research projects</td>
<td>11</td>
</tr>
<tr>
<td>Continued efforts to promote adopted recommendations made during the 2018 Peer Exchange hosted by SCDOT</td>
<td>11</td>
</tr>
<tr>
<td>Submitted recently completed topics to AASHTO Research Advisory Committee’s Value of Research Task Force for consideration as “high-value” research projects</td>
<td>12</td>
</tr>
<tr>
<td>Developed research projects approved by the Research and Development Executive Committee (RDEC)</td>
<td>12</td>
</tr>
<tr>
<td>Hosted Dr. Nelson Gibson for the Biennial 2019 Transportation Research Board (TRB) State Partnerships Visits Program</td>
<td>13</td>
</tr>
<tr>
<td>Met with David Pamplin of FHWA’s “Research &amp; Technology Program Development &amp; Partnership Team”</td>
<td>13</td>
</tr>
</tbody>
</table>
Part III: Description of the Four Studies Initiated in FFY 2019

- **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 744** SCDOT Preconstruction Program Management Manual & Updated Project Development Process
- **SPR 745** Update to SCENARIO_PC

Part IV: Summaries of SPR Studies Completed in FFY 2019

- **SPR 702** Compliance with the United States Environmental Protection Agency (USEPA) Effluent Limitation Guidelines - Turbidity Control and Surface Outlets
- **SPR 712** Development of South Carolina Databases and Calibration Factors for the Highway Safety Manual
- **SPR 714** Implementation of the U.S. Geological Survey’s StreamStats Application for South Carolina Department of Transportation
- **SPR 716** SCDOT Asset Data Collection Assessment
- **SPR 717** Cost Effective Strategies for Estimating Statewide AADT
- **SPR 721** Better Construction Project Management Through Better Scheduling
- **SPR 724** Feasibility Study for Rapid Evaluation of Bridge Decks
- **SPR 728** Best Practices for Longitudinal Joint Construction and Compaction

**List of Figures**

- **Figure 1** FFY 2019 Research Program Funding
- **Figure 2** Distribution of Funds by General Area for All Research Projects in the Program During FFY 2019

**List of Tables**

- **Table 1** FFY 2019 SPR Research Program Summary
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, A.P.E.
Research Engineer
Phone: 803 737-6691
Email: SwygertTL@scdot.org

Meredith W. Heaps
Program Manager
Phone: (803) 737-1969
E-mail: HeapsMW@scdot.org

Judy P. Hundley
Program Coordinator I
Phone: (803) 737-6652
E-mail: HundleyJP@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 2019 were:

• Conducted a Research Topic Solicitation Meeting.
• Balloted the Research and Development Executive Committee (RDEC) for approval and prioritization of topics for development as research projects.
• Continued efforts to promote adopted recommendations made during the 2018 Peer Exchange hosted by SCDOT.
• Submitted recently completed topics to AASHTO Research Advisory Committee’s Value of Research Task Force for consideration as “high-value” research projects.
• Developed research projects approved by the Research and Development Executive Committee RDEC.

Other accomplishments achieved by the Research Unit in FFY 2019 were:
• Hosted Dr. Nelson Gibson for the biennial 2019 Transportation Research Board (TRB) State Partnerships Visits Program.
• Met with David Pamplin of FHWA’s “Research & Technology Program Development & Partnership Team.”

This annual report provides a description of the FFY 2019 SPR Research Program that includes the period from October 1, 2018 through September 30, 2019. 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 2019 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 2019.
Research Program/Project Funding and Research Program Summary

PART I
In FFY 2019, the SPR Research Program received $3,575,913.00 in Federal funds. Figure 1 provides a general breakdown of items funded and amounts, including appropriate matching funds, in FFY 2019.

- Research Projects $2,023,677
- NCHRP $786,701
- Pooled-Fund Studies $825,000
- Transportation Technology Transfer Service (LTAP Center) $310,979
- TRB Core Program $140,349
- AASHTOWare Project Data Analytics™ System Cooperative Software Development $187,500

Figure 1. FFY 2019 Research Program Funding
A total of twenty-six projects were included in the program. Four research projects were started during FFY 2019. Eight studies were completed during the year. Figure 2 shows how the funds were obligated for research projects in FFY 2019 and distributed by general area and amounts.

- Preconstruction $349,383
- Pavement Design $251,371
- Structural Design/Seismology $1,274,033
- Planning/Road Data Services $148,890

Figure 2. Distribution of Funds by General Area for All Research Projects in the Program during FFY 2019
Table 1 below lists all items included in the FFY 2019 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 2019.

<table>
<thead>
<tr>
<th>SPR No.</th>
<th>Item</th>
<th>Previously Funded</th>
<th>FFY 2019 Funds</th>
<th>% Split Fed-State</th>
</tr>
</thead>
<tbody>
<tr>
<td>702</td>
<td>Compliance with USEPA Effluent Limitation Guidelines-Turbidity Control and Surface Outlets</td>
<td>$498,629.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>710</td>
<td>Determination of Changes in Water Quality, Streambed Settlement, and Benthic Macroinvertebrates as a Result of Stormwater Runoff from Selected Bridges in South Carolina</td>
<td>$993,563.42</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>712</td>
<td>Development of SC Databases and Calibration Factors for the Highway Safety Manual (HSM)</td>
<td>$181,020.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>714</td>
<td>Implementation of the U.S. Geological Survey’s StreamStats Application for South Carolina Department of Transportation</td>
<td>$698,183.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>716</td>
<td>SCDOT Asset Collection</td>
<td>$473,803.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>717</td>
<td>Cost Effective Strategies for Estimating Statewide AADT</td>
<td>$370,027.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>721</td>
<td>Better Construction Project Management through Better Scheduling</td>
<td>$200,988.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>724</td>
<td>Feasibility Study for Rapid Condition Assessment of Bridge Decks and Other Structures</td>
<td>$247,500.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>725</td>
<td>Evaluation of Open Graded Friction Courses: Construction, Maintenance, and Performance – Phase II</td>
<td>$481,849.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>728</td>
<td>Best Construction Practices for Longitudinal Joint Construction and Compaction</td>
<td>$107,074.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>729</td>
<td>Effects of Culverts on the Natural Conditions of Streams in South Carolina</td>
<td>$898,000.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>731</td>
<td>Deep Soil Test Borings to Determine Shear Wave Velocities Across South Carolina</td>
<td>$532,107.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>732</td>
<td>Calibration of the AASHTO Pavement Design Guide to SC Conditions - Phase II</td>
<td>$1,762,300.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>733</td>
<td>Updating Techniques for Estimating Magnitude and Frequency of Floods for Rural Basins in the Southeastern United States</td>
<td>$493,612.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>734</td>
<td>SCDOT Crash Analysis Using Precisely Geocoded Crashes</td>
<td>$197,496.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>735</td>
<td>Development of Pavement Investigation Strategies for Non-Interstate Routes</td>
<td>$86,677.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>SPR No.</td>
<td>Item</td>
<td>Previously Funded</td>
<td>FFY 2019 Funds</td>
<td>% Split Fed-State</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td>736</td>
<td>Characterization of Bases and Subbases for AASHTO ME Pavement Design</td>
<td>$392,158.64</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>737</td>
<td>Adaptive Signal System Safety Impacts</td>
<td>$359,993.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>738</td>
<td>Development of a User’s Manual for Application of the South Carolina Unit Hydrograph Method</td>
<td>$74,926.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>739</td>
<td>Assessment of Structural Degradation for Bridges and Culverts</td>
<td>$349,927.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>740</td>
<td>Design-Build Project Selection and Effectiveness Evaluation</td>
<td>$262,441.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>741</td>
<td>Improving SCDOT Project Delivery Through Identifying Potentially Suitable Locations for Mitigation and Standardizing Section 401/404 Permit Application Process</td>
<td>$640,678.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>742</td>
<td>Automatic Extraction of Vehicle, Motorcycle, Bicycle, and Pedestrian Traffic from Video Data</td>
<td></td>
<td>$148,890.00</td>
<td>80-20</td>
</tr>
<tr>
<td>743</td>
<td>Pavement Performance Curves - Modeling Pavement Deterioration for SCDOT</td>
<td></td>
<td>$251,371.00</td>
<td>80-20</td>
</tr>
<tr>
<td>744</td>
<td>SCDOT Preconstruction Program Management Manual &amp; Updated Project Development Process</td>
<td></td>
<td>$349,383.00</td>
<td>80-20</td>
</tr>
<tr>
<td>745</td>
<td>Update to SCENARIO_PC</td>
<td>$1,274,033.00</td>
<td></td>
<td>80-20</td>
</tr>
<tr>
<td>SPR No.</td>
<td>Item</td>
<td>FFY 2019 Funds</td>
<td>% Split Fed-State</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------</td>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>5(193)</td>
<td>Midwest States Pooled Fund Crash Test Program</td>
<td>$67,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(228)</td>
<td>SuperPave Regional Center, SE Region</td>
<td>$20,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(279)</td>
<td>High Performance CFD Modeling Services for Highway Hydraulics</td>
<td>$240,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(305)</td>
<td>Regional and National Implementation and Coordination of ME Design</td>
<td>$10,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(313)</td>
<td>Technology Transfer Concrete Consortium (TCCC)</td>
<td>$12,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(316)</td>
<td>Traffic Control Device (TEC) Consortium</td>
<td>$10,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(330)</td>
<td>No Boundaries Roadway Maintenance Practices</td>
<td>$10,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(345)</td>
<td>Pavement Surface Properties Consortium – Managing the Pavement Properties for Improved Safety</td>
<td>$20,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(354)</td>
<td>Improving the Quality of Highway Profile Measurement</td>
<td>$20,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(357)</td>
<td>Connecting the DOTs: Implementing ShakeCast Across Multiple State Departments of Transportation for Rapid Post-Earthquake Response</td>
<td>$15,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(374)</td>
<td>2018 NCAT Pavement Test Track</td>
<td>$210,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(375)</td>
<td>Pavement Preservation Techniques (MnROAD/NCAT Joint Study)</td>
<td>$50,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(385)</td>
<td>Pavement Structural Evaluation with Traffic Speed Deflection Devices</td>
<td>$141,000.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(397)</td>
<td>TRB Core Program Services (TRB FY19)</td>
<td>$140,349.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td>5(419)</td>
<td>NCHRP</td>
<td>$786,701.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- AASHTOWare Project Data Analytics™ System Cooperative Software Development (FY19)</td>
<td>$187,500.00</td>
<td>100-0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Transportation Technology Transfer (T3) Service (LTAP Center)</td>
<td>$310,979.00*</td>
<td>80-20</td>
<td></td>
</tr>
</tbody>
</table>

*Additional $150,000.00 funded by LTAP
PART II

Accomplishments
ACCOMPLISHMENTS

The Research Unit established and achieved the following goals in the FFY 2019 program.

1. Conducted a Research Topic Solicitation Meeting

The South Carolina Department of Transportation (SCDOT) Research Topic Solicitation Meeting was held November 1, 2018, in Columbia, SC. The SCDOT contracted with the Transportation Technology Transfer Service (T3S) at Clemson University to provide the logistical and administrative support for the meeting. This meeting, the seventh of its type, was intended 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. Approximately 90 people, including representatives from the SCDOT, FHWA, USGS, academia, and industry participated in the meeting.

The meeting began with a plenary session of all participants during which Research Staff provided a brief overview of the research program and discussed the purpose of the meeting. Each participant then attended one of five breakout sessions, each on a different subject area of potential research interest for the SCDOT. The five breakout groups included:

- Construction/Materials
- Maintenance/Bridge Maintenance
- Preconstruction/Environmental
- Traffic/Safety
- Intermodal Planning/HR

Moderators from SCDOT’s Office of Materials and Research were assigned to each breakout group. This was the third meeting to require that the solicited research topics be submitted prior to the meeting. Topics were solicited from all research partners, were reviewed by Research Staff, and separated by subject matter corresponding to one or more related breakout group if the subject matter clearly impacted more than one area. The topics were then forwarded to the appropriate Director or Deputy Secretary for their review and recommendation of topics to be included for further consideration in the topic selection and approval process. Review of the topics aided the Director or Deputy Secretary in identifying participants for the meeting from the units they supervise.
All participants were identified and assigned to a breakout group prior to the meeting. All attended the morning breakout session to discuss the topics included in their group. After lunch, only SCDOT and FHWA attendees participated in the afternoon breakout session to determine the higher priority topics to ensure that topics most beneficial to SCDOT were advanced for consideration by the RDEC. Of the 92 topics discussed in the breakout groups during the morning session, 28 were identified as higher priority topics for further consideration. A “Champion” from SCDOT was determined during the afternoon session for each higher priority topic and was responsible for preparing a problem statement for their topic.

2. Balloted the Research and Development Executive Committee (RDEC) for approval and prioritization of topics for development as research projects.

Topics resulting from the Research Topic Solicitation Meeting that were recommended for consideration for funding were balloted by the RDEC in accordance with the procedures outlined in Section 5.1 of SCDOT’s Research Manual. Ten topics were approved by the RDEC in its winter meeting held February 14, 2019. The approved projects in prioritized order are shown in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>18-PC-01</td>
<td>SC Flood Inundation Mapping</td>
</tr>
<tr>
<td>2.</td>
<td>18-CM-01</td>
<td>Risk-Based Inspection Program</td>
</tr>
<tr>
<td>3.</td>
<td>18-PC-05</td>
<td>Evaluating the Construction Cost and Schedule Impacts of SCDOT’s Traffic Control Restrictions</td>
</tr>
<tr>
<td>4.</td>
<td>18-IP-01</td>
<td>Utilization of Traffic Speed Deflectometer (TSD) for Pavement Management</td>
</tr>
<tr>
<td>5.</td>
<td>18-PC-03</td>
<td>South Carolina StreamStats Phase II: Additional Tools and Layers for Enhanced Workflow and Efficiency</td>
</tr>
<tr>
<td>6.</td>
<td>18-CM-02</td>
<td>Optimization of Cement Modified Recycled Base (CMRB) Mixture Design</td>
</tr>
<tr>
<td>7.</td>
<td>18-CM-05</td>
<td>Impact of Utility Delays on Project Delivery</td>
</tr>
<tr>
<td>8.</td>
<td>18-PC-02</td>
<td>Create a Standardized Scope of Services Template</td>
</tr>
<tr>
<td>9.</td>
<td>18-MB-03</td>
<td>Investigation and Assessment of Effective Patching Materials for Concrete Bridge Decks</td>
</tr>
<tr>
<td>10.</td>
<td>18-MB-04</td>
<td>Safe and Cost-Effective Reduction of Load Postings for South Carolina Bridges</td>
</tr>
</tbody>
</table>

Table 1. 2019 Topics Approved as SPR Research Projects
3. Continued efforts to promote adopted recommendations made during the 2018 Peer Exchange hosted by SCDOT.

The Research Unit continued with efforts in promoting adopted recommendations made during the 2018 Peer Exchange hosted by SCDOT. New guidelines and templates developed by Ms. Heaps are currently being used with FY 19-20 SPR Projects. The Research Manual was updated to reflect these changes and was submitted and approved by the FHWA South Carolina Division.

Members of the Research Unit met Dr. de la Garza of Clemson University, Dr. Caicedo of the University of South Carolina, and with Ms. Mary Corley of Tri-County-Technical College to inform them of the new guidelines and share concerns that were raised during the Peer Exchange meeting. Mr. Swygert shared the same information in telephone calls/emails with Dr. Ihekweazu of South Carolina State University and with Dr. Davis at the Citadel.

4. Submitted recently completed topics to AASHTO Research Advisory Committee’s Value of Research Task Force for consideration as “high-value” research projects.

Every January, 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 Research Sweet Sixteen Awards.” SCDOT received a Sweet Sixteen award for the recently completed SPR No. 714, “Implementation of the U.S. Geological Survey’s StreamStats Application for South Carolina Department of Transportation.” SCDOT’s project was featured in the “Research Makes the Difference 2019: Award-Winning Innovations from State DOTs.”

Sweet Sixteen research project awards are given to State DOT CEOs at the AASHTO Annual Meeting and to Research Managers at the AASHTO RAC/TRB Representative meeting. Mr. Swygert attended the 2019 National RAC and TRB State Representative Meeting, in Santa Fe, New Mexico, July 21 – 25, 2019, and made a poster presentation about the project. The project will also be included at a poster session at the 2020 TRB Annual meeting in Washington, D.C.

This was the second year in a row that SCDOT received this award for innovative research.

5. Developed research projects approved by the Research and Development Executive Committee RDEC.

Research Staff continued developing the projects approved and prioritized by the RDEC in December 2017. During the remainder of FFY 2019, contracts were signed on the final five projects. The Research Staff began developing the first five of the projects from the 2018 Research Topic Solicitation Meeting in FFY 2019 that were approved and prioritized by the RDEC in February 2019.
The Research Unit’s other accomplishments in the FFY 2019 program included the following:

**6. Hosted Dr. Nelson Gibson for the Biennial 2019 Transportation Research Board (TRB) State Partnerships Visits Program.**

Dr. Nelson Gibson visited SCDOT for the biennial 2019 Transportation Research Board (TRB) State Partnerships Visits Program on August 27, 2019. TRB staff with expertise in various modes and topics visit state departments of transportation (DOTs) on an annual or biennial basis. The visits, which typically last one or two days, support TRB’s mission of promoting innovation and progress in transportation through research and information exchange. Dr. Gibson is responsible for 19 of TRB’s standing committees focusing on design, construction, and materials. During his visit, he met with Engineers from Construction, Preconstruction, and the Office of Materials and Research.

**7. Met with David Pamplin of FHWA’s “Research & Technology Program Development & Partnership Team.”**

David Pamplin of the “Research & Technology Program Development & Partnership Team” in the “Office of Corporate Research” (HRTM-10) at FHWA’s Turner-Fairbank Highway Research Center conducted an FHWA South Carolina Division site visit on August 27, 2019. HRTM-10 site visits are intended for the Center to get a better understanding of each state DOT’s research program’s practices and issues and how the FHWA Division Office interacts with and supports them. Mr. Swygert, Mr. Zwanka, and visiting TRB representative Dr. Nelson Gibson met with Mr. Jim Garling and Mr. Pamplin, and gave an overview of the SCDOT Research Program. Mr. Pamplin also met with FHWA Division Office leadership earlier in the day.

After the meeting and hearing the Research Unit’s presentation, Mr. Pamplin informed Mr. Garling that SCDOT has one of the best Research Programs that he has seen. He complimented the dynamic working relationship between SCDOT and the FHWA South Carolina Division, and held the SCDOT Research Unit’s well-managed, forward-thinking program as an example for other DOTs to follow.
Description of the Four Studies Initiated in FFY 2019
<table>
<thead>
<tr>
<th>SPR 742</th>
<th>Automatic Extraction of Vehicle, Motorcycle, Bicycle, and Pedestrian Traffic from Video Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization:</strong></td>
<td>University of South Carolina</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Dr. Nathan Huynh</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>01/15/2019</td>
</tr>
<tr>
<td><strong>Completion Date:</strong></td>
<td>07/15/2020</td>
</tr>
<tr>
<td><strong>Objective:</strong></td>
<td>The objective of this research is to develop image processing algorithms to automatically extract vehicle counts and classifications, as well as counts of motorcycles, bicycles, and pedestrians from real-time and offline videos. An easy-to-use graphical user interface will enable SCDOT staff to obtain multimodal traffic data accurately, safely, and cost-effectively to use for HPMS reporting and prioritize infrastructure design improvements and investments.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPR 743</th>
<th>Pavement Performance Curves - Modeling Pavement Deterioration for SCDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization:</strong></td>
<td>University of South Carolina</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Dr. Nathan Huynh</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>03/01/2019</td>
</tr>
<tr>
<td><strong>Completion Date:</strong></td>
<td>02/28/2022</td>
</tr>
<tr>
<td><strong>Objective:</strong></td>
<td>The objective of this research is to identify changes in service life resulting from time, vehicular, and environmental wear on asphalt and concrete pavements. The goal of this project is to provide updated performance curves to model future conditions by studying new construction, existing pavements, and treatment types currently employed by SCDOT for preservation and/or rehabilitation.</td>
</tr>
<tr>
<td>SPR 744</td>
<td>SCDOT Preconstruction Program Management Manual &amp; Updated Project Development Process</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Organization:</strong></td>
<td>Clemson University</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Dr. Dennis Bausman</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>03/01/2019</td>
</tr>
<tr>
<td><strong>Completion Date:</strong></td>
<td>02/28/2021</td>
</tr>
<tr>
<td><strong>Objective:</strong></td>
<td>The objective of this research is to improve project delivery by streamlining activities, promoting consistent action, and maximizing the efficiency of SCDOT staff. Further, the project will strive to update and standardize the project development process to assist in the identification of critical tasks, provide clear identification of the initiation responsibilities, and establish detailed expectations for tasks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPR 745</th>
<th>Update to SCENARIO_PC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organization:</strong></td>
<td>Clemson University</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Dr. Ronald Andrus</td>
</tr>
<tr>
<td><strong>Start Date:</strong></td>
<td>03/03/2019</td>
</tr>
<tr>
<td><strong>Completion Date:</strong></td>
<td>03/03/2024</td>
</tr>
<tr>
<td><strong>Objective:</strong></td>
<td>SCENARIO_PC (2006) is used to develop SCDOT current acceleration design response spectra and to develop time histories for use in site-specific response analysis. The objective of this research is to update this program to use Next Generation Attenuation (NGA) models which include models developed by the USGS for the Eastern United States. This research will add capabilities for users to incorporate existing databases for factual time histories and will address existing program issues.</td>
</tr>
</tbody>
</table>
Summaries of SPR Studies Completed in FFY 2019
This research evaluated turbidity and surface water withdrawal associated with SCDOT construction site stormwater discharge. Experimentation with and without the use of polymer flocculants (PAM) determined effluent values for TSS and turbidity from SCDOT BMPs and evaluated effectiveness of surface water withdrawal systems and baffle configurations deployed within sediment basins. Results indicate PAM applied directly to ditch checks can significantly improve the water quality of site discharge. Results also showed greater than 80% reduction in turbidity and TSS could be achieved with skimmers or through a combination of skimmer and baffle arrangements. With addition of PAM, turbidity and TSS reductions could be greater than 90%.

Problem:
U.S. Environmental Protection Agency originally published effluent limitations guidelines (ELGs) to control discharge of pollutants from construction sites. Though the decision has been put on hold, ELGs may ultimately require numeric turbidity limits for active construction in South Carolina. For SCDOT to be capable of complying with potential numeric turbidity standards, assessment of current best management practices and development of potential new BMPs would be necessary. To meet this potential standard, research was conducted to measure and evaluate turbidity in stormwater discharges from SCDOT construction sites and in controlled experimental field testing of current SCDOT specified sediment control BMPs. The research also studied other passive treatment BMPs such as polymers and chemical flocculants.
Research:
This research evaluated turbidity and total suspended solids (TSS) in stormwater discharges from SCDOT construction sites employing various linear BMPs. Selected sites from the different regions of the state were used to quantify BMP performance with different South Carolina soil types. Evaluation of these on-site BMPs involved testing with and without the addition of flocculants. Both turbidity and TSS measurements were taken during storm events to quantify effects that different BMPs have on improving water quality. Research then evaluated similar BMPs under controlled experiments to assess performance with and without polymer flocculants under different application techniques and time intervals. Research also evaluated the effectiveness of surface water withdrawal systems (skimmers) and baffle configurations deployed within sediment basins using a SCDOT scaled-model sediment basin. Experiments consisted of generating an inflow sediment load that was conveyed across the installed BMPs. Turbidity and TSS was measured to determine removal efficiencies of various BMP configurations.

Finally, a series of laboratory bioassays was conducted to evaluate acute and chronic toxicological effects resulting from exposure to commercially available PAM formulae.

Two key findings of this research were:

1. The use of PAM on construction sites can significantly reduce TSS and turbidity in stormwater discharges.
2. Proper maintenance and regular inspections must be a priority to reduce both TSS and turbidity on active sites.

Results:
Research on SCDOT linear best management practices analyzed reducing turbidity and TSS using sediment tubes, rock ditch checks and rock ditch checks with washed #57 stone on the upstream face at three active roadway construction sites in the upstate, midlands, and coastal regions of South Carolina. In addition, data were collected from these BMP installations with and without a granular PAM application.

It was observed that both rock ditch checks and rock ditch checks with washed stone using PAM were most effective in reducing turbidity showing an average decrease of 58-63%. It was also observed from field sites where proper installation and/or maintenance of BMPs did not occur, increases in both TSS and turbidity was possible.

Results from the experimental linear BMP study showed that granular PAM applied directly to sediment tubes provided better reductions in turbidity and TSS than PAM delivered through other measures. Results also showed that reapplication of PAM will be required over the course of construction.

Results from the scaled basin study suggest that with skimmer alone or skimmer and baffle combination, greater than an 80% reduction in turbidity and TSS could be achieved. With addition of PAM, reductions...
could exceed 90%. Turbidity effluent levels ranged between 6-160 NTUs when PAM was used. A final basin study element compared single baffle and three-baffle configurations. For these tests, PAM was applied within the basin as a flocculant. While there was a difference between single and three baffles, both configurations resulted in reductions greater than 90%. For TSS, no difference between single baffle and three baffles was found. TSS reductions for both configurations were greater than 95%.

Results from the laboratory bioassays conducted to evaluate acute and chronic toxicological effects resulting from exposure to commercially available PAM formulae showed that toxicities reported were all above dosage recommendations made by the manufacturers.

**Value & Benefit:**

Results of this research have provided better understanding of turbidity and TSS effluent levels being discharged from various linear BMPs. Findings have also led to a revised supplemental technical specification for porous baffles (SCDOT Designation: SC-M-815-16) and development of a new supplemental technical specification for polymer coagulants/flocculants for sediment control. To accompany the new polymer coagulant/flocculants spec, a qualified products policy (QPP) for polymer use has also been established. These two specifications and new QPP will allow for improved performance of sediment BMPs on active construction sites.

*This research also confirms that proper BMP installation, maintenance and regular inspections must be a priority to effectively reducing TSS and turbidity. Infrequent maintenance often corresponded to higher turbidity and TSS levels and thus lower observed trapping efficiencies.*

The Principal Investigator acknowledges the work of Co-Principal Investigator Calvin Sawyer; Master of Science students Ethan Barnette, Tripp Berry, Jacob Burkey, and Daniel Dixon; Doctoral student Dan David; Research Associate Jeremy Pike; SCDOT Engineers Jackie Williams and Ray Vaughan (Ret.); and Advisor JP Johns.
The goal of most safety-related researches is to reduce the number and severity of crashes on the roadways. This research aids in accomplishing this goal by providing knowledge and data to undertake better decision making on safety in improvements through the methods of the Highway Safety Manual (HSM). The objectives for this research were threefold: 1) provide calibration factors for each safety performance function (SPF) in the HSM predictive models to account for jurisdictional variations such as crash reporting, driver populations, topography, and climate; 2) provide crash distributions specific to South Carolina to increase the reliability of predictive models; and 3) develop state-specific safety performance functions and test against calibrated HSM models.

Most the work associated with this research involved collection and compilation of all the various data necessary to calibrate each of the 18 SPFs in the HSM and basic freeway segments. While some of these data variables could be found in the SCDOT Roadway Inventory Management System (RIMS), others had to be obtained from other sources, such as aerial LiDAR and Google Street View. Calibration factors were developed for three distinct areas within the state - coastal areas, midlands, and the upstate, as well as dense and sparsely populated counties. Each of these areas has different terrain, weather patterns, and traffic patterns and these variations were expected to produce varying calibration factors. While some calibration factors were significantly different across areas of the state, others were not, and a single statewide calibration factor was recommended for use.
In this project, 2,700 roadway segments (684 miles) and 6,824 intersections were selected for data collection. The vast number of samples and comprehensive data also allowed the team to develop state-specific safety performance functions. The models themselves are limited in predictive capability at the site level because they have few significant variables - AADT being among significance in all models. Also, the models predict only total crashes and not crashes by severity level. However, these models and their limited variables allow them to provide a valued function as networking screening models.

The products resulting from this research will allow the SCDOT safety office to confidently use the HSM with expectations that the resulting predictions are going to be a fair estimate of the effects of safety improvements in different areas of South Carolina. While better data will always produce better results, the calibration factors, safety performance functions and crash distributions provided herein are derived from the best possible data from South Carolina and currently represent the best opportunity for improving safety decisions.


<table>
<thead>
<tr>
<th>Type</th>
<th>Sample Size</th>
<th>Total Length</th>
<th>Average AADT Major</th>
<th>Average AADT Minor</th>
<th>Total Observed Crashes</th>
<th>Total Predicted Crashes</th>
<th>Calibration Factor</th>
<th>Calibration Factor C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2U</td>
<td>1,841</td>
<td>1,117.73</td>
<td>753</td>
<td>--</td>
<td>447</td>
<td>451</td>
<td>0.99</td>
<td>5.10%</td>
</tr>
<tr>
<td>R4D</td>
<td>508</td>
<td>161.16</td>
<td>9,934</td>
<td>--</td>
<td>253</td>
<td>413</td>
<td>0.61</td>
<td>8.17%</td>
</tr>
<tr>
<td>R4U</td>
<td>484</td>
<td>126.25</td>
<td>3,921</td>
<td>--</td>
<td>58</td>
<td>189</td>
<td>0.31</td>
<td>14.24%</td>
</tr>
<tr>
<td>U2U</td>
<td>667</td>
<td>201.65</td>
<td>2,109</td>
<td>--</td>
<td>261</td>
<td>157</td>
<td>1.66</td>
<td>7.95%</td>
</tr>
<tr>
<td>U4U</td>
<td>536</td>
<td>201.65</td>
<td>2,109</td>
<td>--</td>
<td>275</td>
<td>367</td>
<td>0.75</td>
<td>8.70%</td>
</tr>
<tr>
<td>U4D</td>
<td>352</td>
<td>85.02</td>
<td>19,172</td>
<td>--</td>
<td>321</td>
<td>387</td>
<td>0.83</td>
<td>6.87%</td>
</tr>
<tr>
<td>U5T</td>
<td>673</td>
<td>155.59</td>
<td>16,059</td>
<td>--</td>
<td>1,035</td>
<td>1,348</td>
<td>0.77</td>
<td>5.15%</td>
</tr>
<tr>
<td>R3ST</td>
<td>7,000</td>
<td>--</td>
<td>892</td>
<td>205</td>
<td>907</td>
<td>2,253</td>
<td>0.40</td>
<td>3.98%</td>
</tr>
<tr>
<td>R4ST</td>
<td>2,785</td>
<td>--</td>
<td>995</td>
<td>233</td>
<td>787</td>
<td>1,660</td>
<td>0.47</td>
<td>4.97%</td>
</tr>
<tr>
<td>R4SG</td>
<td>97</td>
<td>--</td>
<td>1,014</td>
<td>1,497</td>
<td>131</td>
<td>287</td>
<td>0.46</td>
<td>11.76%</td>
</tr>
<tr>
<td>RM3ST</td>
<td>613</td>
<td>--</td>
<td>8,061</td>
<td>357</td>
<td>261</td>
<td>471</td>
<td>0.55</td>
<td>10.91%</td>
</tr>
<tr>
<td>RM4ST</td>
<td>284</td>
<td>--</td>
<td>6,438</td>
<td>271</td>
<td>63</td>
<td>244</td>
<td>0.26</td>
<td>17.52%</td>
</tr>
<tr>
<td>RM4SG</td>
<td>80</td>
<td>--</td>
<td>1,161</td>
<td>1,375</td>
<td>272</td>
<td>682</td>
<td>0.40</td>
<td>9.42%</td>
</tr>
<tr>
<td>U3ST</td>
<td>5,607</td>
<td>--</td>
<td>1,765</td>
<td>287</td>
<td>2,136</td>
<td>1,782</td>
<td>1.20</td>
<td>3.92%</td>
</tr>
<tr>
<td>U4ST</td>
<td>2,992</td>
<td>--</td>
<td>1,702</td>
<td>234</td>
<td>1,650</td>
<td>1,719</td>
<td>0.96</td>
<td>5.00%</td>
</tr>
<tr>
<td>U3SG</td>
<td>299</td>
<td>--</td>
<td>16,181</td>
<td>3,170</td>
<td>1,255</td>
<td>629</td>
<td>2.00</td>
<td>5.05%</td>
</tr>
<tr>
<td>U4SG</td>
<td>538</td>
<td>--</td>
<td>12,870</td>
<td>2,725</td>
<td>3,334</td>
<td>1,362</td>
<td>2.45</td>
<td>4.52%</td>
</tr>
<tr>
<td>R4F</td>
<td>138</td>
<td>59.38</td>
<td>35,055</td>
<td>--</td>
<td>785</td>
<td>2,59</td>
<td>5.77%</td>
<td></td>
</tr>
<tr>
<td>U4F</td>
<td>105</td>
<td>36.34</td>
<td>49,218</td>
<td>--</td>
<td>902</td>
<td>2.69</td>
<td>6.82%</td>
<td></td>
</tr>
<tr>
<td>U6F</td>
<td>126</td>
<td>38.33</td>
<td>73,592</td>
<td>--</td>
<td>1,972</td>
<td>3.66</td>
<td>5.22%</td>
<td></td>
</tr>
</tbody>
</table>

*Note that the sample size provided in the above table represent the number of observations in the analysis which is the multiplication of location of sites and years of crash data. Basically, the number of locations for each year is the above sample size divided by 3 years of crash data.

The Principal Investigator acknowledges significant contributions to the project by Mahdi Rajabi, Ph.D. In addition, this project would not have been possible without the countless hours of tedious computer-based data collection undertaken by a number of graduate and undergraduate students, including: Hind Ali, Sababa Islam, Nancy Chhetri, Bryanna Saunders, Nabarjun Vashisth, Ashley Springs, Colen Johnson, Yucheng An, Jonathan Cranston, Adika Mammadrahimli, Vijay Bendigiei, and Chi Zhang (Visiting Scholar).
The U.S. Geological Survey (USGS) developed the South Carolina StreamStats application in cooperation with the South Carolina Department of Transportation. StreamStats ([https://water.usgs.gov/osw/streamstats/](https://water.usgs.gov/osw/streamstats/)) is a map-based web application that provides analytical tools useful for water-resources planning and management and many engineering purposes (Ries and others, 2017). The web application delineates drainage areas at user-selected sites on South Carolina streams, generates basin characteristics, and, where appropriate, estimates peak-flow statistics for the selected sites. StreamStats users also can obtain published flow statistics for USGS streamgages, such as peak flow, low flow, and daily mean flow durations.

**Use of Lidar**

From 2007 to 2013, light detection and ranging (lidar) data were collected by fixed-wing aircraft for each county in South Carolina, resulting in base elevation and derived hydrography datasets (South Carolina Department of Natural Resources, 2012) that provide the best elevation and streamflow data available for the South Carolina StreamStats application. Lidar is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth (National Oceanic and Atmospheric Administration, 2018). These light pulses provide precise, three-dimensional locational and elevation data (x,y,z coordinates), which can be used to determine the shape and surface characteristics of the Earth. North and South Carolina are the first States to have statewide lidar-derived elevation data in the StreamStats application. In addition, the South Carolina StreamStats application uses lidar-derived streamlines, which are at the same scale as the elevation data, to ensure spatial alignment of the data.

**Data Processing**

The bulk of the project tasks encompassed processing the lidar-derived elevation and streamline data by using a geographic information system (GIS). Processing began with preexisting terrain datasets available from the South Carolina Department of Natural Resources. The terrain datasets were created from the bare-earth elevation measurements from lidar point cloud data and a streamline data layer that was horizontally and vertically integrated with the lidar point cloud data. Digital elevation models (DEMs) were derived from the terrain datasets as 30-foot resolution raster grids. Some of the original data were found to have an incorrect vertical datum. To ensure proper basin delineation and spatial accuracy, the incorrect datum was corrected by applying a shift. The DEMs were further processed by “burning” streamlines into the elevation surface and filling sinks or depressions to programmatically

![Figure 1. Examples of (A) National Hydrography Dataset streamlines and (B) light detection and ranging (lidar)-derived flow accumulation streamlines. The difference in area between the lidar-derived and Watershed Boundary Dataset hydrologic units shown is approximately 10 square miles.](https://water.usgs.gov/osw/streamstats/)
force water downhill. Burning essentially forces the DEMs to match the locations of the streams and removes any objects (for example, bridges) at the points where streams pass through. The result of this process was the creation of flow direction and flow accumulation rasters with increased accuracy for the delineation of basins (fig. 1).

Streamline data were derived from the lidar data by using intensity images and photogrammetry. The streamline data were used in the DEM processing to ensure that the flow direction and flow accumulation rasters matched the streamlines. Although the streamlines are highly accurate, they could be derived by automation only where there was standing water. Therefore, in some areas, the dataset is not as complete as the National Hydrography Dataset (NHD), and in other areas, it is far denser (fig. 2).

Additionally, new hydrologic unit code (HUC) boundaries at the 8-digit level were generated on the basis of the lidar data derivatives. The lidar-based HUCs were used instead of 8-digit Watershed Boundary Dataset (WBD) HUCs because the elevation and streamlines produced from the lidar derivatives are more accurate (fig. 1B). When funding allows, the lidar-based HUCs will be incorporated in a future update of the WBD.

**Application Functionality**

Functionality in the current (2018) South Carolina Stream-Stats application includes the following:

- View an interactive map with a choice of base-map layers such as topography, political boundaries, roads, and aerial imagery (fig. 3).
- Zoom in or out to areas of interest by (1) searching for a place of interest (for example, USGS station identification number, zip code, or address), (2) choosing latitude and longitude coordinates, or (3) manually panning and setting the zoom level on a target. Click “Help” under the search box for additional search strings (fig. 3).
- Access published peak-flow frequency and other streamflow statistics, basin characteristics, and the USGS National Water Information System (NWIS) (fig. 4).
- Delineate and edit the watershed boundary for a user-selected site on any stream (fig. 5).
- Compute basin characteristics, such as drainage area, percentage of impervious area, mean basin elevation, and mean annual precipitation, for a user-selected site along a stream and output results to a table and Portable Document Format file (fig. 6).
- Estimate rural and urban peak-flow frequency statistics at ungaged locations (Feaster and others, 2009, 2014) (fig. 7).
- Download the watershed boundary and basin characteristics as a geographic-oriented JavaScript Object Notation (GeoJSON) file, shapefile, or Environmental Systems Research Institute, Inc. (Esri) file geodatabase for use in a GIS.
- Obtain an elevation profile by clicking on two or more points.
• View additional South Carolina-specific layers, including bridge locations used in various scour reports and indirect flood-measurement locations

**Streamflow Statistics for Ungaged Sites**

The South Carolina StreamStats application ([https://water.usgs.gov/osw/streamstats/](https://water.usgs.gov/osw/streamstats/)) can be used to estimate peak flows for the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent annual exceedance probability (AEP) flows at rural and urban ungaged, unregulated (at high flows), and nontidal stream locations in South Carolina (Feaster and others, 2009, 2014). The AEP flows have traditionally been known as the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence interval flows, respectively. The AEP conveys the probability, or odds, that a flood of a given magnitude will be equaled or exceeded in any given year. For example, a 1-percent AEP (traditionally known as the “100-year flood”) corresponds to a flood that has a probability of 0.01 (or a 1-percent chance) of being equaled or exceeded in any given year.

StreamStats generates the AEP peak-flow estimates using regional regression equations developed by the USGS. The regional regression equations are functions of basin characteristics such as drainage area, percentage of the drainage area in each defined hydrologic region, and percentage of impervious area. Obtaining the basin characteristics and generating the peak-flow statistics for ungaged locations in South Carolina is accomplished by using the following steps:

1. **Identify Study Area**—The study area can be located by entering the decimal latitude and longitude of the location, searching for a desired location, or by zooming to the location and selecting South Carolina as the study area in the sidebar.

2. **Delineate Basin**—After clicking on a stream (visible when zoomed in to at least 1:24,000 scale), the delineated basin will appear in the yellow on the map (fig. 5).

3. **Select Scenarios**—The application can compute all available basic characteristics, a selected subset, or only the characteristics needed for regional regression equations (fig. 6). Peak-flow statistics will then be estimated by using the computed basic characteristics (fig. 7).

4. **Build a Report**—After the basic characteristics and peak-flow statistics have been computed, StreamStats produces a report with a map of the delineated basin and the site’s summary statistics (figs. 4-7).

Other methods used to determine basin area and characteristics could take days of work, whereas StreamStats completes the process in minutes.
StreamStats provides estimates of streamflow statistics at USGS streamgages obtained from published reports along with tools to estimate peak-flow statistics at ungaged locations. Users should be familiar with the assumptions and data used to develop these estimates, which are detailed in the citations provided for the various estimates.

Estimates of the peak-flow statistics at ungaged locations are based on regional regression equations documented in Feaster and others (2009, 2014). The methods used for those estimates are not appropriate for sites where the peak-flow magnitudes are substantially affected by regulation from impoundments, channelization, levees, or other manmade structures. The methods also do not apply where flooding is substantially influenced by extreme ocean storm surge or tidal events.
The regional regression equations used in StreamStats were developed using a specific range of basin characteristics, as documented by Feaster and others (2009, 2014). If StreamStats is used to obtain streamflow statistics for locations with basin characteristics outside of the specified ranges, StreamStats will warn the user that extrapolation has occurred. In such cases, the user should be aware that the uncertainty in those estimates is unknown and should not assume that the streamflow statistics are accurate.

**Exploration Tools**

The Exploration Tools menu (fig. 8) provides several useful tools. The Measure tool computes the distance between two user-selected points. The Elevation Profile tool produces a plot of the elevation profile between selected points on the map and generates a table of latitude, longitude, elevation, and distance at various locations across the profile. The Flow Path tool allows the user to select any point on the map and traces the path that a raindrop falling at that location would take to enter a stream and reach the outlet at the Atlantic Ocean. The Network Path tool traces the flow paths from two user-selected points until a common streamline is found. If no common streamline is found, the tool traces both paths until the network ends. The Network Trace tool allows a user to trace upstream or downstream from a selected point to find network-linked data such as streamgages or flowlines.

**Future Work**

Future additions to the South Carolina StreamStats application could include an upstream regulation identification tool, water-use withdrawal and discharge locations, dam locations, and unit hydrograph and rational methods for additional statistics. Other basin characteristics such as percentage of agriculture land use and basin population density also could be developed and added to the application. These and other improvements can increase efficiency by providing more functionality, placing the necessary information in the hands of users, and streamlining hydrology-related tasks. A complete list of current (2018) basin characteristic possibilities is available at https://streamstatsags.cr.usgs.gov/ss_defs/basin_char_defs.aspx (U.S. Geological Survey, 2017). Users interested in additional functionality, basin characteristics, or data layers can contact the USGS to discuss potential solutions.

**References Cited**


For further information, please contact:

Director, South Atlantic Water Science Center
U.S. Geological Survey
720 Gracern Road, Suite 129
Columbia, SC 29210
(803) 750-6100
https://www.usgs.gov/centers/sa-water

The MAP-21/FAST Act requires state departments of transportation to transition to data driven, performance and outcome-based programming, which has required states across the nation to revisit their data collection and maintenance efforts. This report documents research conducted to ensure that the future SCDOT database specifications and data collection efforts support federal requirements for data-driven performance-based management of transportation facilities, as well as meet the needs of SCDOT in a cost-effective manner.

The SCDOT GIS/Mapping online portal has an ARNOLD compliant basemap and a single uniform LRS that is accepted as a statewide standard

Problem

A large portion of South Carolina Department of Transportation's (SCDOT) current data is stored in the Roadway Information Management System (RIMS). SCDOT, like most states, originally developed their RIMS system to support reporting requirements for the Federal Highway Administration's Highway Performance Monitoring System (HPMS) program. Thus, the individual elements contained in the database do not always meet the needs of alternate users in other departments within the DOT. Over time, other datasets have been merged with RIMS to enable expanded data analytic capabilities including crash information, video log, and traffic counts. In addition to RIMS, SCDOT maintains several databases to support specific business operations such as maintenance (signs and roadside hardware) and traffic operations (signals and ITS equipment). The overarching goal of this research is to ensure that
the future SCDOT database specifications and data collection efforts support the MAP-21 requirements for data-driven performance-based management of transportation facilities, as well as meet the needs of SCDOT in a cost-effective manner. To achieve this goal, three specific objectives were established:

- **Obj 1** – Identify SCDOT state of practice for asset data collection/maintenance.
- **Obj 2** – Conduct vendor assessment of MLS to seek accuracy and efficiency.
- **Obj 3** – Provide recommendations for database development and related data collection methods/technologies.

**Research**

The review of critical and non-critical data elements from the FHWA Model Inventory of Roadway Elements (MIRE) and SCDOT databases revealed that about 60% (122 of 202) of MIRE data elements were not collected by SCDOT (i.e., gaps). This included a few MIRE Fundamental Data Elements (FDEs), mandated Highway Performance Monitoring System (HPMS) Full Extent Elements (FE), and a considerable number of Highway Safety Manual elements needed for use with SC-specific safety models. Several gaps were identified and listed below:

- SCDOT lacks more than 50% of the database elements required for HSM safety implementation on state roadways. These data elements contain information on Segment Cross Section, Segment Roadside Description, At Grade Intersection/Junctions, and Approach Descriptors (Each Approach).
- The SCDOT databases have about 88% of the MIRE FDE data elements (excluding HOV because there were none in SC).
- MIRE Fundamental Data Elements follow HPMS reporting requirements closely. Unfortunately, the HPMS coverage is biased toward the higher functional classes and only sampled for lower classes. This leaves several gaps for lower functional class roadways.
- Data gaps for primary elements include MIRE and HSM variables related to traffic control, horizontal and vertical alignment. Ramps, ramp volumes, and intersection configuration were the most critical gaps in secondary elements.
- An assessment of Mobile LiDAR System vendors and literature indicate that 70% of the SCDOT gaps in first priority data elements can be collected using LiDAR technology.

**Recommendations**

Three main recommendations include:

1. Raise the level of importance of data – treat it as an asset, define core principles, and develop a department-wide directive that recognizes the strategic uses of data across all business offices;
2. Implement a tiered approach to data governance, appoint a dedicated data governance coordinator, and promote structured decision-making and active oversight of the Department’s data assets; and
3. Undertake a new inventory of roadway attributes using mobile LiDAR technology to replace the data inventoried 30 years ago and develop enterprise-wide plans to capitalize on additional opportunities for MLS point cloud data.
Value & Benefit

This study evaluated data needs within the department and developed recommended data specifications for a state-of-the-art enterprise data system to support the business SCDOT functions as well as meet requirements of federal reporting mandates. The analysis reported here will aid SCDOT in implementation of an asset data system that meets the department’s needs without redundancies and maintaining only data elements that have positive cost-benefit for the department. Having a comprehensive roadway inventory with supporting business data will allow the SCDOT to make better decisions faster, and this should translate to improved effectiveness.

The Principal Investigator would like to thank the Co-PIs for their contributions: Wayne Sarasua, Mashrur ‘Ronnie’ Chowdhury, and Brad Putman of Clemson University; Jeffrey Davis of The Citadel; and Nathan Huyhan and Paul Ziehl of the University of South Carolina. In addition to the Steering and Implementation Committee, the research team would like to thank Meredith Heaps and Terry Swygert for their efforts in research oversight and report reviews. The authors would like to acknowledge the efforts of several students and the countless hours of sifting through data, analyzing LiDAR data, and developing analysis databases: Mahdi Rajabi, Hind Ali, Sababa Islam, Nancy Chhetri, Adika Mammadrahimli, and Fengjiao Zou.
Annual Average Daily Traffic (AADT) is defined as the average daily measure of the total volume of vehicles on a roadway segment over a year divided by 365 days. AADT is one of the most important traffic measures used in many transportation engineering projects (e.g., roadway design, transportation planning, traffic safety analysis). In many cases, yearly traffic volume can be directly counted each day with Automatic Traffic Recorders (ATR) along the roads. However, installing and maintaining ATRs along every road is prohibitively expensive because of the number of roads, and the cost to install and maintain the ATRs. To compensate for this reality, AADT is often estimated based on the short-term counts on an as-needed basis. Since this input is needed for most transportation engineering projects, the accuracy of AADT estimation using short-term counts is critical for any transportation study that uses AADT as an input parameter.

To identify accurate and cost-saving methods for estimating AADT, the research team began with a review of federal legislation in terms of data collection requirements. This included different state traffic monitoring program manuals as well as legislative documents themselves, including HPMS, SHSP, MAP-21, and the FAST Act. It was determined that the South Carolina Department of Transportation (SCDOT) meets all federal requirements. As part of the review of common practices, available technology for count collection was explored and summarized based on strengths and weaknesses. While mature and established technologies such as pneumatic tubes continue to hold value, new technology such as LIDAR, Probe Vehicles, Crowdsourcing and Unmanned Aerial Vehicles (UAV) have emerged as promising prospects for use in future data collection.

Next, a national survey was developed and distributed to state DOTs in the United States, as well as the governing bodies in Canadian Provinces. This survey sought to understand the AADT data collection procedures of other states, as well as challenges faced and opportunities for improvement. This survey identified some trends in the responses. Namely, that the primary use for the data was reporting to the federal government, but the data are also used in traffic safety studies and for pavement management. Many states indicated a desire to work with local agencies to conduct these counts, as well as improving communication with these agencies to collect accurate and well-coordinated data. A second survey was distributed to cities and counties within South Carolina. This survey collected information on how cities and counties use the AADT data provided by SCDOT, as well as needs the cities and counties have, and the challenges they have. From this information, the researchers determined recommendations for improving the data collection plan in South Carolina. While ten of the responding cities and counties were satisfied with the data provided by SCDOT in the past, fifteen cities and counties indicated that more timely and accurate data would be beneficial in the future. Seven city and county agencies indicated challenges with performing short-term counts, with the primary concerns being lack of staff and vandalism or accidental destruction of short-term count equipment.

Lastly, the research team developed three separate models for estimating AADT. The first, based on the Origin-Destination Centrality Method, estimated AADT using deterministic variables based on the theory of centrality. It was found that the number of count stations can be reduced by 60% without
compromising accuracy. Although the result was positive in this case study, the assumptions made in the input parameters may not be applicable at all sites, thus producing an inaccurate estimation of AADT.

The next model developed was based on regression. Based on certain roadway characteristics like functional class, setting, and socioeconomic variables such as mean income, age, poverty level, number of vehicles and other inputs, regression models were used to determine which of the factors affect AADT. The last model developed was based on Machine Learning (ML). Two methods were used to determine which performed the best, the Artificial Neural Network (ANN) and the Support Vector Regression (SVR) methods. A case study was conducted based on a complete year of data from 2011, with 2016 data used for model validation. Evaluating both models, it was found that the SVR method outperformed the ANN method when compared to the ground truth AADT data from the ATRs. For each functional class, the SVR model performs the best, with lower RMSE and MAPE values. Overall, when comparing the SVR method with the factor method, the SVR method has an average percent error of 3% while the Factor method has an average percent error of 6%.

Pilot testing to evaluate the regression and ML models were conducted with new data that were not used previously for model calibration. Overall, the SVR based machine learning model performed the best, compared to the Artificial Neural Network (ANN) or the Ordinary Least Squares (OLS) linear regression model. As such, a software, estimAADTion, was developed, based on the SVR method for use by SCDOT. This software functions using 24-hour counts, rather than the typical 48-hour counts conducted by SCDOT. This will allow the reallocation of temporal and fiscal resources as seen fit by SCDOT.

Future opportunities for improvement of AADT data collection by SCDOT includes annual ATR counts at each location and improved delivery of data to cities and counties within South Carolina. In addition, an improved scheme for the vehicle classification tree was developed as part of this project. Utilization of this improved scheme will allow for more accurate classification of pickup trucks and buses. Next, in the event of an evacuation, the method used by the Delaware DOT can be used in conjunction with the South Carolina formula to estimate the number of occupants per evacuating vehicle. This method considers census data, GIS data, and percent occupancy of seasonal units along the coast which will likely result in a more accurate occupancy estimation. Finally, in terms of estimating ADDT, based on the results of the pilot study of each of the models developed, the SVR-based machine learning model will allow for cost-effective and accurate estimation of AADT. As such, it is recommended to use the estimAADTion software, developed for this project. Each of these opportunities identified will strengthen the South Carolina data collection plan in future years.

The study was conducted by Clemson University under the guidance of Dr. Mashur “Ronnie” Chowdhury and Dr. Nathan Huynh, University of South Carolina.
Better Construction Project Management Through Better Scheduling

**Organization:** University of South Carolina  
**PI:** Robert L. Mullen & Nathan Huynh  
**Report No.:** FHWA-SC-18-03  
**Date:** December 2018

This project investigated the relationship between project scheduling and project delivery. Specifically, the project sought to 1) determine the best practices of using Critical Path Method (CPM) for project management, 2) determine whether a South Carolina Department of Transportation (SCDOT) project is delivered on time when Critical Path Method (CPM) is used, and 3) identify the factors that influence project delay.

**Research**

In this project, descriptive and statistical analyses were conducted on data joined from two databases: SiteManager® and Primavera®. The dataset consists of 2,097 projects let after February 2007 and substantially completed by August 2015.

In addition, an online survey was conducted to determine state-of-the-practice on CPM scheduling by states department of transportation (DOTs), resident construction engineers, and contractors.

Chi-square tests were conducted to evaluate the strength of any association between scheduled/unscheduled projects and delay/no-delay. Also, t-tests were conducted to determine if there were statistically significant differences in delay (number of days) between scheduled and unscheduled projects. These statistical tests were performed for each project type, size, duration, and location.

Logistic regression models, probability density functions, text analytics, and neural network models were developed to predict project delay.

**Results**

Responses from 23 state DOTs and 51 Resident Construction Engineers (RCE) and 45 contractors from 16 different states were received. Nearly 96% of the state DOTs use CPM for project management. 55% of the RCE indicated that the time between notice-to-proceed and first work date consumes a significant portion of the total duration and 60% of the RCEs believe that CPM does not reduce change orders. About 75% of contractors keep separate schedules than the ones provided to the RCEs. Table 1 presents descriptive statistics of the provided dataset. Having a CPM schedule provided by the contractor did not result in a statistically significant reduction in the number of delayed projects or the average length of the delay. The contract bid amount was found to be statistically significant in explaining project delay.

Text analytics of daily work reports did not provide useful predictions of project delay. The neural network model correctly predicted a project will be delayed 54% of the time.
Probability distributions were determined for project delay. The best fit distribution for delayed projects was found to be the Pearson 6 (4 Parameter), and the best fit distribution for the early completion projects was found to be the Johnson SB. Using these distributions and the Total Law of Probability, one can estimate the probability of a project being delayed. For example, it was found that the probability that the duration of a SCDOT project being extended beyond the average delay (36.57% past the original duration) is 0.24; in other words, approximately 1 in 4 SCDOT projects will be delayed longer than the average delay.

**Recommendations**

The current selection criteria for requiring a CPM schedule be provided to the SCDOT depends upon design field review or estimates. The level of scheduling effort should be tied to the risk of managing delay for a project as well as the impact of that delay to SCDOT stakeholders. Other state DOTs have implemented a more detailed procedure in their selection. For example, Virginia DOT uses five levels of scheduling that depend on certain risk parameters (complexity, constraints, uncertainty and delay consequence). Additionally, the SCDOT could implement scheduling criteria based on a combination of project bid amount and project duration. Some state DOTs have already implemented this procedure (e.g., Caltrans).

The SCDOT should consider incorporating probabilistic information about project delay into the schedules, such as providing a range for the activity duration in the CPM schedule instead of simply using the expected duration. Lastly, it is recommended that the SCDOT consider including a provision in future contracts to ensure that all personnel (SCDOT and contractors) are using the same schedule for project management.
Degradation of concrete bridge decks is an ongoing challenge facing the South Carolina Department of Transportation (SCDOT). Different methods for concrete bridge deck evaluation are utilized by SCDOT including visual inspection and chain dragging. The current methods for concrete bridge deck evaluation are effective, but they require traffic control and many operators. To address these limitations, this project investigates rapid evaluation methods including vehicle mounted scanning (utilizing ground penetrating radar, infrared sensing, and high definition video scanning), pole mounted scanning (utilizing ultra-time domain infrared sensing), and deck acoustic response to identify which method, or combination of methods, is well suited for the evaluation of concrete bridge decks in South Carolina. Among the methods, deck acoustic response was found to be the most suitable for detection of delamination, with infrared and ultra-time domain imaging also providing good results. Ground penetrating radar was less effective for detection of delamination but showed promise for detection of chlorides and moisture intrusion. Benefit-cost analysis was performed to better understand the potential for implementation.

Problem
The deterioration of concrete bridge decks presents a maintenance challenge for most transportation agencies and bridge owners. When a bridge deck exhibits a significant percentage of degraded area decisions must be made regarding approaches for repair. Potential methods include patching, hydro-blasting with subsequent partial depth overlay, and replacement of the deck. To aid in decision making, different methods for bridge deck evaluation have been employed by the SCDOT including visual inspection, chain dragging, and chloride sampling. While these methods are informative, they have the drawback of requiring traffic control, thereby increasing the cost of the evaluation and decreasing safety of workers during the evaluation.
Research

This project is motivated by a desire to identify a bridge deck evaluation method (or combination of methods) that would provide useful information and is similarly effective in comparison to current methods used by SCDOT while not requiring traffic control. Many approaches to this issue have recently become commercially available and others are under development. These approaches vary in terms of traffic control requirements, cost, and fidelity of the results. Among the different approaches are a) vehicle mounted scanning (commonly utilizing ground penetrating radar, infrared sensing, and high definition video scanning); b) pole mounted scanning (utilizing ultra-time domain infrared sensing and high definition video scanning); and c) deck acoustic response enabled by a trailed device (utilizing trailed impactors in combination with acoustic detectors).

To assess the feasibility of different evaluation methods for South Carolina bridge decks in-service decks with differing damage levels were selected to serve as testbeds. Chloride sampling, chain dragging, and coring were performed in addition to rapid evaluation methods to enable assessment of the results. Bridge deck specimens removed from a bridge in South Carolina were also investigated under an accelerated aging protocol in the laboratory. Instrumentation was added to a new bridge deck during construction to aid in assessment of conditions potentially related to early degradation. It was found that many of the rapid evaluation methods offered levels of accuracy in a similar range to existing evaluation methods. Furthermore, vehicle mounted scanning is amenable to evaluation on a widespread basis, e.g. asset management.

Results

Bridge decks with differing damage levels were investigated using rapid bridge deck evaluation methods (ground penetrating radar, conventional and ultra-time domain infrared sensing, high resolution video, and deck acoustic response) to assess the efficacy of such methods for concrete bridge decks in South Carolina. It is envisioned that such methods may be used in the future either in place of, or in addition to, traditional evaluation methods for bridge deck evaluation (coring, chloride concentration testing, and chain dragging).

The rapid evaluation methods investigated varied in terms of cost, need for traffic control, type of traffic control when needed, and interpretation of results. To address accuracy, results gathered from each of the rapid evaluation methods were compared to results gained by sampling (referred to as ‘ground truth’ comparison, in this case gained through coring and/or chloride concentration testing).

Results related to the rapid evaluation methods (vehicle mounted, pole mounted, and deck acoustic response) are as follows:

1. Deck acoustic response demonstrated the highest accuracy for detection of delamination.
2. Vehicle mounted infrared and pole mounted infrared ultra-time domain sensing demonstrated promising results for detection of delamination.
3. Contour plots attained through vehicle mounted ground penetrating radar did not correlate well with detection of delamination. However, the most extreme contours did provide reasonable correlation with delamination. Because ground penetrating radar is sensitive to moisture conditions and chlorides in the bridge deck, ground penetrating radar is thought to be sensitive to conditions causing future degradation.
In addition to the field studies, a bridge deck specimen was subjected to an accelerated corrosion environment in a laboratory setting. Results are as follows:

1. Half-cell potential results indicate that corrosion initiated after 45 days of conditioning.
2. Impact echo and ultrasonic pulse velocity were used to detect damaged area with minor wave velocity variation and evidence of damage.

To better understand the conditions that lead to degradation of bridge decks in South Carolina, instrumentation was installed in the deck of the Leaphart Bridge over I-26. Initial readings are within the expected range of behavior. It is recommended that the readings in this bridge deck be continued by SCDOT for a period of ten years.

Life cycle cost analysis indicates that most of the rapid evaluation methods investigated (vehicle mounted, pole mounted, and deck acoustic response) have similar cost when compared to chain dragging.

**Value & Benefit**

With a growing population and aging infrastructure, the SCDOT will require frequent monitoring of bridge health to ensure the continued safety of the public and to inform maintenance decision making. These goals can be met by the alternative inspection methods mentioned, which have similar cost, require less time, and yield inspection quality comparable to current methods. This study provides useful information related to promising bridge deck rapid evaluation methods to be implemented by SCDOT. The accuracy of these methods was compared to current traditional methods and specific recommendations are as follows:

1. For local evaluation, deck acoustic response (DAR) may serve as a reasonable replacement to chain dragging for detection and assessment of delamination.
2. For asset management, vehicle mounted infrared sensing proved to be the most feasible means of evaluation as traffic control is not required with this approach.

The Principal Investigator would like to thank the following for their contributions to this work: Associate Professor Dr. Nathan Huynh; Research Assistants Rafal Anay, Rawya Abduljabbar, Bhavya Padmanabhan, and Vafa Soltangharaei; Will Pointer of SCDOT; and Russell Inglett and the technical staff at the University of South Carolina Structures and Materials Laboratory.
Introduction

In an asphalt pavement, joints are considered the weakest part of the pavement as they frequently fail quicker than the surrounding pavement areas, resulting in the need for costly repairs. In particular, longitudinal joints typically tend to exhibit performance problems before the rest of the pavement structure. Improving construction practices specific to the compaction of longitudinal joints in HMA pavements could extend the life and decrease the life-cycle cost of these pavements by preventing premature failure at longitudinal joints.

The overarching goal of this study was to identify best practices for construction of longitudinal joints in asphalt pavements in South Carolina and subsequently create a best practices guide informed by the research and make recommendations for potential specification revisions.

To accomplish the objective of this study, the research involved two primary tasks:
- Survey of longitudinal joint construction practices in South Carolina and nationally.
- Field and laboratory testing to evaluate the performance of longitudinal joints.

Longitudinal Joint Evaluation

Longitudinal joints were evaluated at nine paving projects across South Carolina as part of this study. At each project, testing was conducted in the field and cores were taken for further laboratory testing. The field testing protocol included:

Joint Temperature
The temperature of the new asphalt pavement mat and the matching pavement was measured with an infrared thermometer at regular intervals to assess the temperature difference between the hot and cold lanes during construction.

In Place Density
A density gauge was used to measure the in-place density of the new pavement across the width of the pavement from the free edge to the joint.

In-Place Pavement Infiltration
A field permeameter was used to measure the pavement infiltration at the joint and the center of the new pavement lane.
Pavement Cores
Cores were cut at the joint and the center of the new pavement lane at the same locations were infiltration testing was conducted. These cores were then tested in lab to measure the density and air voids; permeability; and indirect tensile strength along the joint.

Conclusions
This study observed construction of longitudinal joints in projects in South Carolina and compared the performance of the joint and interior portion of the hot lane. Based on the density, permeability, and indirect tensile strength (ITS) results from this research, conclusions related to the performance of longitudinal joints considering individual site, surface mix type, thickness, and nominal maximum aggregate size (NMAS) were made. In addition, the effectiveness of in-place density, lab and in-place infiltration, and ITS were evaluated based on the results.

Based on the results of this study, the following conclusion were made:
• Out of the nine asphalt surfacing construction projects evaluated in this study, eight projects showed significant differences between the interior portion of the pavement and the joint based on density, permeability, and/or ITS results.
• None of the projects exhibited a statistically different in place density (gauge density) when comparing the interior of the pavement to the edge of the joint. Only one of the projects exhibited statistically different in-situ infiltration rates between the pavement interior and joint edge.
• As the density of asphalt increased, the ITS increased linearly and as the density of asphalt decreased, the lab permeability increased exponentially.
• All the field testing results had higher variability than lab testing results, indicating the field testing may not be as reliable for checking the quality of the joint.
• The density gauges were more capable of accurately measuring the density of the interior portion the lane when using the cores as a baseline, but the accuracy decreased when measuring density of the joint. This is likely due to the fact that the joint density in the field was measured next to the joint, but the cores were taken on the joint.
• The safety edge joint technique without compaction on the wedge did not significantly improve the performance of the joint compared to the butt joint technique.
• Using the Surface type A or B mix and increasing the depth of asphalt pavement, statistically improved density of the joint.
• The survey indicated that more research needs to be conducted in South Carolina to determine the effectiveness of other joint construction techniques.

Recommendations
Based on the results of this research, guidelines for best practices for longitudinal joint construction were developed. These best practices include the following categories:

Planning and Design - Practices relating to location of longitudinal joints and minimum pavement lift thickness and mix design.
Mix Design - Mix design considerations to facilitate quality joint construction.
Mix Delivery - Proper timing of material delivery to the job site and transfer to the paver.
Joint Preparation - Practices that ensure a straight and clean joint.
Tack Application - Guidance for application of tack coat to the joint to ensure proper bonding between lanes at the joint.
Paver Operation - Practices that help ensure appropriate density across the entire pavement width.
Roller Operation - Compaction practices that typically result in the highest joint density including roller type and patterns.

Quality Control - Practices to measure quality of the pavement at and near the longitudinal joint during construction.

Training - Communication and training programs for paving crews and QC personnel.

Other - Alternative practices to improve joint quality (e.g., sequential mill and fill).

Project Investigators: Bradley J. Putman, Ph.D., Associate Professor, and Eric Mu-Young Kim, Graduate Research Assistant.