National Cooperative Highway Research Program

Fiscal Year 2022 **May 2021**

Announcement of NHCRP Synthesis Topics

The National Cooperative Highway Research Program (NCHRP) is supported on a continuing basis by funds from participating member states of the American Association of State Highway and Transportation Officials (AASHTO), with the full cooperation and support of the Federal Highway Administration, U.S. Department of Transportation. The NCHRP is administered by the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine. The NCHRP is an applied contract research program that provides practical and timely solutions to problems facing highway and transportation practitioners and administrators.

NCHRP syntheses are state-of-the-practice reports prepared under contract by outside individuals or firms. These reports seek to document current practice within state departments of transportation (DOTs), to identify ongoing and recently completed research, to learn what problems remain largely unsolved, and to organize and document the useful information acquired. They do not undertake new research, nor do they contain policy recommendations. Syntheses document and describe current practice in a given area and highlight practices that are viewed as successful by many of the agencies surveyed in developing the synthesis or that are characterized as such in the literature reviewed by the synthesis author.

Nominations of others and self-nominations for panel members should be submitted by June 30, 2021 through the MyTRB portal at this link: Online Panel Nominations

You will be asked to login to MyTRB. If you do not already have an account, you will be asked to quickly create one using your email and a password. To ensure proper consideration of nominations, please provide all of the information requested. A current resume is necessary to determine relevant knowledge and experience.

Note to FHWA employees: Although you may be on the distribution list for this e-mail, assignment of FHWA liaisons is coordinated through Ms. Jean Landolt's office. You will receive a separate e-mail from Ms. Landolt to initiate that process. As a reminder, FHWA employees may serve as liaisons to NCHRP panels but not as members.

Communication to determine an individual's interest and availability in serving will be made from this office only after we have matched available expertise (e.g., knowledge and experience as presented in the resume) with that required by the nature of the project.

NCHRP is also looking for consultants to perform as synthesis principal investigators. To formally express interest in authoring a topic, a two-page letter of interest and professional resume or CV is required. The fixed-price fee is $45,000. Please submit letters of interest to the Letters of Interest Submission Portal.

The letter of interest and resume or CV should convey a concise idea of the principal investigator's knowledge of the topic and related work and experience in the subject area. **The deadline for letters of interest is August 27, 2021.** Virtual panel meetings are anticipated during September and October 2021. During the meetings, scopes of work will be finalized and principal investigators chosen.

National Cooperative Highway Research Program Synthesis Topics in the Fiscal Year 2022 Program
(Titles are HYPERLINKS)

Synthesis Topic 53-01
Practices to Promote Equity in Transportation Funding

NCHRP Staff: Trey Joseph Wadsworth

State departments of transportation (DOTs) are increasingly acknowledging that underserved communities and persons of color have in the past experienced fewer benefits and a greater share of negative impacts associated with our transportation system. Some of these disparities reflect a history of transportation decision-making, policies, and processes in funding that have resulted in barriers, divided communities, and amplified racial inequities.

The objective of this synthesis is to document state DOT practices to promote equity in programmatic and project funding distribution methodologies, formulas, tools, or evaluation criteria.

Information to be gathered includes (but is not limited to):

- Equity statements, action plans, or stated recognition of the problem or problems;
- Practices or strategies to promote equity in transportation funding (e.g., methods, formulas, tools, evaluation criteria, or stakeholder involvement processes);
- Practices in funding of different transportation phases (e.g., asset management, planning, design, construction, maintenance, and operation);
- Performance measures associated with funding and equity; and
- Communication practices related to funding, to equity, and to demonstrating transparency.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-02
Practices to Motivate Safe Behaviors with Highway Construction and Maintenance Crews

NCHRP Staff: Leslie C. Harwood

Highway construction and maintenance is a uniquely hazardous industry. In 2019, Occupational Safety and Health Administration (OSHA) incident data reported the recordable injury rate was 21% higher for highway construction and maintenance than for general construction. Safety programs and policies have been created to seek improvement in safety performance. A common strategy to improve safety outcomes is the use of incentives and disincentives to motivate workers to perform safe behaviors. OSHA states that "incentive programs can be an important tool to promote workplace safety and health." Examples of such incentive programs include rewarding workers for reporting near-misses or hazards and encouraging the use of safety committees. Conversely, disincentive strategies can be used to discourage unsafe behaviors such as disciplinary actions for unsafe behaviors. Most safety incentive programs are either injury/illness/incident-based or behavior-based incentive programs. The former received some restrictions and clarification from OSHA stating that injury/illness/incident-based are allowable assuming there are no ramifications for reporting incidents. A recent study found that safety incentive programs have been effective at reducing experience modification ratings; lost-time workday incidents; and days away, job restrictions, or transfers. The same study also found that workers have a positive perception of safety incentive programs and believe they do improve safety outcomes.

The private construction sector has deployed incentive and disincentive programs with regularity. However, state departments of transportation (DOTs) have unique limitations on their abilities to financially incentivize safe actions or use corrective actions as disincentives for unsafe actions. While difficult, some state DOTs have found unique approaches to institute incentives, such as office-based grants, awards, and more.

The objective of this synthesis is to document state DOT practices regarding safety incentive and disincentive programs for highway construction and maintenance crews, related motivational techniques, and written policies or training to implement these programs.

Information to be gathered includes (but is not limited to):

- Formal safety incentive or disincentive programs;
- Informal safety incentive or disincentive programs;
- Other safety motivational approaches;
- Strategies for implementation;
- Training requirements; and
- Program policies and procedures.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Al-Shabbani, Z., Ammar, A., Nassereddine, H., and Dadi, G. B. (2021). Development, Implementation, and Tracking of Preventative Safety Metrics. Research Report KTC-21-10/SPR19-568. Kentucky Transportation Center, Lexington, KY.

- Employer Safety Incentive and Disincentive Policies and Practices. United States Department of Labor, Occupational Safety and Health Administration. https://www.osha.gov/as/opa/whistleblowermemo.html
- Goodrum, P. M., and Gangwar, M. (2004). Safety Incentives: A Study of Their Effectiveness in Construction. *Professional Safety*.
- Recommended Practices for Safety and Health Programs. United States Department of Labor, Occupational Safety and Health Administration. https://www.osha.gov/shpguidelines/

Synthesis Topic 53-03
Practices Leveraging Social Media Data for Emergency Preparedness and Response

NCHRP Staff: Leslie C. Harwood

Emergencies are often unpredictable and hard to track. Timely response to emergencies on highways is a critical issue faced by state departments of transportation (DOTs). State DOTs have been developing emergency response protocols and procedures. The popularity of social media provides an unprecedented opportunity for state DOTs to obtain information immediately after an emergency happens. Social media data provide vital spatial and temporal information during and after emergencies, and the use of social media is popular in emergency management for its high accessibility and effectiveness. Many state DOTs have undergone technology renovations and have started using social media data for rapid emergency situation detection, damage assessment, and evacuation plan propagation. However, there is still a lack of documentation of state DOT practices for using social media and corresponding data under different emergency scenarios.

The objective of this synthesis is to document current state DOT practices that leverage social media data for emergency preparedness and response.

Information to be gathered includes (but is not limited to):

- Types of emergency scenarios for which social media data are being leveraged; and
- Systems, methods, models, and/or tools for emergency identification, assessment, warning, and response using social media.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Smith, J. F., and Kenville, K. A. (2017). *ACRP Synthesis 82: Uses of Social Media to Inform Operational Response and Recovery During an Airport Emergency*. Transportation Research Board, Washington, D.C.
- Ernest R. Frazier, Sr., et al. (2020). *NCHRP Research Report 931: A Guide to Emergency Management at State Transportation Agencies,* supplemented by Ernest R. Frazier, Sr., et al. (2017). *NCHRP Web-Only Document 267: Developing a Guide to Emergency Management at State Transportation Agencies*. Transportation Research Board, Washington, D.C.
- Houston, N., and Hamilton, B. A. (2006). Best Practices in Emergency Transportation Operations Preparedness and Response: Results of the FHWA Workshop Series. FHWA-HOP-07-076. FHWA, U.S. Department of Transportation.
- Samuels, R., Mohammadi, N., and Taylor, J. E. (2020). Social Media-Informed Urban Crisis Detection. FHWA-GA-20-1834. Georgia DOT, Atlanta.
- NCHRP Synthesis 20-05/Topic 51-10 (Active). Practices for Integrated Flood Prediction and Response Systems.
- Baglin, C. (2014). *NCHRP Synthesis 454: Response to Extreme Weather Impacts on Transportation Systems. Transportation Research Board, Washington, D.C.*
- NCHRP Project 20-128: "Emergency Response: Organizational and Operational Models Used by State DOTs". (Ongoing research as of 2021).

Synthesis Topic 53-04

Practices in the Collection and Use of Utility As-Built Information for Minimizing Project Risks

NCHRP Staff: Jo Allen Gause

In a recent Federal Highway Administration review of state department of transportation (DOT) utility programs, federal regulations (23 CFR 635.105 and 23 CFR 635.123) cited the need for states to improve in their inspection and collection of utility as-built information as part of relocation operations. It has further been noted that utility as-built information as collected through permitted accommodations varies substantially by state and by utility company. The effective collection and use of this information can minimize utility-related impacts and delays resulting in savings to state DOTs and utility companies alike.

The objective of this synthesis is to document current state DOT practices related to utility as-built collection and use, including approaches taken by the agencies in working with utility companies for sharing as-built information.

Information to be gathered includes (but is not limited to):

- Approaches to collecting utility company records and information;
- Practices for collecting utility company records through non-disclosure agreements;
- Approaches to the use of utility data repositories and 3-D utility as-built information;
- Practices for surveying or collecting information on aboveground utilities;
- Uses of utility as-built information in planning, project development, or maintenance operations; and
- Opportunities realized by state DOTs through using utility as-built information during planning, project development, and maintenance.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Every Day Counts, 3D Engineered Models: Schedule, Cost and Post-Construction. Program Case Study, As-Built Utility Surveys: A Tale of Two State Transportation Department. (2016). FHWA-HIF-16-016. FHWA, U.S. Department of Transportation.
- Taylor, T., Lasley, V., Waddle, S., Li, Y., and Sturgill, R. (2020). *NCHRP Synthesis 148: Development and Use of As-Built Plans by State Departments of Transportation.* Transportation Research Board, Washington, D.C.
- FHWA. (October 2018). National Utility Review: Utility Coordination Process. Final Report rev. FHWA-HIF-18-039. FHWA, Office of Infrastructure, U.S. Department of Transportation.
- Sterling, R. L., Anspach, J., Allouche, E., Simicevic, J., Rogers, C. D. F., Weston, K., and Hayes, K. (2009). *SHRP 2 R-01: Encouraging Innovation in Locating and Characterizing Utilities.* Transportation Research Board of the National Academies, Washington, D.C.

Synthesis Topic 53-05
Practices for Stormwater Bioretention

NCHRP Staff: Jo Allen Gause

Bioretention is one of the most common stormwater control measures used by municipalities, and state departments of transportation (DOTs) are increasingly being asked to use bioretention to meet federal National Pollutant Discharge Elimination System stormwater permit requirements. Some state DOTs, like Washington State DOT, have integrated aspects of bioretention into their roadway embankment, such as vegetated filter strips, compost amended vegetated filter strips, and media filter drains that treat stormwater as part of the roadway embankment.

The objective of this synthesis is to document current state DOT practices for bioretention design, construction, and maintenance.

- Siting constraints, including nearby contaminated soil, groundwater, or wetlands, high sediment loads, and steep terrain or erodible soils;
- Requirements for physical and chemical characteristics of bioretention soil mix (e.g., content, gradation, nutrients, micronutrients, or source material);
- Allowances for bioretention soil mix variations or substitutions (e.g., biochar amendments);
- Local sourcing requirements for materials;
- Quality control requirements (e.g., project-specific material acceptance criteria prior to placement);
- Underdrain usage guidance (e.g., when to use an underdrain), underdrain matrix material (e.g., specifications for crushed rock or permeable base), and underdrain pipe material, elevation, and slope;
- Written state DOT guidance on the use of impermeable liners;
- Compaction requirements (inside and outside clear recovery zones);
- Outlet control (flow restriction or elevation);
- Plant type, including allowance for trees;
- Use of temporary or permanent irrigation;
- Operations and Maintenance inspection and maintenance protocols, feasibility evaluation criteria, and considerations affecting design;
- Cost-benefit guidance for using enhancements for water quality (e.g., more expensive filter media); and
- Bioretention-related terms and definitions (e.g., raingardens vs. bioretention vs. bioswales and planting soil vs. bioretention mix vs. filter media).

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-06

Local Calibration of LRFD Geotechnical Resistance Factors

NCHRP Staff: Jo Allen Gause

The load and resistance factor design (LRFD) framework for foundations of bridges and other structures provides the advantage to adapt and improve resistance factors—other than those generally prescribed in the code—based on local geology, design practice, and construction practice through statistics and reliability analysis. The codified AASHTO LRFD resistance factors were developed based on load tests conducted across the country, with variable conditions and practices. This approach, while allowing broad applicability, results in comparatively large coefficients of variation and conservative resistance factors. While many state departments of transportation (DOTs) use these codified resistance factors, other agencies have invested in evaluation of local geology and local design practice, and have established and adopted resistance factors for these specific design or construction practices. State DOTs have used different methods to locally calibrate various resistance factors associated with different design methodologies or foundation construction control.

The objective of this synthesis is to document the extent to which state DOTs have developed local resistance factor calibration, which factors have been calibrated, and how locally calibrated factors have been used.

Information to be gathered includes (but is not limited to):

- Extent to which state DOTs have developed local resistance factor calibration;
- Factors calibrated;
- Uses of locally calibrated factors;
- Performance monitoring and load testing techniques used;
- Local calibration of shallow foundation design methods;
- Local calibration of deep foundation design methods;
- Local calibration of deep foundation construction methods;
- Methods used for the exchange of data associated with site investigation and characterization or foundation performance testing; and
- Risks and obstacles identified by state DOTs for local resistance factor calibration.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-07
Curing Practices for Concrete Pavement

NCHRP Staff: Jo Allen Gause

The curing of concrete is widely recognized as a critical step for achieving high-quality long-lasting concrete pavements. While the most common curing practice is the application of membrane-forming curing compounds, the compound specifications, including application rates and the quality control/quality assurance (QC/QA) practice, differ among state departments of transportation (DOTs). The timing of the curing application—which is critical to the success of the curing process—also differs among DOTs. State DOTs may also adopt additional curing measures during adverse weather conditions.

The objective of this synthesis is to document state DOT practices for curing pavement concrete including procedures, materials, application rates, timing, QC/QA procedures, and specific measures adopted when paving under adverse weather conditions.

Information to be gathered includes (but is not limited to):

- Curing procedures allowed by state DOT specifications;
- Curing materials (e.g., curing compounds) specifications and—if applicable—dose;
- How the timing of the curing is established, including objective (e.g., tests) and subjective evaluations (e.g., sheen of the concrete surface);
- Pre-construction testing to verify the validity of the curing approach;
- Approaches followed to ensure the right application of the curing (QC);
- Weather conditions under which concrete paving is permitted;
- Use of support software;
- Use of sensors (e.g., temperature, internal relative humidity) to aid curing procedure or QC evaluation;
- Additional measures required when paving under adverse weather conditions; and
- Procedures taken if early age cracking (including plastic shrinkage cracking) is observed.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Taylor, P. C., van Dam, T. J., Sutter, L. L., and Fick, G. J. (2019). *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*. Second Edition. National Concrete Pavement Technology Center, Iowa State University, Ames, IA.
- *Curing Concrete Paving Mixtures.* (2018). FHWA Tech Brief. FHWA-HIF-18-015. FHWA, U.S. Department of Transportation.
- *Guide to External Curing of Concrete*. (2016). ACI 308R-16. American Concrete Institute, Farmington Hills, MI.
- *Guide to Cold Weather Concreting*. (2016). ACI 306R-16. American Concrete Institute, Farmington Hills, MI.
- Ruiz, J. M., Garber, S., and Dick, J. C. (2015). Computer-Based Guidelines for Concrete Pavements. HIPERPAV III®, Version 3.3 User's Manual. FHWA-HRT-14-087. FHWA, U.S. Department of Transportation.

- *Guide to Hot Weather Concreting.* (2010). ACI 305R-10. American Concrete Institute, Farmington Hills, MI.
- *Early Cracking of Concrete Pavement-Causes and Repairs.* (2002). American Concrete Pavement Association, Washington, D.C.
- Taylor, P. C. (2014). *Curing Concrete.* CRC Press, Boca Raton, FL.

Synthesis Topic 53-08
Strategies and Programs for Electric Vehicle Charging

NCHRP Staff: Trey Joseph Wadsworth

There are currently more than 1 million electric vehicles (EVs) in the nation, and this is envisioned to grow to 20 million by 2030 (about 7% of the total fleet). This 20-fold increase in 10 years and forecasted growth in fleets afterward will require additional charging infrastructure and distribution networks. A clear need exists for charging stations at the home end and at the non-home end. The introduction of driverless vehicles might increase the need for non-home charging, as many will likely be fleet vehicles. State departments of transportation (DOTs) have employed a variety of approaches to deployment and operation of charging stations, often through pilot programs. With fledgling needs, pilots may have been appropriate, but as EVs become a greater share of fleets in both consumer and freight vehicles, a consistent and sustainable strategy of implementation and operations may be needed.

The objective of this synthesis is to document current strategies and practices in use by state DOTs to facilitate and coordinate the provision and operation of EV charging facilities. The synthesis will also include current plans to address the future maturity of EV fleets.

Information to be gathered includes (but is not limited to):

- Practices for EV charging infrastructure deployment, delineation of operating and maintenance responsibilities, public/private partnerships, and pricing strategies;
- Plans for expanding pilot programs into full scale build-outs (both for consumer and freight vehicles, and in urban and rural contexts);
- Funding strategies to pay for stations and cost recoup strategies through pricing to users;
- Guidance or technical assistance to local governments (e.g., rezoning needs for home-based charging facilities, charging for public and private parking lots and garages, etc.); and
- State DOT policies for EV charging stations along curbs of state-owned roadways or in public rights-of-way.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-09
Use of Unmanned Aerial Systems for Highway Stormwater Inspections

NCHRP Staff: Leslie C. Harwood

Monitoring of stormwater best management practices (BMPs) is a requirement of most state departments of transportation (DOTs) construction permits and post-construction EPA National Pollutant Discharge Elimination System permits. This monitoring typically involves expensive and staff-intensive efforts for regular inspection to ensure the BMPs are functioning as designed and are not in imminent need of maintenance (e.g., clean-out). In recent years, the use of Unmanned Aerial Systems (UAS) has evolved rapidly as a tool with the potential to both reduce the costs and improve the data collected during stormwater management inspections for state DOTs. To date, UAS monitoring of stormwater BMPs conducted by state DOTs has demonstrated promising results (or potential applications) with regard to speed, accuracy, and repeatability for several important BMP performance and maintenance factors.

The objective of this synthesis is to document the current practices of state DOTs in using UAS as a tool for stormwater BMP inspections.

Information to be gathered includes (but is not limited to):

- Extent and type of UAS used for highway stormwater BMP monitoring;
- Specific types of UAS monitoring and factors for selection (e.g., improving accuracy of monitoring efforts and reducing staff time and costs associated with routine stormwater monitoring);
- Technical limitations, problems encountered, and lessons learned in using UAS monitoring; and
- UAS field monitoring protocols for stormwater BMPs and associated data post-processing methods.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Technical Memo—Small Unmanned Aerial System (sUAS) Stormwater Control Measure (SCM) Inspection Pilot. (2019). Prepared for MassDOT by Comprehensive Environmental Inc.
- 2019 AASHTO UAS/Drone Survey of All 50 State DOTs. https://www.transportation.org/wp-content/uploads/2019/05/MissionControl_Drones3.pdf
- NC State: Unmanned Aircraft (drones) in Sediment and Erosion Control. (2019). https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Erosion%20and%20Sediment%20Control/design_workshops/dec-2019-raleigh/Austin_Hairston_UAV_ESCWorkshop_2019.pdf
- The Application of Unmanned Aerial Systems in Surface Transportation. (MassDOT 2019). https://www.mass.gov/doc/volume-i-executive-summary/download
- McDonald, W. (2019). Drones in Urban Stormwater Management: A Review and Future Perspectives. *Urban Water Journal,* Vol. 16, Issue 7, pp. 505-518. DOI: 10.1080/1573062X.2019.1687745
- Banks, E., Cook, S. J., Frederick, G., Gill, S., Gray, J. S., Larue, T., and Wheeler, P. (2018). NCHRP Project 20-68A: "Successful Approaches for the Use of Unmanned Aerial Systems by Surface Transportation Agencies". Scan Team Report 17-01. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP20-68A_17-01

- Fischer, S., Lawless, E., Lu, J., and Van Fossen, K. (August 2020). Global Benchmarking Program Study on Unmanned Aerial Systems (UAS) for Surface Transportation: Domestic Desk Review. FHWA-HIF-20-091. https://www.fhwa.dot.gov/uas/hif20091.pdf
- *Use of Small Unmanned Aerial Systems for Construction Inspection*. (October 2019). Tech Brief. FHWA-HIF-19-096. FHWA, Office of Infrastructure, U.S. Department of Transportation. https://www.fhwa.dot.gov/uas/resources/hif19096.pdf
- Harper, C. (PI). (2019). NCHRP Synthesis 20-05/Topic 49-02: "Emerging Technologies for Construction Delivery". http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4386
- Gheisari, M., and Esmaeili, B. (2019). Applications and Requirements of Unmanned Aerial Systems (UAS) for Construction Safety. *Safety Science,* Vol. 118, pp. 230-240.
- MnDOT. (2018). Unmanned Aircraft System POLICY-2071545-v1. MnDOT Policy OP006. Minnesota Department of Transportation, Saint Paul. https://www.dot.state.mn.us/policy/operations/oe006.html
- Perez, M. A., Zech, W. C., and Donald, W. N. (2015). Using Unmanned Aerial Vehicles (UAVs) to Conduct Site Inspections of Erosion and Sediment Control Practices and Track Project Progression. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2528, pp. 38-48. https://journals.sagepub.com/doi/abs/10.3141/2528-05

Synthesis Topic 53-10
Practices for Contrast Pavement Markings

NCHRP Staff: Leslie C. Harwood

Contrast pavement markings are currently being used by several state departments of transportation (DOTs) and will likely be implemented by others in the future. There are several different contrast pavement marking designs currently utilized, but knowledge gaps exist regarding practices for varied roadways, drivers, or autonomous vehicle technology. Furthermore, the safety benefits of contrast pavement marking designs have not been identified. However, benefits of contrast pavement markings may include crash reductions stemming from lane departures, reduced life-cycle costs related to durability, and identification of lanes based on strip location by autonomous vehicle technologies.

The objective of this synthesis is to document the current practice of contrast pavement markings by state DOTs.

Information to be gathered includes (but is not limited to):

- Use of contrast pavement markings;
- Use of contrast pavement marking design configurations;
- Documented benefits regarding contrast pavement markings; and
- Design factors, including autonomous vehicle sensing capabilities.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-11
Resilient Design with Distributed Rainfall Modeling

NCHRP Staff: Jo Allen Gause

According to the National Oceanic and Atmospheric Administration, the number and cost of weather and climate-related disasters are increasing in the United States due to a combination of increased exposure, vulnerability, and the fact that climate change is increasing the frequency of extreme events. The increased frequency of hurricanes and severe storm events are requiring state departments of transportation (DOTs) to consider how to anticipate, plan for, and adapt to these changing conditions. In addition, state DOTs are considering how to withstand, respond to, and recover more rapidly when disruptions occur. For this reason, conventional methods of hydrologic analysis are being supplemented by more complex hydrologic modeling that allows for scenario testing and impact assessment.

Distributed rainfall methods are empirical models that use physical equations to describe rainfall patterns and water movement to create flow rates. Distributed rainfall models are unique among hydrologic models, in that they have more detailed methods of tracking runoff accumulation. These models split the watershed into small elements that are used to calculate and track infiltration and movement of runoff on the ground by using empirical equations and simplified momentum equations. In comparison, statistical methods do not explicitly track accumulation and empirical methods such as the Natural Resources Conservation Service methods and have simpler methods of tracking water accumulation that only use a few locations within the watershed. Historically, these distributed rainfall models have been used mostly in research settings for two main reasons: (1) they can have a higher level of accuracy and complexity due to the more detailed physics modeling, and (2) they are computationally expensive because they are solving the water movement in many locations within the watershed.

Increased computing power and modeling efficiency have made distributed rainfall models more cost effective for mid-level to simple engineering projects. Because distributed models are empirical, they also have more flexibility than statistical methods because they are not linked to gauge data within a specific region. As a result, there has been an upsurge in popularity among engineering practitioners using distributed rainfall models to create more resilient designs. However, there has been little documented guidance on applying distributed rainfall models to help engineers use them in the highway design process.

The objective of this synthesis is to document state DOT uses of distributed rainfall models. The synthesis will focus on the use of distributed rainfall methods for hydrologic analyses of bridge projects and highways in floodplains.

Information to be gathered includes (but is not limited to):

- The extent to which state DOTs are using distributed rainfall models;
- Documented guidance for distributed rainfall models;
- Types of projects for which distributed rainfall models are used (e.g., watershed basin size, watershed characteristics, calibration information availability, complexity of transportation project, future event scenarios, funding, etc.);
- Distributed rainfall modeling software packages used (e.g., HEC-RAS 2D rain on grid);
- Modeling techniques being used (e.g., grid sizes and set up, parameterization of hydrologic processes such as groundwater infiltration and sheet flow and other processes, modeling hydraulic control structures, calibration techniques, etc.);
- Comparisons performed by state DOTs between distributed rainfall models and other hydrologic models for projects;
- Documentation on cost differences from using distributed rainfall models by state DOTs; and

- Documentation of the benefits from using distributed rainfall models by state DOTs.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

Relevant Organizations:

Federal and state agencies that have dealt with flooding over the past decade include California DOT, Iowa DOT, North Carolina DOT, North Carolina Floodplain Mapping Program, South Carolina DOT, South Carolina Emergency Management Division, South Carolina Department of Natural Resources, Texas DOT, and Virginia DOT; and federal agencies (e.g., U.S. Geological Survey and U.S. Army Corps of Engineers.

Literature References:

- Knightes, C., et al. (2017). An Overview of Rainfall Run-off Model Types. Environmental Protection Agency, Washington, D.C.
- Brunner, G. *HEC-RAS 2D User's Manual*. U.S. Army Corps of Engineers.
- Jain, M., et al. (2004). A GIS Based Distributed Rainfall-Runoff Model. *Journal of Hydrology*, Vol. 299, Issues 1-2, pp. 107-135.
- Takahiro, S., et al. (2020). Ensemble Flood Predictions Using a High-Resolution Nationwide Distributed Rainfall-Runoff Model: Case Study of Heavy Rain Event of July 2018 and Typhoon Hagibis in 2019. *Progress in Earth and Planetary Science.* Article 75.
- Du, J., et al. (2007). Development and Testing of a Simple Physically-based Distributed Rainfall-Runoff Model for Storm Runoff Simulation in Humid Forested Basins. *Journal of Hydrology,* Vol. 336, Issues 3-4, pp. 334-346.

Synthesis Topic 53-12
Practices for Adding Bicycle and Pedestrians Access on Existing Vehicle Bridges

NCHRP Staff: Trey Joseph Wadsworth

State departments of transportation (DOTs) have created plans for improving or expanding existing bicycle/pedestrian networks to increase active transportation options along their state owned roadways. Expanding these networks on roadways might be accomplished by reallocating roadway space and dedicating bicycle lanes or by constructing new sidewalks or cycle tracks to safely accommodate pedestrians and bicycle riders. However, since many vehicle bridges were not originally designed for pedestrians or bicycles (e.g., no sidewalks or shoulders), they represent one source of gaps in existing and potential bicycle and pedestrian networks. Closing these gaps across an existing vehicle bridge is a common problem for state DOTs with no "one size fits all" solution.

The objective of this synthesis is to document the practices employed by state DOTs to provide or improve access to existing bridges for active transportation users. The synthesis will only focus on existing bridges and not on new construction.

Information to be gathered includes (but is not limited to):

- Techniques that state DOTs have used, are using, or have considered using to improve access to existing bridges (e.g., dedicated bicycle lanes, shared bicycle/vehicle lanes, sidewalk extensions, new sidewalks, cantilevered sidewalks, dedicated bridges, or other treatments);
- Characteristics of the bridges where access has been added (e.g., superstructure, original lane layout, average daily traffic, or another unique charateristic that enabled success); and
- Case studies for a select number of completed projects or projects in construction.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-13
Practices for Steel Bridge Fabrication and Erection Tolerances

NCHRP Staff: Jo Allen Gause

Research on tolerances for prefabricated elements used in accelerated bridge construction was completed under NCHRP Project 12-98: "Recommended Guidelines for Prefabricated Bridge Elements and Systems Tolerances and Dynamic Effects of Bridge Moves". The majority of the work covered precast concrete elements for bridges such as decks, substructure elements, and wall elements. Typical steel bridge elements were not covered because the majority of prefabricated elements used to date have been precast concrete. NCHRP Project 12-98 also did not include traditional prefabricated elements such as steel and concrete girders, since there are already specifications for tolerances for these elements NCHRP Project 12-98 research found that large tolerances cause problems with member connections. In precast concrete, large element tolerances require large joints in order to accommodate the tolerances. The AASHTO/National Steel Bridge Alliance Steel Bridge Collaboration group has noted that the use of oversize holes can lead to loss of overall structure geometry and fit-up problems during erection. Tolerances in steel fabrication require special processes such as shop blocking beams to drill field splices to ensure proper fit-up. Some state departments of transportation (DOTs) require full shop erection and fit-up to resolve tolerance issues in connections.

The purpose of this proposed synthesis is to document current state DOT practices of tolerance management for steel bridge elements.

Information to be gathered includes (but is not limited to):

- Current fabrication tolerances;
- Usefulness to state DOTs of current steel bridge fabrication tolerances (e.g., excessive, easily achievable, too small);
- Accuracy of steel fabrication methods (e.g., plate cutting method, drilled holes, camber management);
- Impact of tolerances on connection fabrication;
- Quality assurance issues; and
- Ways that stakeholders are improving tolerance management.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- *(NCHRP Web-Only Document 243* "Recommended Guidelines for Prefabricated Bridge Elements and Systems Tolerances and Dynamic Effects of Bridge Moves" (http://www.trb.org/Main/Blurbs/177187.aspx

Synthesis Topic 53-14
Use of Probe Data for Freight Planning and Operations

NCHRP Staff: Trey Joseph Wadsworth

With the increase in e-commerce, state departments of transportation (DOTs) rely more on probe data to understand the freight infrastructure needs, monitor freight infrastructure performance, and manage the demand. As the penetration of probe data has increased in the last decade, its usage in transportation planning and operations at state DOTs has become common. However, the application of probe data in freight is vastly different from traditional transportation planning usage. For instance, freight application tends to be specific to freight generators, freight attractors, and freight bottlenecks such as those near ports and borders, whereas the probe data may not be sufficient by itself.

The objective of this synthesis is to document current state DOT practices regarding the use of probe data in freight planning and operations management applications.

Information to be gathered includes (but is not limited to):

- The range of applications and the observed limitations associated with the available probe data (e.g., applications near borders, ports, and other freight generators or attractors;
- Cases where probe data was leveraged for freight planning and operations;
- Probe data providers for truck traffic; and
- Practices for fusing the probe data with other data sources.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-15

Coordination of Upgrades and Installation of New Software Required by Traffic Operations and Maintenance

NCHRP Staff: Leslie C. Harwood

Many new and emerging technologies can benefit the traveling public if integrated into traffic operations and maintenance systems, and thereby into information technology (IT) systems. Research divisions/sub-divisions within state departments of transportation (DOTs) have tested new technologies and upgrades to existing technology that are ready for implementation. However, integration into IT systems can create bottlenecks due to the complexity and/or inconsistency of requirements. Furthermore, various issues must be considered during upgrades and installation of new technologies, such as security concerns, compatibility of different software with existing software systems, indirect communication, rural connectivity issues, and integration of systems.

This synthesis will document the methods used by state DOTs for coordinating upgrades and installation of new software required by traffic operations and maintenance teams into their IT systems.

Information to be gathered includes (but is not limited to):

- Processes and timelines for integrating new/upgraded software into IT systems;
- How upgrades and installations are coordinated (i.e., internally, externally, or both);
- Methods for planning upgrades and new installations (e.g., formation of teams in functional areas to handle upgrades);
- Organizational efficiencies that allow for successful technology integrations; and
- Strategies for resolving issues associated with upgrades and new installations.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Coordination of Information Technology and TSMO. (n.d.) FHWA Office of Operations.

Synthesis Topic 53-16
Critical Findings for Tunnel Functional Systems

NCHRP Staff: Jo Allen Gause

In the National Tunnel Inspection Standards (NTIS) Final Rule, FHWA used the same definition of critical findings highway tunnels as for highway bridges. The *Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual*, incorporated into the regulation by reference, does not provide criteria for defining critical findings in functional systems. Tunnels have unique characteristics, including critical functional systems for ventilation, lighting, drainage, fire/life safety/security, and signage for traffic management and emergency evacuation. The intent of the NTIS and *TOMIE Manual* is that tunnel owners will define critical findings for each tunnel based on its unique characteristics.

The operation of functional systems is highly variable between different tunnels. Some may have different modes of function for emergencies such as fires in tunnels, while others do not. Some have automatic or remote controls that can alter operation modes in response to changing conditions, while others may have fixed modes of operation that can only be adjusted manually or cannot be adjusted at all.

The objective of this synthesis is to document state DOT methods and criteria for defining critical findings for tunnel functional systems.

Information to be gathered includes (but is not limited to):

- Identification of state DOTs that have tunnels and those that do not;
- Current and proposed methodologies and criteria for defining critical findings in functional systems; and
- Types of tunnel functional systems for critical levels of function.

Information will be collected through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- *Tunnel Operations, Maintenance, Inspection, and Evaluation (TOMIE) Manual.* (2015). FHWA--HIF-15-005. FHWA, U.S. Department of Transportation.
- *LRFD Road Tunnel and Construction Guide Specifications*. (2017). AASHTO, Washington, D.C.
- National Tunnel Inspection Standards. (2018). https://www.fhwa.dot.gov/bridge/inspection/tunnel/ntis.cfm

Synthesis Topic 53-17
Integrating Freight into Policies, Planning, and Project Development for Active Transportation

NCHRP Staff: Trey Joseph Wadsworth

Historically, freight elements have not been incorporated into active transportation policies, planning, design, implementation, and construction. Freight elements in roadway designs are an increasingly important consideration due to the growth in e-commerce deliveries and conflicts between freight vehicles and active transportation users. Whether a bicyclist, pedestrian, or freight delivery person, each desires additional bicycle lanes, sidewalks, or ready access to curbs, respectively. State departments of transportation (DOTs) have to balance freight elements such as pull-outs for truck parking, temporary halting space for delivery trucks, truck lanes, or other considerations to facilitate freight movement.

The objective of this synthesis is to document state DOT practices, tools, and approaches related to the integration of freight into active transportation policy and planning.

Information to be gathered includes (but is not limited to):

- Policies or plan guidelines on freight elements;
- Policies or plan guidelines on active transportation; and
- Approaches taken to balance freight elements in roadway designs where active transportation is planned or designed.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Synthesis Topic 53-18
Moisture Measurement for Foundations and Slopes for Pavements and Structures

NCHRP Staff: Jo Allen Gause

Accurate and timely moisture measurement of soils, aggregates, and recycled materials is critical to properly compact these geomaterials. In addition, moisture measurement is also very important in transportation applications such as landslide warning systems, rainfall-induced slope failures, embankment settlement, and pavement performance monitoring. New devices and sensors are available that could replace traditional methods that are more expensive and time-consuming.

The objective of this synthesis is to document current state department of transportation (DOTs) practices for field and laboratory moisture measurement for foundations and slopes for pavements and structures.

Information to be gathered includes (but is not limited to):

- Laboratory and field testing equipment used by state DOTs (e.g., devices, instruments, systems);
- Techniques by state DOTs for moisture measurement; and
- Spatial and seasonal variation of moisture measurements.

Information will be gathered through a literature review, a survey of state DOTs, and follow-up interviews with selected agencies for the development of case examples. Information gaps and suggestions for research to address those gaps will be identified.

Information Sources (Partial):

- Abu-Farsakh, M.Y., et al. (2015). Incorporating the Effect of Moisture Variation on Resilient Modulus for Unsaturated Fine-Grained Soils. *Transportation Research Record: Journal of the Transportation Research Board,* No. 2510, pp. 44-53.
- Camacho-Garita, E., et al. (2020). Effect of Moisture on Full-Scale Pavement Distress. *Journal of Testing and Evaluation*, Vol. 48, Issue 1, pp. 235-246.
- de Morais França, M. B., et al. (2018). A Multiprobe Heat Pulse Sensor for Soil Moisture Measurement Based on pcb Technology" *IEEE Transactions on Instrumentation and Measurement,* Vol. 68, Issue 2, pp. 606-613.
- Han, Z., and Vanapalli, S. K. (2016). State-of-the-Art: Prediction of Resilient Modulus of Unsaturated Subgrade Soils. *International Journal of Geomechanics,* Vol. 16, Issue 4.
- Jacobsz, S. W. (2018). "Low Cost Tensiometers for Geotechnical Applications. *Proc. 9th International Conference Physical Modelling Geotechnics*.
- Kejun, Y., et al. (2019). Soil Moisture Sensor Design Based on Fiber Bragg Grating. *Proc. 10th International Symposium Precision Engineering Measurements Instrumentation.*
- McCartney, J. S., and Khosravi, A. (2013). Field Monitoring System for Suction and Temperature Profiles under Pavements. *Journal of Performance of Constructed Facilities,* Vol. 27, Issue 6, pp. 818-825.
- Nokkaew, K., et al. (2014). Effect of Matric Suction on Resilient Modulus Compacted Recycled Base Course in Postcompaction State. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2433, pp. 68-78.
- Placidi, P., et al. (2020). Characterization of Low-Cost Capacitive Soil Moisture Sensors for IoT Networks. *Sensors,* Vol 20, Issue 12, p. 3585.