Announcement of Research Projects

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.

Each year, AASHTO refers a research program to the TRB consisting of high-priority problems for which solutions are required by the states. The NCHRP program for FY 2021 is expected to include 13 continuations and 47 new projects.

This announcement contains preliminary descriptions of only those new projects expected to be advertised for competitive proposals, and for which nominations for qualified professionals to serve on research oversight panels are sought. Nominations will be accepted on the TRB website through MyTRB at https://volunteer.mytrb.org/Panel/AvailableProjects. Detailed Requests for Proposals (RFPs) for these new projects will be developed beginning in August 2020.

Please note that NCHRP requests for proposals (RFPs) are available only on the TRB website. Those who have an interest in receiving RFPs can register on the website http://trb.org/nchrp. Upon registration, you will receive an e-mail notification of every RFP posting and an e-mail notification of new anticipated projects in future years.

Because NCHRP projects seek practical remedies for operational problems, proposals should demonstrate strong capability gained through extensive successful experiences in the relevant problem area. Consequently, any agency interested in submitting a proposal should first make a thorough self-appraisal to determine whether it possesses the capability and experience necessary to ensure successful completion of the project. The specifications for preparing proposals are set forth in the brochure titled Information and Instructions for Preparing Proposals. Proposals will be rejected if they are not prepared in strict conformance with the section titled “Instructions for Preparing and Submitting Proposals.” The brochure is available on the Internet at the website referenced above.

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IMPORTANT NOTICE

Potential proposers should understand clearly that the research program described herein is tentative. The final program will depend on the level of funding available from the Federal-aid apportionments for FY 2021. Meanwhile, to ensure that research contracts can be executed as soon as possible after the beginning of the fiscal year, the NCHRP is proceeding with the customary sequence of events through the point of research agency selection for all projects. The first round of detailed Requests for Proposals will be available starting in August 2020; proposals will be due beginning in September 2020, and research agency selections will be made beginning in November 2020. This places the risk of incurring proposal costs at the election of the research agencies. Beyond the point of selecting agencies, all activity relative to the FY 2021 program will cease until the funding authorization is known. These circumstances of uncertainty are beyond NCHRP control and are covered here so that potential proposers will be aware of the risk inherent in electing to propose on tentative projects.
National Cooperative Highway Research Program Projects in the Fiscal Year
2021 Program

(Titles are HOTLINKS)

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The National Committee on Uniform Traffic Control Devices (NCUTCD) Signals Technical Committee (STC) has reviewed treatments for several types of midblock pedestrian crosswalks that include highway traffic signals or beacons and has developed research recommendations for a new Manual on Uniform Traffic Control Devices (MUTCD) chapter in Part 4, titled "Midblock Pedestrian Signals" or MPS. The MPS would operate similarly to a standard vehicular traffic control signal at a midblock crossing, except that it would (1) use the same pedestrian crossing volume guidelines as are used for the HAWK Signal/Pedestrian Hybrid Beacon (PHB) and (2) display a flashing RED indication in place of a solid RED indication during the pedestrian clearance interval.

The MPS supports the concept of “complete streets,” a transportation policy and design approach that calls for roadways to be consistently designed and operated with all users in mind: bicyclists, public transportation users, drivers, and pedestrians of all ages and abilities. In today’s world of longer-spaced blocks and wide, high-speed suburban arterials, pedestrians frequently find themselves in a predicament when needing to cross these roads to access transit stops, medical facilities, businesses, and residences. With no easily accessible signalized crossing, they are forced to chance a crossing with no guarantee of safety or visibility from other roadway users. Moreover, increases in lower-density “sprawl-like” development mean that these crossings rarely happen in such a concentrated manner as to justify a midblock signal based on conventional signal volume warrants described in MUTCD, Chapter 4C.

The proposed MPS is intended to further expand the available options to improve safety at midblock crossings, while reflecting modern pedestrian crossing needs and roadway contexts. The MPS concept has been used for more than 40 years in several cities, including Los Angeles, to protect pedestrian crossings, and previous FHWA studies have reported this type of operation to have a very high driver compliance.

The MPS will also reduce delays experienced with the traditional MUTCD-approved solid RED indication, by incorporating a flashing RED interval, like the PHB. The requirement of a solid RED indication at midblock signals has generally been one of the limiting factors for their use, since this can result in excessive delays to motorists if the crossing is not being actively used by a pedestrian. The new concept will allow a motorist to proceed after yielding on a flashing solid RED indication and will reduce excessive delays. Such an operation has been in use in various cities, especially Los Angeles, since 1975.

Full pedestrian traffic control signals are often considered to remedy pedestrian safety crossing issues. If a full pedestrian traffic control signal is not justified or warrants are not being met, agencies require additional traffic control tools, such as PHBs or the proposed MPS, to improve pedestrian safety while maintaining efficient traffic operations.

Many agencies have successfully used the HAWK Signal or PHB; however, some agencies have expressed a desire to use a device that looks more like a conventional traffic control signal with standard three-section RED-YELLOW-GREEN signal faces that rest in a green indication.
Accordingly, the MPS is proposed as an additional traffic control device for non-intersection crosswalks. The MPS operates very similar to a traffic control signal at a midblock location, with the exception that it displays a flashing RED, instead of a steady RED, during the pedestrian clearance time. As with the PHB, the flashing RED reduces unnecessary delay.

The objectives of this research are to (1) document the benefits of the Midblock Pedestrian Signal (MPS) and develop language for a new section of the MUTCD (including definitions for the MPS, warrants, and operations guidance, including at driveways and minor side streets).

The work will provide a comprehensive review of MPS locations and procedures for their use to reduce pedestrian crashes at midblock crossings. This project is the natural extension of the work in the field of pedestrian traffic control signal systems and would create a reference that would be used by all agencies in the United States through the MUTCD.
Safety is a paramount issue for motorized and non-motorized road users. In an era that sees increasing challenges with keeping up with the life-cycle costs of added infrastructure, including lighting hardware and electrical systems, the ability to optimize where, when, and how much lighting to place throughout the system is critical. While roadway lighting is a common countermeasure used to increase visibility at night and it is recognized that lighting may offer substantial safety benefits, not all locations will experience benefits to the same extent because of the localized characteristics, climate, and circumstance. In addition, the environmental impacts (e.g., on animals, plants, and energy consumption) further create urgency to better understand safety performance as part of countermeasure selection and asset management so that a more thorough understanding of trade-offs can be gained. The need to light for vehicles may differ greatly than those for vulnerable road users, but choosing one mode’s needs over the other may not lead to optimal solutions that balance the safety needs with environmental and asset management concerns. With the advent of LED and adaptive roadway lighting systems, the lighting characteristics can be adjusted as a function of need that may increase safety performance at a much lower cost and save energy. Adaptive lighting also allows for adjustment of roadway lighting levels based on real-time data. Reducing lighting levels at night when traffic volumes are low has been shown to not adversely affect safety performance. However, much of the criteria for determining when and how to adjust systems are limited and based on older research using less statistically reliable methods.

The objective of this research is to develop safety performance models that will evaluate the impacts of LED and variable lighting systems in different roadway contexts, conditions, and for different user groups. This research would include a critical scientific review of the current state of the practice related to lighting design in different contexts, the scientific basis for the lighting design decisions and warrants, the assumptions regarding the safety benefits for these installations, under what conditions, and the level of scientific rigor applied to estimates in manuals used by practitioners. The project would evaluate the trade-offs related to lighting systems under different conditions and operating scenarios and investigate the safety effects of roadway lighting through random coefficient models or similar models to allow for crash effects to be considered as a distribution versus fixed coefficients along with cross section and contextual characteristics to allow for analyzing roadway, roadside, traffic, and weather characteristics impact on the safety performance of the lighting. The research will use and add to the data sets used for the development of Chapters 18 and 19 in the Highway Safety Manual (HSM 1st Edition), and incorporate existing knowledge regarding relationships between cross section, geometrics, and other factors to safety performance into guidelines for the installation of lighting and variable lighting systems.

The deliverables will enable agencies to determine when it may be appropriate for additional or less lighting through removal of unneeded lighting or installation of new adaptive lighting and what protocols agencies should follow for each of these scenarios on limited access freeways and multilane roadways. Results of this research could be included in the Highway Safety Manual,
Crash Modification Clearinghouse, and AASHTO and FHWA lighting design guidelines roadway design manuals. Individual states may also incorporate the research results in their policies and manuals.
The FHWA compiled statistics that showed that during the 10-year period 2005-2014 approximately 321,000 vehicle crashes per year were attributed to icy or snow-covered roads. These same statistics showed 5,650 fatalities per year were attributed to adverse weather. This is approximately 10 times more fatalities than all the other adverse weather fatalities tracked by the National Weather Service. While participation fluctuates from year to year, 44 state DOTs and one Canadian Province rely on AASHTO’s SICOP Technical Service Program, the Clear Roads, and/or Aurora Pooled Fund Studies to help them fulfill their winter maintenance mission. This clearly demonstrates the impact winter weather has on the transportation network across North America. Road maintenance agencies employ a variety of strategies to maintain safe, passable roadways during wintertime weather events. In general, these strategies can be categorized into those that rely on the use of chemicals (primarily sodium chloride --salt) and non-chemical-based strategies utilizing mechanical means (e.g., brooming, plowing, scraping, or mechanical ice breaking). The reliance on deicing chemicals alone has presented issues for agencies as some salt supplies are becoming irregular with some agencies not able to secure sufficient quantities and the resulting increases in salt prices adversely affecting state wintertime budgets. In addition, some agencies are under increasing scrutiny from environmental and other user groups who question the impacts to the environment, durability of motor vehicles, as well the roadway infrastructure. During very low temperatures the effectiveness of sodium chloride is diminished, and alternative chemicals may not be available or affordable in large quantities. For these reasons, agencies have identified the need to develop methods to reduce the dependence on these chemicals by exploring cost effective non-chemical strategies.

This research and resulting guidebook will assist state DOTs and other agencies across North America in providing a safe and reliable transportation network during winter weather events while reducing the amount of chemicals utilized and the resulting impact deicing chemicals have on the environment. This will be accomplished by evaluating new, non-chemical deicing systems such as specialized brooms, plow blades, motor-graders, and mechanical icebreakers, and developing best practices for their use. These best practices will be incorporated into a guidebook and implemented through training. Since the initial work on improved cutting edge research was conducted during the Strategic Highway Research Program (SHRP) in the 1990s (W. A. Nixon, Improved Cutting Edges for Ice Removal, National Research Council, SHRP Report, SHRP-H-346, 1993, 98 pages), little research has been accomplished on this topic until the California Department of Transportation published an in-depth Preliminary Investigation (PI) on the subject (Using Mechanical Ice Breakers to Improve Snow and Ice Removal Operations, Produced by Duane Bennett, Advanced Highway Maintenance & Construction Center Technology Research Center for the Caltrans Division of Research, Innovation and System Information, February 18, 2016). This PI indicated the need to research new snow fighting technology to find ways to improve snow and ice removal while minimizing the use of deicing materials. The outcome of this research will
be a best practice guide for snow removal operations utilizing non-chemical strategies. It will include methods that reduce the dependence on deicing chemicals during winter weather events. The research will then be implemented by holding training events.

The objectives of this research are (1) A literature review of non-chemical snow and ice removal techniques; (2) Review practices and interview operators at agencies who have adopted various types of non-chemical snow and ice removal techniques, including but not limited to Caltrans, Ontario, Minnesota, Alaska, and Utah; (3) Evaluate (a) Effectiveness in the removal of snow and ice pack, and improvement in time-to-bare-pavement; (b) Operational considerations including speed of operation, equipment maintenance, carrier vehicle requirements, and transport; (c) Impacts to pavement and other roadside infrastructure; (d) Identification of safety issues, and (e) Benefits and cost of ownership; (4) Develop a final report; (5) Create a guidebook and training syllabus covering appropriate application of non-chemical strategies; (6) Perform the training as part of, or in conjunction with at least two winter Maintenance Events (e.g. Clear Roads meeting, National Winter Maintenance Peer Exchange, APWA North American Snow Conference).
AASHTO’s *A Policy on Geometric Design for Rural Highways* (the Blue Book, first published in 1954) and *A Policy on Arterial Highways in Urban Areas* (the Red Book, first published in 1957) were early nationally recognized standards for geometric design. In 1984, the Blue Book and Red Book were combined to create the first edition of the AASHTO Green Book. The 1984 Green Book was organized around roadway Functional Classification (Local, Collector, or Arterial) and broad Context Classification (Urban or Rural), with design criteria based primarily on motor vehicle users. Subsequent Green Book editions retained this basic framework for geometric design guidance.

While the basic 10 chapter framework in the Green Book has served practitioners well for new construction or new location projects, it lacks the guidance needed today for practitioners to select design criteria for multimodal projects. Additionally, public works projects are more sensitive to funding than ever before. In many cases, cost magnitude and cost effectiveness play increasingly large roles in scoping projects. Often, reconstruction projects are limited in scope or available funding or may be affected by physical constraints or social or environmental considerations. In some locations, especially constrained locations, designing to the recommended Green Book criteria is not feasible. Through experience and applied research, practitioners have learned that roadways engineered using flexible design approaches often perform as well or better than robustly designed facilities and adapt better to the unique needs of each contextual design environment. The approaches of context-sensitive solutions and practical design recognize this and offer principles for project development informed by this understanding. The recently published Green Book, 7th Edition introduces three additional context zones (Rural Town, Suburban, and Urban Core), providing a finer-grained contextual basis.

The AASHTO Technical Committee on Geometric Design (TCGD) has established the following goals for the 8th Edition of the Green Book:

- Fully address the issues raised in the 2016 AASHTO Standing Committee on Highways (SCOH) Resolution on Direction of Flexibility in Design Standards,
- More fully develop the consideration of all transportation modes and the importance of project context to decisions,
- Change the emphasis from green field construction to projects on existing alignment, and
- Incorporate performance-based design using modern analysis tools to find effective solutions to actual problems.

At the July 2019 TCGD meeting, the TCGD decided the next Green Book, the 8th Edition (GB8), would better serve designers and transportation agencies by reorganizing the Green Book based on context (i.e., rural, rural town, suburban, urban, or urban core) rather than on functional class. They prepared the following draft outline.

**Part I—Introduction**

Chapter 1, Overview
Chapter 2, Performance-Based Design Concepts
Chapter 3, Design Decision Making
Part II—Performance-Based Evaluations
Chapter 4, Performance Metrics
Chapter 5, Design Model
Chapter 6, Applying a Performance Based Process Framework
Part III—Geometric Elements and Configurations
Chapter 7, Design Information and Sources
Chapter 8, Elements of Design
Chapter 9, Cross-Section Elements
Chapter 10, Intersection Fundamentals
Chapter 11, Freeways and Controlled Access Fundamentals
Chapter 12, Interchange Fundamentals
Part IV—Facility Design in Context
Chapter 13, Context and Facility Type Considerations
Chapter 14, Rural and Natural Areas
Chapter 15, Rural Towns
Chapter 16, Suburban Roadways
Chapter 17, Urban Roadways
Chapter 18, Urban Core Roadways
Chapter 19, Industrial, Warehouse, or Port Roads

The objective of this research is to develop a draft 8th Edition of the Green Book (GB8) suitable for balloting through AASHTO processes. The work plan will include:

- Based on the draft chapter outline above, prepare an annotated outline for the GB8 and a map of how GB7 content will be incorporated into the new context-based structure, and how issues in the 2016 SCOH resolution will be addressed.
- Prepare a map of AASHTO documents related to the Green Book that describes their relationships and identifies topics that are shared or incorporated by reference.
- Meet with the Technical Committee on Geometric Design during their 2021 and 2022 meetings to review the organization and content of the GB8 and related efforts. It is expected that there will also be web conferences between these meetings to resolve issues that arise.
- Meet with the Joint Council on Highways and Streets and Council on Active Transportation to review the organization and content of the GB8 and related efforts.
- Extensive outreach to AASHTO committees responsible for related documents to ensure that the interfaces between the documents are set and that content is compatible.
- Outreach to other stakeholder groups such as the FHWA, the Institute of Transportation Engineers, and the National Association of City Transportation Officials to ensure their perspectives are considered.
- The research should recommend a performance-based process approach to geometric design, which, when used, will allow practitioners to quantify and convey design trade-offs to a broad audience in meaningful terms and ultimately considered by decision makers.
- The design process should address all legal road users, not only motor vehicle drivers and passengers (including motorcycles) but also cyclists and pedestrians, and the spatial and operational design requirements to serve all users.
- The research should identify any Green Book criteria based on past practices and professional judgment and draft potential research needs statements to confirm or update the criteria in an
effort to utilize criteria in future Green Book editions based on known, proven, and meaningful operational or safety performance effects.

Annual average daily traffic (AADT) is one of the most widely used data inputs in transportation engineering. Transportation agencies use AADT to meet data reporting requirements, allocate resources, better inform decision-making, and support various agency functions. State departments of transportation (DOTs) are required to report AADT every year to the Highway Performance Monitoring System (HPMS) for the full extent of mainlines, samples, and ramps on all Federal-aid facilities (Federal Highway Administration, Traffic Monitoring Guide--TMG). In addition, the 2016 Highway Safety Improvement Program (HSIP) Final Rule requires States to have access to AADT for all paved public roads by year 2026. Transportation agencies estimate AADT using variations of a traditional method that was first introduced by Drusch in 1966 and is recommended by FHWA’s TMG. The traditional approach combines traffic data from permanent and portable traffic counting equipment. Continuous count sites (CCSs) collect traffic data 24 hours a day, seven days a week for all days of the year or extended periods of time. Because of the high installation, operation, and maintenance cost of CCSs, agencies tend to install them at select locations and conduct short-duration counts at locations that have not been counted. The goal is to adjust and expand the short-duration counts to obtain accurate AADT estimates. The main steps of the traditional method are (a) Gather traffic volume data from CCSs and calculate adjustment factors (e.g., seasonal, monthly, day-of-week, axle, etc.) for each CCS--widely known as the “factoring” step; (2) Establish monthly pattern groups that are homogenous. Create factor groups based on one or multiple grouping approaches--widely known as the “grouping” step; (3) Compute adjustment factors (e.g., hour-of-day factor, month of year factor) for each group (from the factors of the CCSs contained in each group); (4) Assign short-duration counts to the previously determined factor groups; agencies typically base the assignment task on the location, functional class or other characteristics of the roadway section where a count was taken--widely known as the “assignment” step; and (5) Multiply the average daily traffic (ADT) of a short-duration count with the appropriate group adjustment factor(s) to generate an AADT estimate.

One caveat of the traditional AADT estimation process is that the accuracy of the predictions is subject to errors inherent within each step of the process. Prior research has shown that the “assignment” step is the most critical element in the AADT estimation process. Potential ineffective allocation of short-duration counts to factor groups may triple the prediction error, yet, a small number of studies have dealt with the improvement of the assignment procedure. Because of limited research and knowledge on this topic, current guidelines are not prescriptive on how short-duration counts should be assigned to factor groups. Previous studies have concluded that statistical methods are necessary to support the assignment step, which is subject to human errors stemming from engineering judgment. This research will fill this gap by determining the most effective assignment methods that agencies can use to improve the accuracy of AADT estimates derived from short-term counts. The problem statement directly relates to the scope, objectives,
and seven core data principles (valuable, available, reliable, authorized, clear, efficient, accountable) of the AASHTO Committee on Data Management and Analytics.

The literature reveals a limited number of studies that have concentrated on the assignment process. Though some of these methods have produced promising results, the majority of past studies are limited in scope and objectives; examine, validate, and compare a small number of methods; focus on small regions and transportation networks that have specific characteristics; use limited data from a small number of carefully selected CCSs; and consider short study periods. As a result, it is difficult to generalize past research findings and results and draw safe conclusions about the most effective count assignment methods. An assignment method that has proved to be effective in one region or state may not necessarily be effective in a different part of the country that exhibits different traffic, roadway, demographic, socioeconomic, and/or weather characteristics. Because of those limitations, there is limited guidance on how short-duration counts should be assigned to factor groups. To fill this gap, there is a need to conduct a comprehensive and in-depth study that will have wider scope and validate the performance of several assignment methods for different transportation networks nationwide. The need for this research study is described in a recent TRB e-Circular.

The objective of this project is to determine the most effective methods of assigning traffic volume counts to adjustment factor groups. The project should be conducted in two Phases. Phase I, Research includes Task 1, Review the current state of practice and state of the art and identify candidate assignment methods for further examination; Task 2, Select up to five states to apply the assignment methods identified in Task 1; Task 3, Gather and process data needed to apply the assignment methods identified in Task 1; Task 4, Apply the assignment methods selected in Task 1 and validate their performance; and Task 5, Develop project deliverables, including a Phase II Work Plan. Phase II, Implementation, includes Task 6, Conduct at least five pilot studies with three state and two local public agencies to apply the most appropriate method(s) at each agency and Task 7, Develop Phase II project deliverables, including a Final Guidebook that will provide separately for each assignment method all the necessary information and elements (e.g., pros, cons, data inputs, methodological considerations, assumptions, anticipated accuracy, software requirements, implementation time and costs) to help transportation agencies select and implement the most appropriate assignment method(s).
Project 07-31

**State DOT Usage of Bicycle and Pedestrian Data: Practices, Sources, Needs, and Gaps**

Research Field: Traffic  
Source: AASHTO Council on Active Transportation  
Allocation: $800,000  
NCHRP Staff: Stephan A. Parker

State DOTs need data to inform the decision-making process, from statewide and regional planning, to project-level planning and development, to the evaluation of completed projects. However, data sources are not always available for a variety of reasons: agencies might not know of their existence; data collection may be cost-prohibitive; or existing data that is mainly utilized for other purposes has not yet been identified as usable for active transportation purposes. Data could be a powerful tool for agencies when determining which bicycle and pedestrian corridors/projects are most critical and, once built, clearly quantifying their impacts. There are many facets to state DOT usage of active transportation data. Some state DOTs use third-party data providers although those data sources have limitations and may not always be representative of a state’s larger population. When states collect their own information, they need the resources to gather, clean, maintain, and update the data and the IT resources to store it. States also need up-to-date geospatial data that indicates where sidewalks, bicycle facilities, and other infrastructure is located. It is also not enough to have geospatial data noting the physical location of a piece of infrastructure; for active transportation purposes, the condition of the infrastructure is important, especially when considering ADA requirements. On a larger scale, data could also identify populations more likely to utilize active transportation infrastructure and potentially aid in determining latent demand for the construction of such infrastructure. Clear data related to existing active transportation facilities would also help states quantify the effectiveness of these facilities and aid in pre- and post-construction analysis. If the data were standardized across states, the data could facilitate direct comparison and analysis on a state-to-state or national level. Active transportation data could also be combined with other data sets (including those focused on environment, equity, environmental justice, and public health, etc.) for additional analysis.

States would benefit from research that summarizes the existing literature on active transportation data and catalogs relevant sources and data sets related to active transportation. Furthermore, innovative, cost-effective data use cases could provide scalable examples among state DOT practitioners. The research should also capture any untraditional or unusual sources or applications of data that may be primarily for other purposes but could be adapted or integrated into active transportation analysis. This research would inform practitioners on the expanse of available data, which may be unconventional, such as police and hospital reports; capture information on how peer agencies are identifying and using data, identify gaps for future research, and provide recommendations (identification, collection, cleaning, utilizing, analyzing, standardizing, storing, funding, privacy and legal concerns, etc.) Submitting a data-related research problem statement is part of AASHTO’s Council on Active Transportation’s work plan and the Council’s number one priority.

The research proposed in this problem statement complements ongoing research. In particular, this problem statement expands the scope of NCHRP Project 20-05/Topic 50-10 to include bicycling data and conduct research aimed at identifying the data needs and wants of state DOTs and the gap between them and what is available. NCHRP Project 08-108, Developing National
Performance Management Data Strategies to Address Data Gaps, Standards, and Quality, does not include any information on data related to active transportation. This proposed research will dive deeper into data than the more general NCHRP Project 20-123(02), Research Roadmap for the AASHTO Council on Active Transportation. It will also build upon FHWA’s Roadway Data Improvement Program (RDIP), which seeks to improve the quality of states’ roadway data. Under the Roadway Safety Program, FHWA also prepares Roadway Safety Data Capabilities Assessments for states that include data components.

The objectives of this research are to determine how state DOTs are using data and to identify data sources, gaps, and recommendations on the next steps to develop the data and tools state DOTS need. To fulfill these objectives, the research contractor will need to complete the following:

1. Summarize/synthesize existing research on active transportation data.
2. Survey state DOTs to understand the current state of data sources and uses, as well as unmet needs.
3. Catalog active transportation data sets, common attributes, uses, including both well-known sources (e.g., Strava Metro) and less utilized sources (e.g., police reports, hospital reports, etc.).
4. Conduct a gap analysis between the data that state DOTs need/want versus what is currently available/being used.
5. Develop recommendations on next steps for developing, standardizing, maintaining, and storing the identified data, information, models, and/or tools.

The research will present an urgently needed inventory of available data sources and identify any gaps based on direct feedback from state DOTs. Practitioners will gain valuable insight into how their peers are utilizing data and receive recommendations to bolster data in their agencies. This research will advance the technical expertise of state DOTs.

Active Transportation data are used by many departments within a state DOT. Planning, engineering, safety, asset management, and maintenance all could utilize the research findings. State DOTs would need to determine how the findings could be applied and/or scaled to their agencies. They would also need to identify how they would obtain the data, whether through subscription services or manual collection, and how they would clean, maintain, and store the data given budget constraints. Presentations, webinars, and case studies are effective methods for communicating findings.

Given the continued need to support and evaluate facilities for active transportation, there is an important need for research regarding the injury data monitoring/surveillance systems in place and opportunities to further enhance these systems’ abilities to document health and safety outcomes, particularly for active travel modes.

---------------------- Combine with Problem Number: 2021-B-44 ----------------------

Practices and Recommendations in Reporting and Integrating Non-Fatal Injury Data for Active Travel Modes

The objectives of this research are to assess the state of the practice regarding pedestrian and bicycle injury reporting and integration systems, critically examine existing methods, demonstrate best practices, and identify future data improvement needs. Possible tasks to be completed as part of this research may include:

1) **State of the practice scan:** Perform a systematic scan of states (and possibly select regions/cities) to determine:
   a) To what degree states are aware of and adhering to the Consensus Recommendations for Pedestrian Injury Surveillance and using similar or standard and comparable definitions of
pedestrians, bicyclists, wheelchair users for non-fatal injury reporting? For emerging travel modes where standard definitions do not exist (such as e-scooters and other forms of micro-mobility), what definitions are being used to track non-fatal injury reporting?

b) What methods and data sources, if any, are states and cities using to measure injuries that are not reported in police crash report systems, including falls and crashes not directly involving vehicles that occur in the right-of-way and could be attributable to the built environment or used for safety and health planning purposes?

c) To what degree are states or cities linking different data sources (such as police-reported crashes with emergency departments, trauma registries, or EMS data), to establish more integrated reporting systems, and what linkage methods are used?

d) To what degree do state-level incentives, agency or project requirements, or legislation drive reporting practices and can help explain differences across states?

2) Validation/critical examination of practice: Perform data program assessments and/or actual data analyses to determine the extent to which existing data collection and linkage practices and data sources can accurately capture non-fatal injuries amongst pedestrians, bicyclists and other micro-mobility users (such as e-scooters etc.). In particular, identify practices that may lead to disparities in the data (e.g., under-reporting among people of varying ethnicities, languages, birthplaces of origin, housing status, age). It is possible that this research project could also lead to the development of methods to adjust for under-reporting.

3) Demonstration of best practice: Create a case example of a current agency best practice around non-fatal injury data monitoring and linkage that demonstrates the value in investment in data linkage and highlights how agency practices leverage data improvements for various purposes. Acknowledge the limitations and challenges identified in Task 2 and make recommendations for future advancements.

In 2018, 6,283 pedestrians were killed in traffic crashes in the United States, 17% of all traffic fatalities and the highest since 1990. This is a 3.4% increase in pedestrian fatalities from 2017\(^1\). Pedestrian and bicyclist fatalities increased by 32 percent in the ten-year period between 2008 and 2017. During that same time period, total traffic fatalities decreased by 0.8 percent. Studies have shown that pedestrian and bicyclist fatalities represent only the “top of the iceberg” with respect to all crashes involving these modes.\(^2\)

For every state Highway Safety Improvement Program, safety projects are prioritized using a formula that incorporates the number of crashes experienced or predicted along a roadway. Pedestrian and bicycle projects are systematically under-valued in these processes when, as prior research indicates, more than half of all pedestrian/bike injuries are unreported in the police data systems used by state safety programs. Improved data to measure non-fatal injuries will vastly enhance the validity of the tools applied by state DOTs to prioritize their safety investments.

Linking and integrating data has been identified as a key goal of TRB’s Health and Transportation Committee for a number of years, and this Research Problem Statement builds upon a prior Research Need Statement that was submitted in 2012 and has yet to be funded (Estimating the Benefits of a More Complete Pedestrian Injury Reporting System, produced by the Pedestrian Committee, ANF10).

This research will identify states that are creating model programs; critically examine successes and challenges in collecting and linking data to capture non-fatal injuries for pedestrians, bicyclists, non-and other micro-mobility users; and develop new methods and/or recommendations

\(^{1}\) National Center for Statistics and Analysis. (2019, October).

\(^{2}\) http://www.pedbikeinfo.org/factsfigures/facts_safety.cfm
for enhanced, integrated data systems that can measure these impacts for active travelers. It can be used immediately by agency decision makers that fund research regarding data collection and data quality improvement programs, both in state DOTs and State Highway Safety Offices.

The research would help identify and prioritize projects within certain funding programs. The audience for this research are state safety officers, staff of Highway Safety Improvement Programs, TAP programs, members of traffic safety partners (advocacy groups, health departments, departments of public safety, etc.), and pedestrian-bike groups. In addition, members of AASHTO committees/councils on Active Transportation, Safety, and Data Management, as well as members of TRB Committees ANF10 (Standing Committee on Pedestrians) and ANF20 (Standing Committee on Bicycle Transportation) would play an active role in the research process, as well as in the dissemination of the final research products.

Results of the research would be disseminated through TRB, AASHTO, and/or FHWA webinars, through focused articles in national and state-level publications, and through presentations at venues such as TRB and AASHTO meetings. Communications products to highlight the research could also be distributed electronically to state and local agencies and through national organizations such as the Governor’s Highway Safety Association (GHSA) and National Highway Traffic Safety Administration (NHTSA).

The AASHTO Special Committee on Research and Innovation has combined these two problem statements and the eventual NCHRP panel will determine the focus of the combined project.
Ongoing investments in maintenance are key to preserving the highway system and keeping the traveling public moving in a safe and reliable manner. However, it has been difficult for state departments of transportation (DOTs) to obtain adequate and consistent levels of funding to support maintenance needs. In 2014, a domestic scan was conducted to identify Leading Management Practices in Determining Funding Levels for Maintenance and Preservation (Scan 14-01). The scan identified three state DOTs that are using maintenance performance data to support the statewide allocation of funding for maintenance activities. Several additional state DOTs use maintenance performance data to allocate the funds provided for maintenance, but the degree to which performance data are used varies considerably. Using implementation funding provided under National Cooperative Highway Research Program (NCHRP) Project 20-44, a peer exchange was conducted to promote and disseminate the leading practices that were revealed during the 2014 domestic scan. A total of 45 individuals participated in the peer exchange, representing maintenance personnel from 27 state DOTs, private-sector industrial firms, and the Transportation Research Board (TRB). Although many of the maintenance practitioners collect maintenance performance data as part of a Maintenance Quality Assurance (MQA) program, the results are largely underutilized because agencies had little confidence in the data, an inadequate amount of data is being collected to make meaningful decisions, and/or early champions in an MQA program have retired and new employees do not understand its purpose.

Because of the importance to maintenance in life-cycle planning and with the planned investment strategies included in a state DOT Transportation Asset Management Plan (TAMP) specifying planned expenditures in maintenance and preservation activities, it is critical that the disconnect in the use of performance-based management is addressed through the development of guidance on how those management approaches can be best applied to maintenance activities. This will help advance the use of performance-based decisions, as promoted by the AASHTO Committee on Performance-Based Management, and advance the objectives of the AASHTO Committee on Maintenance. To address the needs of both asset management and maintenance personnel, the guidance should address three items: (1) Data-related issues, including the types of performance measures to use (level-of-service [LOS] or pass/fail), the number of samples needed to confidently report levels of service at the district or shop levels, strategies for ensuring consistency on a statewide basis, and leading practices for using technology to maintenance inventory and condition information. (2) Business processes and procedures that support performance-based management, including data strategies to influence maintenance funding allocations, methods of estimating resources required to move from one LOS rating to another, approaches for linking maintenance work activities to performance measures, and ways to hold employees accountable for their performance. (3) Informational or educational needs, including strategies for estimating the benefits associated with a shift toward performance-based management for maintenance and building buy-in among practitioners.
To satisfy those needs, the research will develop guidance in each of the areas listed to support the increased use of performance-based management strategies in maintenance departments. Rather than produce a written guidance document, the results of the research will be presented within a web-based MQA portal that allows maintenance practitioners to navigate the issues associated with the use of performance-based management techniques for maintenance. Following completion of the research, the team will establish the portal framework and populate high-priority areas. Over time, additional features can be incorporated into the portal as funding allows. Initially, the MQA portal, which is expected to be hosted by AASHTO, may include a document library, web-based training modules, MQA apps and tools, and a peer exchange forum. In the future, the portal could be expanded to include a question-and-answer (Q&A) forum, tools to calculate the cost of moving from one level-of-service rating to another using agency data, or apps and tools developed by one DOT to be shared with others. A final report will be developed to document the portal content, the results of the research efforts, and the primary sources used to generate the content.

The objectives of this research are to develop guidance promoting the use of performance-based management strategies in maintenance and to present the resulting information in a format that is easily accessible to the maintenance community. Using a web-based portal, the guidance will be presented in a variety of formats, including peer comparisons, online tools to help agencies address issues that hinder their use of MQA programs, online resources produced during the research, and online training materials to further assist maintenance departments with implementing performance-based practices.
Over the past two decades, asset management practice in transportation asset management (TAM) has been progressing with guidance produced from NCHRP Project 20-24(11), Asset Management Guidance for Transportation Agencies, initiated in 1999 and completed in 2002; NCHRP Project 08-69, Supplement to the AASHTO Transportation Asset Management Guide: Volume 2—A Focus on Implementation (TAM Guide II), initiated in 2008 and completed in 2010; and the current project NCHRP Project 08-109(01), Updating the AASHTO Transportation Asset Management Guide—A Focus on Implementation (TAM Guide III). TAM is an area of great importance to state departments of transportation (DOT) and other transportation agencies. As defined in the transportation legislation Moving Ahead for Progress in the 21st Century (MAP-21), TAM is a “strategic and systematic process of operating, maintaining, and improving physical assets… that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost.” In recent years interest in TAM has intensified in part due to the asset and performance management requirements introduced in MAP-21.

NCHRP Project 08-109, resulting in TAM Guide III, has developed an updated and new version of the existing AASHTO TAM Guide II using a new framework for asset management that has been adapted from the one developed by the UK-based Institute of Asset Management. This project was initiated to improve the existing guide’s effectiveness and thereby advance the practices of public-agency TAM. The research has been conducted in two phases, with the first phase focused on assessing the effectiveness of the current guide and developing a strategy for improving the guide’s effectiveness and presenting the guide in a form well suited to future updating. The second phase focused on developing the new print version of the TAM Guide III, as well as producing a TAM Guide III Digital Guide that will be added to AASHTO’s TAM Portal (http://tam.transportation.org).

With the original project being completed in early 2020, the project panel has focused on both implementation of TAM Guide III and determining additional needs to make the TAM Guide III better based on the original literature research and review. An extensive literature search was conducted as a part of the original NCHRP project phase one work and the results generally incorporated and addressed in the new TAM Guide III; however, because of funding limitations, not all of the desired changes, updates, and enhancements could be addressed. Based on those limitations, the objective of this research is to provide further enhancements and content to the TAM Guide III.
Since the early adoption of transportation asset management (TAM) practices, and performance rule-making association with the Fixing America’s Surface Transportation (FAST) Act, state agencies have been encouraged to add assets beyond pavements and bridges in their risk-based transportation asset management plans (TAMPs). With rapidly growing advancements and uses of technology in transportation system and management operations (TSMO), new assets are becoming widespread critical components of the network such as communications and security technology, sensors, cameras, and other intelligent transportation system (ITS) infrastructure technologies.

TAMPs cross multiple functions (e.g., planning, engineering, maintenance, operation, finance and procurement) entailing the management and inclusion of all the components required to achieve the TAMP goal, which is maintaining and improving physical assets with a focus on engineering and economic analysis based upon quality information. Typically, transportation agencies focus on the benefits of deploying new technologies when installed and implemented in the exploration stage. However, moving forward to an exploitation phase, agencies need to start considering the long-term management of these technologies to maintain their good operational state.

In addition to managing the condition of TSMO assets, TAM decisions to other assets will have an impact on the operations of the network, such as traffic flows, that depend on traffic management and operations. The timing of the traffic management installation could span from the 20 minutes necessary to “make safe” a pothole in a live travel lane, to the multi-year management of lanes through a construction zone. Delivery of the TAMP is therefore dependent on safe, planned, and dependable access to the transportation infrastructure. Several agencies have realized the need to link TAM and TSMO from the early stages of developing their TAMP; however, establishing the connection was challenging and hard to achieve in most cases. Currently, Ohio DOT is in the process of connecting TSMO and TAM as reported in their TAMP. Additionally, Caltrans has been including their transportation management system (TMS) technology assets into the TAMP. Based on these changing conditions, the objective of this research is to investigate the needs and benefits from incorporating TSMO assets in TAMPs. The study will develop a guide for state DOTs to facilitate the inclusion of TSMO in TAMP without disrupting the established and on-going planning process.
Project 08-139

Methods to Prevent Bridge Strikes by Trucks/

Bridge Strike Challenges, Prevention, Mitigation Strategies, and Best Practices

Research Field: Transportation Planning
Source: AASHTO Committee TSM&O, South Dakota Department of Transportation, AASHTO Special Committee on Freight
Allocation: $800,000 (including $400,000 from Federal Highway Administration)
NCHRP Staff: Waseem Dekelbab

The objectives of this research are to (1) develop guidance for state departments of transportation (DOTs) to individually and collaboratively prevent bridge strikes and (2) create an accessible, readable summary of how state DOTs are addressing bridge strikes through engineering, technology, enforcement, education, and collaboration.

Bridge strikes inflict serious damage to trucks and highway structures, cause injuries and fatalities in initial and secondary crashes, impose costly delays and detours on other highway users, and require expensive incident response from highway owners and public safety agencies. Attempts to prevent bridge strikes—including signing, lighting, height detection systems, and actuated warning devices—have achieved only limited success.

Lack of comprehensive information on bridge strikes contributes further to the problem. By one estimate, more than 3,200 bridge strikes occurred during the period of 2007 – 2017 at a cost approaching of $1 billion, but this estimate does not include all states. Many bridge strike collisions are unreported and may go undetected until the next scheduled bridge inspection. Even reported collisions may not be reported as bridge strikes, because no standard “check box” exists on crash report forms. Lack of information limits understanding of the frequency, impact, causation, and potential mitigation of bridge strikes.

Trucks that exceed the posted clearance of a bridge over a roadway can strike the bridge, setting off a chain reaction of damage and danger: (1) the oversized vehicle can be damaged or suddenly stopped and pose a safety risk to other vehicles; (2) the impact to the bridge can damage or destroy part of the bridge structure, causing falling debris or structural damage that affects other vehicles; (3) response (removal of the truck and bridge debris) and recovery (bridge inspection and emergency repairs) after the bridge strike incident can cause significant delays and congestion, which can lead to higher risks of additional crashes; and (4) bridge repairs and reconstruction can be expensive and limit the usefulness of the bridge structure for other traffic (road or rail) and of the roadway under the bridge during the repair process.

The mismatch of truck sizes and bridge clearances can be the result of a number of circumstances: (1) Bridge clearances on state or national freight network roadways can be less than a state’s minimum design standards (there is no federal limit on truck heights), which can affect trucks operating within state legal size limits; (2) Permitted oversize (and/or overweight) trucks can fail to observe routing restrictions and posted clearance signage; (3) Legally sized trucks can malfunction or loads can come loose and trucks can strike a bridge without the driver being aware of the problem; and/or (4) Posted bridge clearances can be inaccurate due to successive pavement overlays on the roadway under the bridge or to modifications to the bridge structure.

This research would equip state DOTs to learn from a comprehensive assessment of bridge strike strategies, beyond a bridge-by-bridge protection approach. This research would
allow states to learn from each other before a high profile, high consequence bridge strike incident compels a more restrictive regulatory response for all states.

The FHWA will provide $400,000 for a combination with Problem Statement G-10: Bridge Strike Challenges, Prevention, Mitigation Strategies, and Best Practices. The NCHRP panel should review the NTSB review and FHWA ballot.
According to the American Transportation Research Institute (ATRI), on average, truck drivers spend over 30 minutes per day looking for truck parking spaces. Many states are developing and installing specialized truck parking information management systems to provide a low cost, high benefit solution to communicate truck parking availability at rest areas and commercial truck stops. As more states begin to develop these systems, there is a need to provide national standards on the Intelligent Transportation Systems (ITS) architecture, physical design, and location of signage and interoperability between systems and states. National standards should be addressed now, before truck parking information systems become standard fixtures in every state.

The objective of this research is to identify national interoperability standards for truck parking information management systems. The outcomes of this work will include, but are not limited to the following:

1. A summary of existing state DOT truck parking systems and their performance
2. Review of technologies that are commercially available for installation
3. Guidance on design specifications for the implementation of new systems
4. Guidance on the spacing of signage and communications to drivers
5. Complete a technical ITS and traffic engineering roundtable to discuss specific issues pertaining to designs and telecommunications
6. Creation of an open ITS architecture that can be used in each state and that allows for the data to be shared with other states or users in an easy to use format
7. A guidebook for state DOT staff that provides information on the development, funding, design and construction of truck parking systems
8. A review of any future technologies that may compliment or advance truck parking systems

The research will evaluate existing information management systems, convene national experts in the areas of truck parking, and traffic engineering and ITS infrastructure to provide recommendations for national standards. In addition, a series of existing systems from Florida, the Mid-America Freight Coalition Truck Parking Information Management System (TPIMS), and others will be reviewed as case studies to understand future performance and integration of these systems in future technologies.
Freight demand continues to grow alongside population and economic growth. With the majority of freight goods being moved by trucks, industrial and residential developments are generating more truck trips and parking demand than local infrastructure can handle. Truck drivers need parking to rest, stage, and store their trucks in order to operate in the communities they serve. Parking is generally a local land use issue, and many cities lack effective codes and regulations to accommodate and manage their commercial truck parking needs. Effective local truck parking ordinances help keep truckers and other drivers safe, improve highway performance, reduce road maintenance costs, support economic growth, and promote community health and livability.

The objective of this research is to examine how and why local truck parking policy decisions are made, identify gaps and opportunities in rules and regulations, showcase model ordinances, and develop guidance for a range of model truck parking ordinances that cities would be willing to adopt, and develop a guide book for truck parking model ordinances. Research tasks should include, but are not limited to the following:

1. Review a nationally representative sample set of decision-making processes on truck parking issues.
2. Survey and/or interview government officials, community representatives, truck drivers, and business owners from the sample set to develop an understanding of the problem, data, and information to support the problem, business and community engagement that was conducted, and basis for decision-making.
3. Identify gaps and opportunities in rules and regulations related to planning, design, land use, safety, and environmental concerns surrounding truck parking.
4. Showcase exemplary truck parking ordinances and identify elements to include in model ordinances.
5. Develop model language and guidance for local jurisdictions.
6. Prepare a concise report summarizing the research effort and findings, lessons learned, and boilerplate code language and guidance that can be customized to fit community characteristics and state needs.
7. Prepare materials for outreach and engagement of end users of the research.

The guidance and sample ordinances produced from this research will provide state DOTs with the necessary tools to work with local and regional governments to shape and/or improve upon local codes. The research will also aid local and state governments in achieving the intent of Jason’s Law Truck Parking Survey (MAP-21; P.L. 112-141), by increasing safe parking options for truck drivers.
Public involvement processes for transportation planning and project development require active participation to ensure that many points of view are taken into consideration. Although transportation agencies strive to ensure that a wide cross-section of people is included, there are often people who want to participate but are unable to because of schedule conflicts or logistical challenges such as physical disability or transportation inaccessibility. Fortunately, the increasing availability of today’s communication technologies offers an opportunity not only to help those with logistic challenges to participate in public meetings but also to provide an alternative to those who may wish to participate remotely. Moreover, transportation agencies have been adopting many new and innovative communication media to increase public participation, especially from minorities and underserved population groups. However, there are no specific guidelines on adopting these communication media in transportation public involvement.

Online public involvement tools have the potential to broaden stakeholder outreach in transportation decision making. Online tools provide opportunities for members of the public to learn about transportation studies or projects and provide input without having to travel to a specific place at a specific time. Online tools provide access to people who may have limitations in time and travel.

As online technology rapidly shifts and changes, having a set of guidelines, or best practices, will assist agencies in successfully using these technologies. Although the concept of “online technology” is relatively new and evolving, there exists a set of lasting public involvement principles that can help guide online public involvement. Developing guidelines to streamline the process of incorporating online tools in public involvement would help improve the perception of using online technologies within transportation agencies and among the general public.

*NCHRP Synthesis 538: Practices for Online Public Involvement*, published in 2019, identified the current state of the practice for online public involvement tools used by state departments of transportation (DOTs). The report also identified additional areas of research, including integrating online tools with traditional outreach activities, managing the quality of public online input, and understanding the impact of staffing and other resources on the use and quality of online public involvement activities. However, as discussed in *NCHRP Synthesis 538*, very little research (if any) was available on the adoption of online communication strategies.

The proposed research would compile best practices for selecting, implementing, and addressing public input received using online public involvement tools. The final product may be an actionable best practices guide with specific lessons learned and recommendations for selecting, creating, and using online public involvement tools; integrating online and in-person public involvement; and priorities for online public involvement with specific population segments (including people of different races/ethnicities, household incomes, ages, genders, languages, and disabilities) to potentially address equity issues.

Major tasks might include
- Formative research with members of the public about their interest in and expectations for effective online public involvement.
- User experience testing with the public and agencies for different online public involvement tools/approaches from identified pilot applications.
- Use of the toolkit included in *NCHRP Research Report 905: Measuring the Effectiveness of Public Involvement in Transportation Planning and Project Development*, published in 2019, to assess the effectiveness of online public involvement for transportation projects.
- Qualitative research with public involvement professionals, online public involvement creators, and members of the public from specific population segments to help validate and refine the final deliverable.
- Identifying and assessing equity-related issues of using online tools for public involvement.

The research results can be presented in a manual or user guide format (both print and online) with actionable guidelines and best practices for conducting online public involvement integrated with traditional in-person outreach. This guide may provide concise principles, objectives, and best practices for each phase of public involvement.

State DOTs will be more readily accepting of leveraging these tools with well-researched guidance about public reception toward these tools and transportation agencies’ effective implementation of them. The proposed research would fill the need for guidance to give transportation agencies direction as to best professional practices to implement a range of online tools for meaningful public involvement. Realizing that tools and technology change over time, the guidance should focus on principles and key considerations to make a range of online tools successful for outreach. Many DOTs are experimenting with online tools, and well-researched guidance would help DOTs avoid pitfalls and improve cost efficiencies and time efficiencies to maximize potential benefits of pairing online tools with in-person outreach.
Project 08-143
Impact of Spatial Segmentation on Travel Time Reliability Performance Measures

Research Field: Transportation Planning
Allocation: $150,000
NCHRP Staff: Lawrence D. Goldstein

It can be shown that measures of variability in corridor travel time, unlike average values, depend in part on how that corridor is broken up into segments for measurement. This affects all agencies that use such metrics in performance measurement and/or project selection, especially all state DOTs and large MPOs subject to the requirements of performance management spelled out in such federal-aid surface transportation requirements as the MAP-21 Act. The proposed research will develop a series of guidelines and best practices suitable for implementation by transportation agencies. Step-by-step processes will be developed, and guidance for implementation (including analysis tools) will be provided.

Only limited research has been conducted on this subject to date. One recent report (cited on page 3) evaluated the impact of spatial segmentation on arterial system delay measures using several data sets from southeastern Virginia. Compared to industry standard TMC road segments, custom segments based on engineering judgment (such as homogeneous traffic volume, speed limit, number of lanes, signal density, etc.) decreased network delay by −3.4% and reliability index measures by 0.7% to 1.9% (using GPS data from INRIX). Use of very long segments, such as the entire corridor in each direction, noticeably averaged out congestion and decreased the delay by 29% and reliability index measures by 2.3% to 4.9%. The corresponding reductions using the National Performance Measures Research Data Set (NPMRDS) were 43% for delay and 5.7% to 9.5% for reliability index measures. This study was focused on arterial roads, and it is unclear if those results would translate to other areas or to freeway facilities.

The objective of this research is to determine the statistical implications of current methods for determining travel time and its reliability and propose a set of corresponding measures, including consideration for segmentation, that are suitable for roadway systems. A recommendation on how to compare travel time reliability among corridors, regions, or even states can facilitate communications of this measure and is an expected outcome from this project. In carrying out this research, attention should be given to Federal Highway Administration work with the I-95 Corridor Coalition and work undertaken by the AASHTO Committee on Performance Based Management.
Finding the right size of a rural public transit fleet is a significant challenge for rural public transit agencies. Those providers must accommodate riders with varying needs at different hours during the day and in varying quantities. For example, Medicaid’s integrated setting rule helped move persons with disabilities out of sheltered workshops and into employment settings and integrate throughout the community. Many rural public transit agencies offer employment or medical shuttles from one community to another. As a result, the need of more varied vehicle sizes is becoming more prevalent. Rather than the typical 18 passenger light duty bus, a standard transit bus size among rural transit providers, transit agencies must consider vans with less capacity or medium-sized buses with higher seating counts. The decision over which size bus to purchase is agonizing for small, rural transit agencies since funding for replacement vehicles is so limited. And when replacement vehicle funding is available from the Federal Transit Administration, the decision remains difficult since local matching funds are required. Another factor weighing into this decision is the length of time a vehicle will be a part of a rural transit agency’s fleet. Many of the vehicles procured by rural public transit agencies are kept two to three times past their federal useful life before replacement funds are available, meaning the size of the vehicle chosen has to be useful well into the future.

It is vital for rural transit agencies to know how to “right-size” their transit fleets, given the changing demographics of rural ridership. State departments of transportation, the funding sources for many of these rural transit agencies, would benefit from understanding what the best practices are from other states about determining rural transit fleet size, to help assist their own transit providers.

The objective of this research is to determine the best practices from the perspective of state departments of transportation and transit providers about how changing demographics and policies (federal public transportation and health care-related policies) are affecting decisions to procure vehicles and what vehicles (size and capacity) are eventually purchased by rural public transit systems to meet these ever-changing needs. And, more importantly, what are the costs associated with those decisions.

Some of the specific tasks that could be a part of this work include, but not limited to,

1. Collecting and analyzing data from the 2010 Census and the Household Travel Survey to determine demographic changes in rural communities.
2. Surveying state departments of transportation and FTA Section 5311 transit providers about procurement practices for vehicles.
3. Selectively interviewing stakeholders and developing case studies based on interviews.
4. Developing recommendations for best practices for state departments of transportation and rural transit providers.
This research provides significant benefits for transit offices of state departments of transportation and their transit providers and will help answer the following pressing industry questions:

1. How demographic changes are affecting vehicle procurement decisions;
2. How policy (federal public transportation and health care-related policies) changes are affecting vehicle procurement decisions;
3. What types of vehicles are procured and the reasons for those procurements;
4. What are the costs associated with those procurements; and
5. What lessons are learned from this process?
Project 08-145

Utilizing Cooperative Automated Transportation (CAT) Data to Enhance the Use of Freeway Operational Strategies

Research Field: Planning Methods and Processes
Source: AASHTO Committee on TSM&O Transportation Systems Operations
Allocation: $500,000
NCHRP Staff: B. Ray Derr

The application of new technologies in traffic operations and management began more than fifty years ago, with the introduction of digital computers. Continuous developments in computer technology, emerging sources of data, and communications have created new opportunities for developing and evaluating the use of operational strategies and performance measures to improve freeway network safety and mobility. Traffic management systems (TMS) continue to evolve and are incorporating the collection and use of real-time information from fixed sources (e.g., loop detectors, radar, cameras), mobile sources (e.g., probes, smart phones), other systems (e.g., weather, pavement monitoring), and other sources (e.g., third party providers).

The presence of Cooperative Automated Transportation (CAT) will provide public agencies with the opportunity to collect, use and share data among vehicles, infrastructure, and other devices to improve surface transportation safety and mobility. The data generated and shared in real-time between connected and automated vehicles (CAVs)—through Vehicle-to-Vehicle (V2V), the infrastructure (Vehicle-to-Infrastructure (V2I)—and connected mobile devices (devices-to-infrastructure or vehicles [D2X]) will provide agencies with information to improve how they actively manage traffic and travel. Furthermore, the ability for agencies to collect and use this information will potentially minimize the need to use data which is now collected by fixed sensors that are costly to acquire, install and maintain.

The sharing and use of electronic messages between traffic management systems and CAVs could transform how agencies actively manage and operate traffic. The exchange of electronic messages beyond just a basic safety message (BSM) will afford agencies to share information based on current and projected conditions unique to a specific location (e.g., geo-fenced area), direction of travel, section of roadway, corridor, traveler advisories, operational strategies, or control plans. These capabilities will allow these systems to issue advisory, warning, and regulatory messages to specific vehicles or sections of roadway. Messages could also enhance the cooperative merging, lane changing, stopping, speed, lane use, or other actions or movements by CAVs and allow new operational strategies to be applied.

The main objective of this research is to develop and demonstrate a process, framework and methodologies to develop, analyze, and integrate data and performance measures generated from electronic messages shared in a CAT environment to proactively manage and use operational strategies on freeway facilities. This research will include developing an example demonstrating how this process, framework and methodologies can be used to develop, evaluate and validate the use of an operational strategy, supporting algorithms and performance measures using data extracted from electronic messages for a range of events expected to occur on a section of freeway. This research will develop the operational scenarios, use cases, conditions, requirements, conditions, (e.g., varying levels of CAV market penetration, and spacing of ITS devices to collect information) to support the electronic messages a TMS would need to share and use.
This research will address how these electronic messages, data elements, and performance measures generated could be combined with existing sources of data that are used to manage and use operational strategies on freeways. Finally, this research will also investigate the implications of where the capture, processing, or synthesizing of data extracted from electronic messages from CAT infrastructure (e.g., Roadside Units [RSU], Hub) will occur and be transmitted to a hub or TMS. The research will identify how all operational strategies used for freeways could change with the use of only CAV data or the fusion of these data with existing sources traffic management systems use.

This project will prioritize the concept of operations, use cases, requirements, electronic messages, data elements, and performance measures that could support or augment existing or new algorithms to use in freeway operational strategies. The project will also assess the potential for modifying or developing new operational strategies based on the availability of CAT data and performance measures generated within a freeway network or region. The second phase of the project will develop, evaluate, and test using traffic simulation models and available CAT data, document, and publish algorithms to support the use of at least one operational strategy selected to use for a range of conditions on a freeway facility. This research will also identify the follow-on research projects that would pursue the development, proto-typing, field testing, acceptance (e.g., validation), publishing, and technology transfer (e.g., sharing of information, outreach material) to develop the performance measures and algorithms for the operational strategies tested.
Project 08-146

*Integrating Resiliency into Transportation System Operations*

Research Field: Transportation Planning
Allocation: $350,000
NCHRP Staff: Lawrence D. Goldstein

Over the past two decades, communities throughout the United States have experienced the consequences of increased frequency and severity of natural and, in some cases, human caused, events that result in both loss of life and major damage to public and private property, including damage to or closure of critical transportation assets and functions. The effects of these events vary in duration from hours to days or weeks and their footprints range from localized to regional. In some cases, these events can be predicted with some degree of accuracy (e.g., weather events, planned special events, planned major roadwork) and, because the events have occurred previously, their effects may be predictable. A resilient transportation system anticipates and plans for these events to the extent possible and, when predicted in advance, manages the transportation system to avoid or minimize the effects of these events and restore “normal” or “new normal” operations as quickly as possible. Thus, operational resilience involves developing and investing in policies, plans, procedures, people, technologies, and equipment so that transportation system owners and operators are prepared to act “before the storm” – regardless of the nature of the “storm,” including events that result in loss of transportation system capacity (e.g., weather, crashes, work zones), exceptional temporary demand on the system (e.g., special events, evacuations, mobilization), lost revenue (e.g., electronic toll collection, turnstile, or network failure), and loss of controls (e.g., loss of signals, dynamic messaging, lane controls).

The place where investment decisions are made that establish and tie together regional priorities is in the transportation planning process. Integrating resilience into planning for operations affords system operators the opportunity to include operations strategies that can benefit both day-to-day operations as well as provide for more robust systems that can accommodate changing demand patterns as well as sustain the system shocks that occur when natural or human caused events disrupt “normal” operations.

The objective of this proposed research effort is to 1) identify the extent to which operational resilience is considered in the transportation planning process within MPOs and state DOTs, 2) determine what the goals of operational resilience would be from the perspective of system operators across multiple modes, and 3) identify mechanisms for integrating operational resilience into the planning process from the perspective of system operators, including strategies that anticipate and plan for events that are likely to occur.
Rural transit systems traditionally operate either conventional fixed route services or conventional telephone-based (dial-a-ride) demand-responsive services. In many instances though, rural transit providers seek to implement intermediate options, often termed “deviated fixed route transit” (DFRT) systems, in which the general route and schedule is pre-determined, but the route can be varied to some degree based on requests from riders.

While traditional fixed route service is efficient for corridors with high ridership density, demand-responsive service is suitable for low-density areas and specialized services. DFRT addresses intermediate and mixed cases. For example, some transit systems combine fixed route service in a central business district with DFRT in outlying low-density residential areas. Similarly, some agencies switch from daytime fixed route service to late-night DFRT.

DFRT service presents a number of policy and service planning issues. These include

• How much deviation from the standard route will be permitted and associated schedule impacts.
• How far in advance a deviation must be requested and penalties for cancellations and no-shows.
• Whether all riders are allowed to request deviations or only those passengers meeting certain criteria (e.g., physician-certified disability).
• Whether vehicles return to the normal route after making a deviation or proceed directly to the location of the next known passenger (thereby bypassing non-appointment passengers waiting at intermediate stops).
• Coordination with neighboring transit systems and other travel modes.
• Target markets, fare policies, adaptation to seasonal demand fluctuations, and fare revenue.
• Eligibility and reimbursement rates for various governmental programs.
• Public communication, service marketing, and customer orientation for elderly riders and people with physical and cognitive disabilities.
• Effects of DFRT on travel time, ridership, operating costs, productivity, and customer satisfaction.

The research should evaluate the characteristics, benefits, drawbacks, and design considerations for rural deviated fixed route systems. Additionally, the experiences of rural transit systems that have implemented DFRT service should be gathered and summarized to identify common issues and opportunities.

The objective of this project is to develop practical guidance that can assist practitioners with all aspects of rural DFRT system design, including policy-setting, physical layout, service planning, and revenue forecasting. The guidebook should address methods for estimating effects on ridership, customer satisfaction, labor and equipment requirements, and operation and maintenance (O&M) costs. The guidebook should also address objective methods for comparing proposed DFRT services with other service delivery methods and validating performance measure estimates against existing service plans.
Aging utility infrastructure, advancement of new technologies, and the growth of populated areas in the United States have all certainly impacted utility companies. It is difficult to both maintain utility infrastructure and manage an increasing demand for products and services. Utility companies must maintain a balance by dividing their finite resources to existing facility maintenance and new utility expansions. Typically, budgets ignore unprofitable endeavors; such as removing abandoned, out of service (OOS) or decommissioned utility facilities that no longer meet the needs of their customer base. When building their infrastructure, utility companies frequently need to encroach within primary highway Right Of Way (ROW) or cross highways with their facilities. State law typically provides utility companies the authority to place their facilities inside highway public ROW. Utility companies that place their facilities in public ROW may later abandon, take OOS, or decommission utility facilities. When this happens, the State Transportation Authority (STA) may not be notified of the change in status. Despite the changed status of the facility’s use, the utility company retains responsibility for the facility/infrastructure. For the purposes of this proposal all abandoned, out of service (OOS) or decommissioned facilities will be referred to as OOS facilities.

Since increasing numbers of utility facilities occupy public right of way, it is to be expected that OOS facilities are becoming significant, partially due to the increased activities within the oil and gas industry and an aging facility infrastructure. OOS facilities often negatively impact STA construction projects and it is expected that this will happen more frequently as the numbers of OOS facilities increase. Since these facilities are not in service, they are typically undocumented on utility company mapping and left unmarked by 811 utility locators. These OOS facilities may not be identified until the contractor actually exposes the facility. When this happens, work stops to identify the facility type, owner, active or inactive status, how to address the facility during construction, and what the potential consequences are. These delays affect the contractor, which is then passed onto the STAs and subsequently taxpayers. Further complexities, delays and costs may occur if the OOS facility is an environmental concern as in cases of OOS asbestos containing concrete pipe. This leads to questions on how to remedy an increasing problem that unduly burdens the STA. What should utility companies do with OOS facilities once they are no longer useful? What should the permitting STA do to minimize OOS facility impacts to their work? Which entity is ultimately responsible to record the locations of these utilities? How can STA’s avoid allowing utility lines to fall into this derelict status? Should OOS utility removal be a required condition of permitting ROW occupancy? How can a STA address OOS facilities during transportation project design and development to minimize negative impacts during construction?

As an element of transportation project development, the utility coordination process is the ideal place for STAs to manage OOS facilities that exist in a project footprint. Defining typical effective and required processes for identifying these facilities and addressing their existence in
the project footprint during the utility coordination will help STAs optimize their efficiency in project execution. It is also necessary for the proposal to identify a long-term resolution to OOS facilities once permitted to occupy ROW. When researching utilities deemed “Abandoned” or “Decommissioned”, some publications discuss the problems they cause, without mentioning ways to go about fixing them. Even fewer appear to address whose responsibility it is to rectify the situation. A search of the Transportation Research Board database indicates that the research done in this area does not answer the questions proposed here. Given the impact OOS utilities have on transportation construction delays, the research would have the opportunity to save time, money, and possibly lives.

The study will focus on three areas of STA operations commonly impacted by OOS facilities: Permitting, Project Development, and Project Construction. This research will minimize impacts due to OOS facilities by documenting and analyzing effective practices in permitting utility occupancy in public ROW and managing OOS facilities via utility coordination before, during, and after transportation project construction. It will find information identifying and assessing various means utility companies and STAs currently handle permitted OOS utilities, finding effective, cost and time efficient practices. A special focus will be needed on asbestos concrete pipe an asbestos-containing material or ACM. This particular aspect should include a review of EPA guidance including NESHAP (National Emission Standards for Hazardous Air Pollutants 40 CFR 61 Subpart M, 61.151(e) and 61.154(h). The study will identify means to increase utility coordination efficiency on transportation projects during project development, identifying OOS utilities, and addressing their proximity to avoid negative impacts during construction. Most STAs and construction entities are aware of the problem and therefore the research would be more focused on finding the best ways to locate, designate and either remove, relocate or revitalize the existing utility. The solutions may include early identification and location of utilities but will also need to address what each entity may be expected to do in the process. The product of the research will be a “Scoping Guide”, defining effective practices, policies and actions for a STA to use in similar situations.
Environmental sustainability and economic benefits motivate maximum use of recycled asphalt materials, including reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS), in asphalt mixtures. However, adequate cracking performance initially and with time when these stiff, brittle, aged materials are added to virgin asphalt-aggregate mixtures must be maintained by engineering each unique materials combination of virgin and recycled materials. To preclude cracking, state departments of transportation (DOTs) currently limit the RAP and RAS contents and their overall recycled binder ratio (RBR). Strategies for partially restoring rheology and improving cracking performance include utilizing a softer base binder or adding a recycling agent (rejuvenator), but the durability of these strategies with aging and exposure to moisture is unknown. In addition, these types of high RBR asphalt mixtures must be included in balanced mix design systems currently being implemented.

A comprehensive standard practice and/or system is needed to specifically address the complexity of engineering durable, high RBR asphalt mixtures with balanced performance to promote environmental sustainability of the most recycled product in the United States and realize significant economic benefits.

The objective of this research is to expand and update the draft AASHTO Standard Practice produced in NCHRP Project 09-58 for high RBR asphalt mixtures to address durability with tools to evaluate moisture susceptibility, updated aging protocols, and verified cracking performance thresholds.

Accomplishment of this objective shall require the following tasks: (1) evaluate tests and methods for characterizing moisture susceptibility of asphalt mixtures, including the guidelines developed for warm-mix asphalt (WMA) in NCHRP Projects 09-49 and 09-49B; (2) review aging protocols developed in past NCHRP studies; (3) define practical parameters to capture field aging of high RBR mixtures in the laboratory that include initial quality and rate of aging; (4) further verify cracking performance thresholds developed in NCHRP Project 09-58 and evaluate alternate cracking tests and thresholds recommended in NCHRP Projects 09-57 and 09-57A; and (5) expand and update the draft AASHTO Standard Practice for high RBR asphalt mixtures produced in NCHRP Project 09-58 to include durability in terms of moisture susceptibility and aging.
Project 09-66

Mechanical Properties of Laboratory Produced Recycled Plastic Modified (RPM) Asphalt Binders and Mixtures

Research Field: Materials and Construction
Source: AASHTO Committee on Materials and Pavements, Louisiana Department of Transportation and Development, and Montana Department of Transportation
Allocation: $500,000
NCHRP Staff: Edward T. Harrigan

In late 2016, media reports and online networks began generating an interest in the possibility of using recycled plastic waste in asphalt mixtures. The idea was marketed as an opportunity to simultaneously improve the quality of asphalt pavements and help address the issue of waste plastic in cities, towns, and waterways across the United States. While magazine articles and videos have trumpeted positive impacts of using recycled plastic modified (RPM) asphalt, such as increased service life and reduced need for polymers to modify asphalt binders, and while preliminary research suggests some of these benefits maybe realized, a full program of research to confidently back these claims is lacking.

The current waste plastic challenge is a critical concern; however, there is equal concern about the current state of the aging transportation infrastructure in the United States. Investment in our system must focus on delivering long-lasting, high performing pavements as cost-effectively as possible. This research will be used to assess the feasibility of using RPM asphalt as a sustainable solution for improving both the performance of asphalt mixtures and reducing the amount of plastic waste in the United States.

Several international papers have recently appeared extolling the virtues of using waste plastics in asphalt. Such “recycled” plastics can be included as a substitute for aggregates, as an aggregate coating, as an asphalt binder modifier, or some combination of the three. For example, Dalhat et al. (2019) used “Recycled Plastic Waste (RPW)” consisting of a mixture of low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyethylene terephthalate (PET), polypropylene (PP), polyvinyl chloride (PVC), and polystyrene (PS) as a partial aggregate substitute in asphalt mixtures. They also modified the asphalt binder with RPW. The experiment included many variables and modifiers and was highly confounded, but the authors did conclude that using recycled plastics in asphalt could enhance asphalt mixture rutting characteristics.

Pre-coating aggregates with recycled plastics prior to their incorporation into asphalt mixtures has also been studied by researchers who have reported that recycled plastic materials tend to increase aggregate toughness, while decreasing water absorption. Asphalt mixtures containing plastic-coated aggregates have also tended to show improved asphalt mixture moisture susceptibility properties.

Using recycled plastics as asphalt binder modifiers appears to decrease binder penetration and ductility and increase softening point and viscosity. Researchers have used such results to suggest the use of recycled plastics in asphalt binders would be good for areas that struggle with permanent deformation in asphalt pavements. These same authors are mostly silent about what such binder modification could do for pavement cracking, as stiffening binders will tend to increase cracking.
Finally, when incorporated in asphalt mixtures, researchers tend to agree that recycled plastics appear to enhance an asphalt mixture’s mechanical properties, although Dalhat et al. (2019) are one of the few groups that have used more modern mixture test methods, such as determining dynamic modulus and flow number and using a wheel tracking test. Other researchers have used Marshall stability and flow to determine the merits of recycled plastics in asphalt, with experimental plans that are often lacking.

While there does appear to be a mounting body of literature on the use of recycled plastics in asphalt, much of the work being reported has lacked a clear experimental plan and suffers from the use of dated test methods. Additionally, from a review of the literature, there does not appear to be a cohesive, well thought out plan to answer the many questions raised about recycled plastics in asphalt.

The objective of this research is to evaluate the impact that recycled plastics—including but not limited to low density polyethylene (LDPE), high density polyethylene (HDPE), and polypropylene)—have on the mechanical properties of both asphalt binders and mixtures when added to asphalt binders using a wet process or asphalt mixtures using a plant-mixed or dry process.

Accomplishment of this objective shall require the following tasks: (1) develop a work plan for completing Tasks 2 through 7; (2) conduct a literature review of current and past research related to the use of recycled plastics in asphalt mixtures that includes both laboratory and field studies which provide a clearer understanding of RPM asphalt mixture performance; (3) submit an interim report including the results of Tasks 1 and 2; (4) determine the impacts of recycled plastics on the rheological stability properties of asphalt binders by evaluating the impacts of binder source, plastic dosage rate, and stabilizer, cohesive and adhesive properties, and aging on rheological and stability properties; (5) determine the impacts of recycled plastics on the mechanical properties of asphalt mixtures using RPM asphalt binders and RPM asphalt mixtures where the plastic is introduced using a dry process by evaluating for low temperature cracking, fatigue cracking, top-down cracking, rutting, and moisture susceptibility performance; (6) develop a best practices manual for handling and using recycled plastics in a laboratory setting and, if warranted, for handling and quality control of the incoming RPM streams; and (7) submit a final report and hold a workshop with state agencies, the Federal Highway Administration, and industry to discuss the results. The final report will include changes to AASHTO asphalt standards if warranted.
The asphalt industry has a well-established history of using new technologies and innovative materials in flexible pavement cross-sections. Examples include warm mix asphalt (WMA), recycled asphalt shingles (RAS), reclaimed asphalt pavement (RAP), recycled tire rubber (RTR) and cold recycled mixtures. These, and other technologies currently in development, offer significant economic, environmental, and engineering advantages over conventional materials if used properly within a structural design framework. The primary structural design approaches in the U.S. are empirical and mechanistic-empirical. At last count, the empirical approach is in use by 28 state DOTs with the majority of those using the 1993 AASHTO Design Guide. The remaining states have implemented or are transitioning to the new M-E approach adopted by AASHTO or have their own state-specific empirical or M-E method. A major challenge every agency faces when making the transition to M-E design is local calibration of the empirical transfer functions that predict pavement performance. Calibration is typically accomplished with a combination of laboratory testing and field-data collection from existing pavements which can take years to complete at relatively great cost. This assumes that existing pavement sections that vary in age and conditions are available from which to extract performance data. Calibration for new pavement materials or technologies is further complicated by the fact that field and lab data may be sparse or non-existent. This fact greatly limits the deployment of the technology or new material until it is fully tested, and transfer functions are fully calibrated. The pace at which new pavement materials and technologies are developed requires more rapid methods for calibrating transfer functions. To this end, calibration should take no longer than one year to be efficient and effectively support technology deployment. This research project aims to identify and develop methodologies to rapidly calibrate M-E transfer functions for new materials and technologies. Since construction of full-scale trial pavement sections, as a matter of routine practice, would be too time consuming, it is anticipated that calibration would rely on extensive laboratory testing. Further, it is expected that the transfer functions calibrated with the new methods could be used in the AASHTO M-E framework.

The AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) and accompanying software (AASHTOWare© Pavement ME Design) represents a major improvement in structural pavement design based on decades of research and development. While the MEPDG has significant advantages over its predecessor (1993 AASHTO Design Guide) it is still limited by the empirical transfer functions which require verification, calibration and validation. The initial national calibration performed on Long-Term Pavement Performance (LTPP) sections represents relatively old sections that did not include more modern materials and technologies. Therefore, local calibration is recommended by AASHTO, even for conventional materials, and ultimately required for any new materials that have yet to be evaluated. Calibration typically involves laboratory testing and field study. Under NCHRP Projects 1-37A and 1-40, the MEPDG was “globally” calibrated across LTPP sites in North America. As documented in the AASHTO Guide for Local Calibration of the Mechanistic-Empirical Pavement Design Guide, the procedure...
followed an 11-step process that is effective, provided sufficient field-sections are available. The problem, of course, with new materials and technologies is that there is insufficient (if any) field data available which forces more reliance on laboratory-derived data. Laboratory-calibration of transfer functions has historically focused on bottom-up fatigue cracking through the bending beam fatigue test. This approach has been used extensively since the 1960s but it has been well-recognized that lab-to-field shift factors are required to make accurate cracking performance predictions. More recent efforts have examined other forms of testing to predict top-down and reflective cracking such as Energy Ratio, Texas Overlay Test, Semi-Circular Bend Test, and the Illinois Flexibility Index Test, to name a few. Some of these approaches were developed primarily as a screening tool for use in mix design. However, there is potential for using them as a predictor of performance for structural design purposes and could be considered in this study.

The primary objective of this research is to identify and develop methods for rapidly calibrating transfer functions for M-E design. The objectives would be achieved through five broad tasks: (1) Comprehensive literature review of existing calibration methodologies; (2) Identify or develop potential transfer function rapid calibration procedure(s); (3) Establish proof-of-concept using new procedure(s) in laboratory; (4) Validate new transfer function calibration procedure(s) with field data; and (5) Develop guidance document for new calibration procedure(s). Transfer function calibration is currently seen as a major challenge in M-E design implementation due to its cost and time requirements. The development of a more rapid approach could greatly enhance the utility and widespread use of M-E design, while also supporting new and innovative materials in flexible pavement cross-sections. The main product will be a guidance document for rapid calibration of M-E transfer functions and implementation would naturally flow through AASHTO in support of MEPDG adoption by state agencies.
Project 10-109

Modern Solutions to Safe and Efficient Work Zone Travel

Research Field: Materials and Construction  
Source: AASHTO Committee on Construction  
Allocation: $600,000  
NCHRP Staff: Camille Crichton-Sumners

Annually, hundreds of lives are lost in roadway construction and maintenance work zones. There are concerns that aside from distracted driving, the traveling public regularly fails to identify and react properly to warning signs associated with maintenance of traffic in these highway work zones. There are many best practices available for work zone travel improvement and recent movement to Smarter Work Zones (SWZ). The Smarter Work Zones initiative promotes the use of innovative strategies to minimize work zone impacts and use technology applications to dynamically manage work zone impacts. Further, there are new approaches being tested and used across the country to grab the attention of the traveling public and have them respond properly to the work zone traffic control information. This would include the use of new and innovative technologies for intelligent transportation systems (ITS) for dynamic management of work zone traffic impacts, such as queue and speed management. Much of the public is aware of other technological solutions that provide guidance to travellers (WAZE, Google Maps, etc). Other data collection techniques involve the use of cellular location data and feedback to monitor queuing and suggest alternate routes.

Research is needed to identify best practices in leveraging technology to assist the traveling public in navigating roadway maintenance or construction work zones or further simply avoiding the congestion associated with these DOT efforts all together. The research should address two primary research goals: 1) develop a guidance document for implementation of Smarter Work Zone technologies with adaptive and attention capturing technologies; and 2) develop guidance for the use of mobile device data and analytics for adaptive work zone devices and congestion reduction through rerouting and alternative routing via crowd sourcing applications (WAZE, Google Maps, etc.).

The research objectives will be achieved through the completion of research tasks to be described by the research team that best addresses the research objectives. Possible tasks may include: 1) State Department of Transportation Surveys; 2) examination of case studies and best practices; 3) development of guidance documents; 4) conduct an exploratory workshop for refinement; and 5) implement a proof of concept demonstration on a state DOT project.

Construction staff and contractors working on DOT projects will use the results of the research to implement safer work zones utilizing technology that is currently available today.
Various advanced technologies have been adopted in the transportation industry to improve the accuracy and efficiency in design and construction, including GPS, LiDAR, and 3D/4D modeling. Transportation design and construction processes have been gradually improved with the emergence of these technologies. Many state DOTs and their contractors and consultants have been using 3D models for various applications in project planning, design and construction phases. The design and survey communities are advancing 3D/4D modeling and design (also referred to as Building Information Modeling (BIM) for infrastructure). The specific goals vary by state; however, the common goal is to eliminate 2D plan sets and make the 3D model the design of record. Construction contractors have been utilizing 3D models to increase their efficiencies utilizing Automated Machine Guidance (AMG) and developing BIMs for applications such as bridge beam erection plans and crane optimization. However, field Inspection staff have very limited exposure to this technology, and inspection processes and procedures using 3D/4D BIM have yet to be developed on a national level. Some states who are piloting 3D modeling generally have 2D plans still available. Eventually 2D plans will be eliminated as a deliverable so guidance and training for field inspectors is needed. Design models contain more data than is represented by 2D plan sheets. Conveying the model to field engineers and inspectors presents an opportunity to leverage this data in the inspection process. However, there is little research into how the exposure to this data, when combined with new technology, can make inspection more efficient or more complete.

The objective of this research is to identify technologies used by DOTs, inspectors in the vertical construction sector (i.e. BIM), or other technologies available that allow element location and dimension information from the model to be viewed, modified, or otherwise consumed by inspection staff. The research should identify the pros and cons of each and explore opportunities for inspectors to use data from the model rather than snapshots of the design plans.

Managers, engineers, and field inspection staff from Departments of Transportation will benefit from this research, as it will identify potential technologies that may be used by field staff, inspection staff, to leverage advancing technologies being used by designers and contractors.
Project 12-121

Developing AASHTO Specifications for the Use of FRP Auxiliary Reinforcement in Prestressed Concrete Beams and Girders

Research Field: Design
Source: Florida Department of Transportation
Allocation: $600,000
NCHRP Staff: Waseem Dekelbab

The objective of this research is to develop a methodology and AASHTO specifications for the design of Fiber Reinforced Polymer auxiliary reinforcement in prestressed concrete beams and girders. This research includes confinement, splitting, transverse shear, and interface shear.

Fiber Reinforced Polymers (FRPs) have made significant progress in highway structures as corrosion mitigation to extend the service life of structures, especially in aggressively corrosive environments. In the effort to further facilitate the use of these materials, AASHTO developed the AASHTO Guide Specification for the Design of Concrete Bridge Beams Prestressed with CFRP Systems (AASHTO-PBCFRP) and the 2nd edition of AASHTO LRFD Bridge Design Guide Specifications for GFRP Reinforced Concrete (AASHTO-BDGFRP).

The design of prestressed beams and girders includes prestressing and auxiliary reinforcement for confinement, splitting, interface shear, and transverse shear. Currently in the design of durable (corrosion free/corrosion-resistant) prestressed concrete beams and girders, engineers could use Carbon Fiber Reinforced Polymers (CFRP) prestressing according to the AASHTO-PBCFRP or Stainless-Steel Reinforcing according to the AASHTO LRFD Bridge Design Specification (AASHTO-LRFD) or shear in accordance with ACI 440. Engineers do not have specifications to guide them in the design of FRP reinforcement auxiliary reinforcement.

While stainless steel reinforcing is durable and can meet the load and durability demands, Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymers (GFRP) Bars and Basalt Fiber Reinforce Polymer (BFRP) reinforcing could provide a more economical solution. However, the behavior and the mechanical properties of CFRP, GFRP and BFRP bars are different from the traditional steel bars which are the basis of the current specifications, design methodology and procedures. Therefore, there is an urgent need for research and development of specifications and guidance for the use of FRP bars for auxiliary reinforcement in prestressed concrete beams.

The research results will be implemented within the AASHTO Guide Specification for the Design of Concrete Bridge Beams Prestressed with CFRP Systems (AASHTO-PBCFRB) and/or the 3rd edition of AASHTO LRFD Bridge Design Guide Specifications for GFRP Reinforced Concrete (AASHTO-BDGFRP). This implementation is expected to improve durability, economy, and efficiency.
Project 12-122
Evaluating and Implementing Unmanned Aerial Systems (UAS) into Bridge Management Methods Through Element-Level Data Collection

Research Field: Design
Source: AASHTO Committee of Bridges and Structures
Allocation: $400,000
NCHRP Staff: Waseem Dekelbab

The objective of this research is to (1) determine which bridge element types are most suited to UAS assessment, (2) determine what types of required element-level bridge management data cannot be collected via UAS and compare to traditional methods, and (3) compare UAS collected element-level data to data collected by an inspector with respect to data type, quality, cost, time required, traffic impact, or other.

There has been increasing interest and use of unmanned aerial systems (UAS, unmanned aerial vehicles / UAVs, or “drones”), especially in the past 10 years. One application of considerable interest to transportation agencies and their private sector partners is augmenting bridge inspections. There is particular interest in performing safety inspections of bridge members that are typically costly to routinely assess by an inspector. Through the use of UAS, the surface and subsurface of bridge decks can be assessed without requiring closing lanes of traffic or having inspectors exposed to traffic. For bridges over rivers or other water bodies, UAS can collect data underneath or along the fascia without the need to close traffic lanes to use a Snooper truck or similar system currently used for inspection of hard-to-access bridge elements.

However, research has not yet focused on the ability of UAS to support collection of element-level data in accordance with the AASHTO Manual for Bridge Element Inspection (MBEI) criteria. There is a need for research on how UAS can be implemented for fast and repeatable collection of location-specific, element-level data to meet federal requirements and to support bridge owner maintenance and identification of preservation needs. This research will help foster innovation in bridge inspection.

The results of this research can be used by transportation agencies as guidance on how to implement UAS where they can meet needs for accurate, and cost-efficient element-level data for bridge asset management.
Project 12-123

Load Rating Examples and Changes to the AASHTO Manual for Bridge Evaluation for Concrete Segmental Post-Tensioned Box Girder Bridges

Research Field: Design
Source: AASHTO Committee of Bridges and Structures
Allocation: $300,000
NCHRP Staff: Waseem Dekelbab

The objective is to develop a “Segmental Bridge Load Rating Guideline” based on real-world examples. These analyses will provide clear templates that will allow engineers to follow comprehensive procedures necessary to produce industry standard accurate load ratings for segmental box girders taking into account all pertinent variables.

Concrete segmental box girder bridges have proven to be an efficient means for accomplishing a solution for long span bridges. However, due to the complexities involved with the section shape, reinforcement, construction type and continuity conditions a common solution for load rating these bridges is essential. There is a lack of understanding among owners and the consulting community about how to accurately load rate new and older concrete segmental box girder bridges.

Concrete segmental box girder bridges were first constructed in the United States in the 1970s. The earliest concrete segmental box girder bridges were designed and load rated using methods that were often not codified by AASHTO, and differ significantly from the current AASHTO LRFD and LRFR. Many construction details used at that time are generally not used in the design and construction of today’s bridges; such as: fewer tendons in a cluster, open joints between precast segments in lieu of double faced epoxied joints, etc. As a result, the use of these details have resulted in significant reduction in capacity when evaluated using the current LRFR from the original load ratings. Current load rating criteria attempts to account for some of the details specific to segmental bridges, by including concrete tensile stresses in the calculation of the load rating at operating. However, applying these criteria to all segmental bridge types does not appear to be a consistent procedure for load rating concrete segmental bridges. As a result, there is a need to develop load rating criteria to accurately determine the load rating capacity of bridges designed in the time period before codification of the AASHTO LRFD and LRFR, to ensure safety and mobility.

A search was done that showed previous research on the barrier effects on transverse loads and a project in Florida that produced a program to analyze the axle equivalent transverse loading for segmental bridges. This project will build upon these reports to provide a comprehensive guide with examples.
Every state department of transportation (DOT) needs to determine the best way to dispose of aged or obsolete fleet assets. Some states require disposal of assets to be done by another state agency while others perform this function internally. In either case a decision guidance tool is needed to determine various methodologies/strategies to maximize sale proceeds.

Subjects to consider may include auction type (local, regional, online, etc.); bidding process (sealed bids, setting a reserve, no minimum bid, etc.); timing and frequency of sales; buyback and trade-in agreements; asset trade-ins; amount of labor and cost to spend to prepare equipment for sale; different strategies appropriate for different equipment types; and opportunities for improving existing operations.

Currently DOTs lack comprehensive information to help determine how prepare and schedule equipment for disposal/sale, estimate capital recovery, target the most appropriate bidders, and time the appropriate marketing method.

The primary objective of this research is to develop decision guidelines for state DOT fleet management organizations to use when disposing of surplus fleet assets. The end-product(s) will address:

- Disposal methods by vehicle and equipment types,
- Disposing of vehicles and equipment that are in various conditions,
- Disposal methods (auction, buy-back, trade-ins, salvage, etc.),
- Time or day of week/year and quantity of items offered,
- Frequency, location, and bundling of items, and
- Amount of reconditioning/clean-up/repair to perform (if any).

Expected tasks include a survey of fleet organizations, including state DOTs, other large public-sector organizations, appropriate private companies, and national equipment marketing companies to catalog information on the relative cost effectiveness of the specific equipment decommissioning and disposal methods they employ; an assessment of the survey results to identify relevant factors that would increase sales values; develop a decision tree.
Centerline and shoulder rumble and mumble strips have long served as a safety treatment tool to alert motorists to realign their vehicles to the driving lane. As part of the 2018 Midwest and Southeast Pavement Preservation Research Survey, rumble strip preservation was identified as a research need. Many rumble and mumble strips are installed as part of contract overlay projects where pavement thicknesses can be as thin as 1 inch. Rumbles are then ground into the new overlay effectively reducing the thickness in the grounded areas to \( \frac{1}{2} \) inch or less. In addition As a result the ground pavement area making up the rumble strip generally displays premature deterioration and requires ongoing maintenance to keep the roadway free of pot holes. The purpose of this research is five fold: (1) Threshold for minimum thickness of pavement or pavement overlay for rumble and mumble strips to be milled; (2) Threshold for the age of pavement or pavement overlay for rumble and mumble strips to be milled; (3) Effects of preservation strategies on pavement markings that are maintained or preserved on rumble and mumble strips; (4) Effects of sealers, rejuvenators and other preservation strategies on the performance of rumble and mumble strips; and (5) Strategies to maintain and preserve rumble and mumble strips to meet the design life of the pavement or pavement overlay. Much of the research done on the topic references the performance of rumble strips on how they perform their function in keeping motorists in their driving lane. More research is needed to determine the effects of rumble strips on older pavements and thin lift pavement overlays and offer solutions to owner agencies on how to maintain and preserve them for the life of the pavement.

The objective of this research is to develop a guide to maintain and preserve rumble and mumble strips that last as long as the main line pavement where they were installed.
Project 15-79  
*Development of Guidance for Non-Standard Roadside Hardware Installations*

Research Field: Design  
Source: AASHTO Committee on Design Technical Committee on Roadside Safety  
Allocation: $400,000  
NCHRP Staff: David M. Jared

Roadside safety hardware is critical for reducing severe crashes on U.S. highways. Roadside safety hardware such as guardrail is crash tested to assess its crashworthiness. The current crash test criteria is contained in the AASHTO *Manual for Assessing Safety Hardware* (MASH), and all highway agencies are in the process of implementing MASH hardware on their systems.

While MASH tested hardware is available for and reduces the risk of severe crashes for the majority of applications, situations may be encountered where the approved roadside safety hardware does not fit the specific location. There is an urgent need to develop guidance for special site-specific designs to guide highway agencies on appropriate hardware use and implementation for these non-standard situations where standard practices of crash tested barrier cannot be used. In absence of this research, the frequency of severe injury and fatal crashes will likely escalate as more miles of roadway with non-standard roadside hardware installations continue to increase.

The objectives of this research are to:
1. Identify common non-standard situations that are encountered by highway agencies  
2. Investigate potential crash tested solutions for these situations, if practical  
3. Identify best practices for situations where a crash tested solution may not be practical  
4. Develop guidelines that agencies can use for these situations

This research will provide guidance to assist state, local, and tribal agencies to provide the most practical solution for non-standard roadside hardware installation conditions. The guidance could be further implemented through an update of appropriate sections of the AASHTO *Roadside Design Guide* (RDG). Recommended guidance or specific solutions could be incorporated into a future update of MASH. Results of this research and the resulting guidance will be disseminated to state DOT design engineers, consultants, and practitioners through presentations and webinars at appropriate industry and professional meetings.
Extreme weather affects every state in the U.S. and hundreds of such events occur each year (e.g., hurricanes, droughts, heat waves, convective storms, floods, wildfires), leading to billions of dollars in asset damage, casualties, and community disruption. Sea levels, temperatures, and precipitation patterns are expected to deviate from the historic record, trending towards increases in extreme weather event frequency and severity. These are expected to stress transportation systems in many ways, increasing the risk of delays, disruptions, damage, casualties, and failure across our land, air and marine transportation systems. Many current permit requirements, design standards, and guidance do not account for extreme weather, future temperatures, changing precipitation, sea level rise, or other impacts from climate change. Infrastructure design needs to account for these conditions to cost-effectively minimize damage, disruptions, and failures.

Translating climate projections and corresponding extreme weather into information applicable to engineers for project-level design and specifications is complex. There are many locations around the country where state and local agencies (e.g., Arizona DOT, Colorado DOT, Delaware DOT, Port Authority of New York and New Jersey, and Genesee Transportation Council) have made incremental innovations in developing resilient infrastructure for the future. However, additional tools are still needed to support the system-wide change that helps support a cost-effective, safe, and high functioning transportation system. The research will identify state and national regulations, design standards, and guidance that are most at risk from extreme weather and climate change. The research will also develop tools and guidance to help state DOTs evaluate and balance the potential costs and benefits of incorporating updated guidance/standard that account for climate change into their project development process.

The FHWA Transportation Engineering Approaches to Climate Resiliency (TEACR) initiative summarizes activities related to this topic and has background on a range of engineering disciplines to help integrate climate considerations into transportation project development. Topics include: 1) why, where, and how to integrate climate considerations into the project development process, 2) practical information in related disciplines such as climate science and economics, and 3) lessons learned from project-level studies of engineering adaptation options.

Current design criteria for building and retrofitting transportation infrastructure are generally developed with an implicit assumption that the climate conditions under which the asset needs to perform will remain static over the design life. The objective of this project is to build on the foundation of the TEACR study to develop national design guidance for consideration of resilience and climate change.

Note: R&I suggested that this project encompass topics described in the original problem statement B-07: Integrating Resilience into Transportation Project Development.
As many states and localities adopt a vision of zero fatalities and serious injuries, increasingly greater attention is being given to communication, coordination, collaboration, leveraging resources, and applying a safe systems approach to traffic safety that requires a change in the culture, both among road users and traffic safety partner agencies, tied to education, engineering, enforcement, and emergency medical services.

Traffic safety culture (TSC) can be defined as the shared belief system of a group of people, which influences road user behaviors and safety partner actions that impact traffic safety. TSC is relatively new for safety partner agencies, and these agencies do not typically hire staff with traffic safety culture expertise. Also, while more research is being conducted on TSC, the majority of research exists on education, engineering, enforcement, and emergency medical services. The lack of research on TSC has resulted in insufficient knowledge in how to effectively and efficiently apply TSC strategies either alone or combined with education, engineering, enforcement, and emergency medical services.

A TSC research roadmap would identify the critical research to be conducted to yield the results that can be implemented by safety partner agencies. A key message from the literature is that a fundamental transformation/paradigm shift is needed to improve traffic safety through a positive TSC. A research roadmap can provide guidance for this fundamental transformation.

The objectives of this research are to (1) identify critical TSC issues that can be addressed by various research programs; (2) produce a prioritized research roadmap; (3) develop research problem statements specific to the research projects identified in the research roadmap; (4) provide next steps to facilitate completion of the research identified in the roadmap; (5) develop a communication plan to disseminate the research roadmap; and (6) develop a process/adaptive management plan to systematically revisit research priorities to guide future research and ensure relevancy into the future.

The roadmap should indicate why the research is critical to improving traffic safety, why it is important to safety partner agencies, and how they will be able to implement the results to improve traffic safety. Input should include the public, private, and academic sectors, as well as non-transportation sectors, such as public health and human services. The final product of this research will be a TSC research roadmap, along with problem statements and a plan to moving the problem statements through the research cycle, including implementation.
An estimated 6,227 pedestrians were killed in traffic collisions in the U.S. in 2018 – a 30.3% increase in pedestrian fatalities over the last five years and the highest number of pedestrians killed in one year since 1990. About 75 percent of these pedestrian fatalities occurred in darkness, and much of the recent increase in fatalities is driven by nighttime crashes. In fact, from 2008 to 2017, nighttime crashes accounted for more than 90 percent of the total increase in pedestrian deaths. Despite the magnitude of this problem, scant research focuses on the reasons for, and solutions to, this important and worrying nighttime trend. This study will identify and examine strategies to improve pedestrian safety in the dark and reduce nighttime pedestrian fatalities and severe injuries.

Pedestrians are at higher risk of a collision in the dark, all else being held equal. Severity of these nighttime collisions are worse than daytime crashes, with nighttime pedestrian collisions at intersections having an 83% higher chance of being fatal without street lighting and a 54% higher chance of being fatal with street lighting.

The reasons for this increased risk are not clear. Much research has been completed on vehicular headlighting and reflective clothing, finding that increased headlight sight distance and clothing conspicuity may improve pedestrian safety outcomes. However, this work was specific to vehicle lighting and reflective clothing and didn’t explore whether these issues are the principal cause of the collisions in the first place. Vehicle speed, limited-access roadways, and alcohol use by pedestrians have also been identified as issues. However, all these studies utilized data from 2004 or earlier, meaning that they don’t explain what has caused the substantial increase in nighttime pedestrian fatalities over the last ten years. Driver and pedestrian distraction and changing vehicle body types have also been suggested as possible explanations for the recent increase in pedestrian fatalities, but available data do not provide conclusive evidence for these connections. An on-going study in Virginia is developing guidelines for intersection and mid-block pedestrian crossing lighting design and warrants for use by the Virginia Department of Transportation, but a better understanding the role of lighting level plays relative to other causal factors would be warranted.

The objective of this research is to identify and evaluate strategies for improving pedestrian safety in the dark. To accomplish this, the research will begin by reviewing root causes of pedestrian-involved fatalities and severe injuries, and then evaluate existing strategies and research regarding nighttime pedestrian safety. It will then explore fatal and non-fatal pedestrian crashes to identify unique patterns in nighttime pedestrian crashes and safety outcomes. These patterns may be related to roadway or facility design, vehicle characteristics, user socio-economics or behavior, etc. With these patterns in mind, the research will propose solutions for the problems identified. Possible strategies may include interventions related to engineering (e.g. enhanced crossings, lighting, etc.), enforcement (e.g. distraction, alcohol use, etc.), and education (e.g. if certain populations are more impacted than others), depending on the patterns revealed in the research. These proposals may be tested with future research.

Specific research tasks may include:
1. Literature review of existing strategies and research regarding nighttime pedestrian safety issues leading to severe injuries and fatalities
2. Data collection (crash, roadway environment such as lighting, geometry, facilities, operational details, users, vehicles, etc.)
3. Identify safety patterns related to exposure (pedestrian and vehicle volumes), roadway or facility design, roadway lighting, traffic operations, vehicle characteristics, user socio-economics or behavior
4. Propose solutions to be investigated in future research

This research is an urgent need, as it seeks to reverse the worrying trend of nighttime pedestrian fatalities and severe injuries. The trend is found throughout the country and will be of high interest to a majority of DOTs as well as regional and local agencies. Arizona and Connecticut DOTs have specifically identified this as a high priority focus area. Findings will also serve to greatly improve overall pedestrian safety, with benefits directly to some of the most vulnerable users of our roads.
Many state DOTs have developed Intersection Control Evaluation (ICE) policies to objectively screen alternatives (e.g., traffic signal, roundabout, all-way stop, and innovative intersection design) and identify an optimal geometric and control solution for an intersection. According to the FHWA’s ICE webpage (https://safety.fhwa.dot.gov/intersection/ice/), these policies can promote (a) Implementation of safer, more balanced and more cost-effective solutions, (b) Consistent documentation that improves the transparency of transportation decisions, (c) Increased awareness of innovative intersection solutions and emphasis on objective performance metrics for consistent comparisons, and (d) The opportunity to consolidate and streamline existing intersection-related policies and procedures, including access or encroachment approvals, new traffic signal requests, and impact studies for development.

With the publication of the 7th Edition of the Green Book, AASHTO has begun a move towards performance-based design that emphasizes the location of the project in the transportation network and the surrounding environment and community, the type of service intended for all modes of travel, a flexible design approach that balances the needs of all users, and a performance-based approach for considering the effects of geometric design decisions. The proposed guide will align with this new direction. Many intersection improvement projects are initiated because of proposed land development. The developer is often not familiar with the options available and can bring political pressure on the agency for a particular design. A nationally recognized guide would promote a more productive dialogue with the developer. FHWA’s ICE Policy Webpage (https://safety.fhwa.dot.gov/intersection/ice/) that includes a primer and evaluation tools.

The objective of the proposed research is to develop an ICE guide that can be readily implemented by state and local transportation agencies. The guide should be applicable to projects initiated by the agency and those driven by land owners and developers. The proposed guide should take into account lessons learned from the 8-10 states that have already implemented ICE policies. The guide should provide the relative advantages of ICE policies that are more prescriptive (policies that are accompanied by step-by-step analysis tools) and ICE policies that are less prescriptive. The guide should describe a process that agencies can readily adopt into their manuals. In addition, model policy language should be included.
The US Department of Transportation (USDOT) developed its Accident Prediction and Severity (APS) models for highway-rail grade crossings (HRGCs) in the early 1980s. These models are used in decision support tools provided to federal, state and local authorities for the identification and evaluation of HRGC upgrades, separations and closures. The APS models, and other guidance documents, must be current as they are key in making informed HRGC judgements. This research will bring the APS models up to date, and specifically by addressing three major needs of the current APS models:

- Incorporating the latest incident data.
- Reflecting improvements in analytical methods.
- Including the full range of HRGC treatments and new HRGC technologies.

This research will provide a compressive synthesis of existing and emerging treatments for improving safety at HRGCs. The research will also offer guidance to assist state DOTs in making appropriate decisions for deploying new types of safety technology, and consistent criteria to evaluate and select HRGC projects. This guidance should aid states’ potential in using suitable funding sources for new types of safety technologies that are promising for enhancing HRGC safety, such as the Railway-Highway Crossings (Section 130) Program funds, found in 23 USC 130(e) of the Fixing America’s Surface Transportation (FAST) Act.

The first objective of this research is to synthesize current practices and emerging technologies focused on improving safety at HRGCs, develop a Concept of Operations (ConOps) for each technology, develop draft language to include in the Federal Highway Administration’s (FHWA) Manual on Uniform Traffic Control Devices (MUTCD), and provide guidance for state DOTs to select and experiment new technologies that are not included in the MUTCD. The second objective is to update the APS modeling framework, expand the assessment to include new technologies, examine the effectiveness of new HRGC safety treatments, and add support for pedestrians and non-motorized vehicles.
Project 19-18

*Transitioning Fuel Tax Assessments to a Road Usage Charge*

Research Field: Administration
Source: Utah Department of Transportation
Allocation: $600,000
NCHRP Staff: Dianne S. Schwager

Transportation agencies have an urgent interest in determining a viable alternative to the current transportation revenue system that is primarily dependent on fuel taxes. Electric and hybrid vehicle registrations are growing rapidly and continue to erode the funding base. Augmenting or replacing the fuel tax system with a road usage charge (RUC) system requires a transition period, especially if vehicle manufacturers need to be part of the solution. It is critical that states work together quickly to research and develop a plan.

Several states have published reports on their road usage charge (RUC) pilots such as California, Colorado, Washington and the I-95 Corridor Coalition, which is comprised of 16 eastern states plus numerous cities and other agencies. Another consortium of 16 western states, RUC West, has published interim reports on its interoperability pilot and final reports on over a dozen RUC related research projects. However, this literature on RUC is not based on field testing nor is it comprehensive enough to provide clear direction for transitioning a state or the nation to a RUC. Oregon is the only state currently charging a small percent of registered vehicles a road usage charge. Beginning in 2020, Utah will become the second state to do so.

The objective of this research is to understand the challenges, opportunities and practical methods for possibly transitioning from fuel-based taxation to an RUC system at state and federal levels. The final deliverable will provide estimates of transportation revenue generation, suggestions for collecting and distributing revenues in different RUC scenarios, and recommendations for transitioning over time to a RUC based revenue system.

The research should consider:

- Efficient solutions for vehicle mileage data collection, privacy protection, and operating processes.
- Recommendations for mileage collection and payment mechanisms such as embedded telematics or connected vehicle communication.
- How different vehicles should be charged RUC such as electric vehicles, high efficiency vehicles, and heavy trucks.
- State-to-state interoperability concepts that could be used to distribute revenues among states for interstate travel.
- Processes to significantly reduce RUC administrative costs e.g., (1) blockchain or other crypto-technologies to make data collection and financial transactions more efficient and (2) system enforcement for increased compliance to reduce revenue leakage.
- Best practices for multi-state standards development and certification processes.
- Uses of RUC to provide opportunities for funding city and county transportation needs.
- Political and public acceptance factors for transitioning to RUC.
Project 22-50

Crashworthiness of Roadside Hardware on Curbed Roadways

Research Field: Design
Source: AASHTO Committee on Design Technical Committee on Roadside Safety
Allocation: $400,000
NCHRP Staff: David M. Jared

Roadside hardware is often installed alongside curbed roadways. The standardized full-scale roadside hardware crash test procedures, however, do not normally include curb near or around the tested roadside safety feature. Although it is generally recommended to not install roadside safety features behind curbs, it is often necessary to do so along roadway corridors where curbs are needed. Some previous research examined the effects of curbs in front of longitudinal barriers but there is relatively little known about the effect curbs on the impact performance of common roadside safety features, especially guardrail end terminals, crash cushions, and breakaway hardware.

The objective of this project would be to determine the effect of curbs on the impact performance of various roadside hardware devices. The approach could be to use in-service performance evaluation, full-scale crash testing, computer simulation or some combination of these methods. There is a need to develop objective guidance for the placement of roadside safety features in addition to w-beam guardrail in combination with curbing. This research will build on the guidance provided in the AASHTO Manual for Assessing Safety Hardware (MASH), the nearing completion NCHRP 22-33, “Multi-State In-Service Performance Evaluations of Roadside Safety Hardware,” and the guidance documented in NCHRP Report 357, Recommended Guidelines for Curb and Curb–Barrier Installations, to expand the body of knowledge beyond w-beam and curb combinations.

The need to identify the most common safety devices and the effect of a curb on the functionality of the device will provide a measure of assurance in the choice and placement of traffic safety devices and a higher level of safety for the traveling public.

State DOTs continue to strive to reduce the frequency and severity of run off the road crashes while balancing community and environmental needs, accommodation of utilities, and effective use of limited transportation budgets. This research will quantify the crash risk and will provide guidance which allow engineers to balance the competing need for both curbing and roadside safety features. It is anticipated that the results of this research will be incorporated into a future update of the AASHTO Roadside Design Guide. State DOTs may utilize this research as a foundation for policy development for the use of curbing in combination with roadside safety features.
AASHTO’s *Manual for Assessing Safety Hardware* (MASH) contains the testing and evaluation criteria used to evaluate various roadside safety features. As written in the preface of MASH’s 2nd edition (MASH 2016), “this document’s purpose is to encourage consistency in crash testing and evaluation.” One of the components to establishing consistency between crash tests is the use of a standard soil, as soil strength can affect the performance of safety barriers embedded within roadside soils. Although a specific soil is not specified, there are requirements for the strength of the soil. Strong soils are typically considered more critical that weaker soils because stiff soil conditions result in higher impact/rail forces, increased propensity for rail tearing and rupture, and increased rail pocketing. Accordingly, MASH 2016 lists a minimum force resistance for soils used in crash testing. The methods and specifications for the standardization of test soil conditions were developed in the mid 2000’s during the formulation of the first edition of MASH. MASH 2016 specifies that a dynamic impact test is conducted on a W6x16 post embedded in the soil, and the post-in-soil must maintain a resistance over 7,500 lb between 5 and 20 inches of deflection. The soil must be verified prior to conducting the crash test. To prevent having to conduct an elaborate dynamic test on test day, MASH describes a methodology in which a soil satisfying the dynamic testing strength is then evaluated in a quasi-static test by pulling on a similar W6x16 post installed in the same soil. The lateral forces recorded at displacements of 5, 10, and 15 inches then become the baseline values to which future static tests (conducted on crash testing days) are compared.

Unfortunately, the establishment of only a minimum force specification has resulted in greatly differing soils among crash test labs and between tests. Recently, the members of Task Force 13’s subcommittee 7 conducted an inter-lab comparison on the soils used for crash testing. This comparison showed a wide variety of soil strengths being recording on test days, some of which could be three times stronger than other soils that had passed the minimum requirements. The inconsistent soil strengths were observed in comparisons between crash testing labs and in comparisons of tests conducted within a specific lab. Additionally, the roadside safety community has started to observe some questionable crash test results. The results may be as small as system deflections and working widths differing from the expected values to system failures of what had been thought to be crashworthy systems. It has been suggested that soil strengths greatly exceeding the MASH specifications may be causing these unexpected test results. Subsequently, questions have risen pertaining to the need for an upper bound, or force maximum, for the soil strengths. Additionally, the inter-lab comparison also revealed significant differences in soil installation procedures, soil gradation analysis methods, and soil testing equipment. Many of these differences are likely the result of ambiguous language or the omission of details within MASH 2016. Therefore, there is a need to review and revise the current MASH 2016 soil specifications and evaluation procedures to provide more consistency between crash tests and prevent unnecessary alterations to crashworthy safety devices.
The soil specifications and evaluation procedures found in MASH 2016 were developed through a study in the mid-2000s for inclusion in the first edition of MASH. Through a survey of the force versus displacement characteristics of posts-in-soil at various crash testing labs throughout the United States, a minimum dynamic force was established to ensure strong soil conditions. The static baseline testing procedure was recommended as a means to avoid having to conduct dynamic tests immediately prior to the crash test. With the MASH soil evaluation procedures being around for more than 10 years now, most likely there are many more dynamic and static post-in-soil tests conducted per MASH evaluation criteria that can be utilized to better define strong soil specifications. Between 2012 and 2014, Task Force Subcommittee 7 had many discussions pertaining to the MASH soil specifications, testing procedures, and areas for clarification and improvement. Numerous recommendations were made, including using absorbed energy instead of force to evaluate soil strength, use of accelerometers instead of load cells to obtain force values, ambiguity and errors in the MASH 2009 test procedures, etc. These recommendations have yet to be included in MASH.

An inter-lab comparison on soil strengths was conducted by the members of Task Force 13’s Subcommittee 7. This comparison of soil types, installation methods, and soil strengths revealed significant variability in the soil conditions between labs and between tests. A significant lack of consistency between soil installations was noted. Additionally, some labs had soil strengths approximately three times higher than other soils that had passed the MASH specifications. Thus, Subcommittee 7 questioned whether MASH only specifying a minimum force had resulted in some labs overcompacting their soil installations and utilizing artificially high soil strengths. Strong-post guardrail systems rely on the posts to rotate through the surrounding soil and absorb impact energy in order for the guardrail system to perform in a safe and reliable manner. Crash tests of guardrail posts installed within in rock, concrete, and asphalt have repeatedly resulted in excessive rail forces, rail ruptures, and test failures. Thus, there have long been recommendations to provide leave-outs around the base of a post installed in rock or pavements. Recent crash testing of guardrail systems that were expected to perform adequately have resulted in similar rail ruptures and failures. These failures have drawn concern that artificially high soil strengths may be causing unexpected failures during the testing of otherwise crashworthy guardrail systems.

The objective of this research is to (1) Review the soil specifications and evaluation procedures in MASH 2016; (2) Review the types and strengths of soils as well as the evaluation procedures used at various crash testing labs conducting MASH testing; (3) Evaluate the need to tighten the MASH soil specifications including the inclusion of a maximum soil strength; and (4) Identify any deficiencies, limitations, ambiguity, and/or inadvertent effects of the current soil specifications; Provide recommendations for the revision of the MASH 2016 soil specifications and evaluation procedures. MASH testing guidelines were intended to provide consistent and reproducible tests. However, as observed in the in the recent Inter-lab Comparison between the crash testing laboratories, soil strengths can greatly differ between labs and between tests. This can and likely has resulted in inconsistent crash test results, which include (a) Variations to the system deflection and working width of a barrier system due to drastically different soil strengths; (b) Failed crash tests on an otherwise crashworthy system due to artificially high soil strengths; and (c) Increased costs to roadway agencies and barrier manufactures who are trying to evaluate their barriers in unintentionally inconsistent soil conditions. The completion of this research project would result in the formulation of recommended revisions to the soil specifications and evaluation procedures in MASH 2016. These revisions are intended to (a) Clarify areas the MASH 2016 soil specifications that may be ambiguous or unspecified; (b) Improve and/or expand upon the soil
strength requirements to provide more consistency in testing procedures and soil strengths between crash test labs; and (c) Simplify and streamline the soil evaluation procedure to reduce time and costs spent on soil evaluations.
State and local DOTs are being asked to solve ever more complex transportation problems and issues. AI tools are being proposed and tested to help address a number of these issues, including improving safety, alleviating traffic congestion, assisting in real-time systems management, accommodating connected/automated vehicles, and preserving the infrastructure, among others. However, transportation agencies have been provided with little overall guidance, policies, standards, or a knowledgeable workforce to effectively apply AI solutions.

A TRID literature search identified almost 100 papers on artificial intelligence applications in transportation published in TRB’s Transportation Research Record: Journal of the Transportation Research Board in the last 5 years alone. However, almost all of these papers deal with very specific applications of AI. With the exception of the TRB e-Circular, “Artificial Intelligence Applications to Critical Transportation Issues,” published in 2012, there does not appear to be any strategic guidance that state and local DOTs can use to most effectively apply AI to help improve their operations and to solve transportation problems. Nor is there any up-to-date overview on experiences to date or any synopsis of the most promising application for state and local DOTs.

The objective of this research is to develop a research roadmap to prioritize and fund research through the NCHRP program that will provide state and local DOTs with a better understanding of AI, potential applications, priorities, and implications for state and local DOT management and operations. The roadmap will also be useful to the U.S. DOT, state DOT research offices, universities, and other research organizations in generating research and in coordinating the research among these organizations. The roadmap should be coordinated with the February 3, 2020, Federal Highway Administration’s Exploratory Advance Research (EAR) Program Broad Agency Announcement seeking demonstration of AI in new areas of importance to highway transportation.

The resulting research roadmap will help state and local DOTs answer the following questions:

- What is artificial intelligence, and how is AI different from what we have been doing for decades, for example, using data to calibrate models?
- When should AI be considered as a possible tool to leverage information and/or to help implement solutions?
- How is AI currently being applied in transportation?
- What are some of the opportunities for AI breakthroughs not previously possible?
- What are the potential longer term implications and opportunities of AI on transportation in general, and on transportation policies in particular?
- What are the workforce and diversity implications of AI in transportation, and how do we prepare the transportation workforce for AI?
- What are the data and privacy challenges of AI in transportation, and how can they be overcome?
- What are some of the potential human impacts of AI, including fairness and equity implications?
• What policies and/or standards are needed to assist state and local DOTs in successfully applying AI?
In most state DOTs, about 40% of the workforce will be eligible for retirement in the next 3 years, taking with them institutional knowledge. In addition, collaboration and interdisciplinary work are increasing the need for effective and efficient knowledge transfer. State DOTs will benefit from knowledge management (KM) to help identify, capture, and transfer institutional knowledge. Development of a research roadmap for KM will identify and prioritize the KM research needs of state DOTs and provide a foundation for maturation of KM practice.

Although existing KM research roadmaps were not found in the literature, some literature exists on KM and institutional knowledge in the transportation sector that provides recommendations which could be considered in a research roadmap. There are also several references about how to start building up KM function in an organization, which could also facilitate development of a KM research roadmap in the transportation sector.

The objective of this research is to develop a 10-year prioritized program of research for KM. The roadmap should identify research that will provide practical and useful information and implementable tools, recommend research priorities and sequence, set a strategy, and provide a rationale for the recommendations. The roadmap should

- Clearly describe a broad set of research topics based on an understanding of current state DOT and industry KM practices.
- Identify gaps in the following: knowledge, interfaces with other subject matter of interest, disciplines, and best practices.
- Outline and prioritize specific research ideas needed to address these gaps.
- Conduct a workshop to review the draft roadmap.
- Produce a research roadmap that (a) facilitates understanding of the topics, sequence, and relationships of the research needs; and (b) supports use for the TRB Research Needs Statement database, website content, outreach material, and funding requests.
- Provide a plan for communication and outreach.

The KM research roadmap will define a strategic approach to KM research to develop the information and tools needed to expedite the integration of KM into state DOTs. The research roadmap can be used to guide development of research funding requests and activities.
The potential emerging change of new technologies, including connected and automated vehicles, brings a long list of potential challenges to DOTs and other agencies who own and manage the existing infrastructure. At the AASHTO Joint Committee on Transportation System Operations (CTSO)—Committee on Transportation System Security and Resilience (CTSSR)—Subcommittee on Risk Management (SRM) meeting held in August 2019, a breakout session focused on listing some of the threats and opportunities but left questions about which were most likely to occur and where the largest impacts could be. This created an opportunity to help prioritize these threats and opportunities as well as potential management strategies using a risk-based approach in order to identify which would be most important to address first, innovate knowing the calculated risks, and to also identify where research can be used as a risk mitigation tool.

A risk-based approach would utilize tools created through NCHRP and AASHTO (i.e., the AASHTO Guide for Enterprise Risk Management) through a facilitated process with key stakeholders to identify threats and opportunities of emerging technologies, their impact and likelihood of occurrence, possible risk response strategies to reduce the level of threat or take advantage of opportunities, ownership level of the response strategies (e.g., national, state, or local agencies; private, public, or nonprofit sectors), and, finally, identify the subsequent risk rating if the response strategies were acted upon. This will provide a prioritized list of strategies to address unknown responses and other risks. Because research can be a very effective tool in managing risk, opportunities for additional research will be identified, the results of which can also provide a national research roadmap to address potential threats and opportunities of emerging technologies. A summary report will be produced with the findings of the risk assessment and research.

Emerging technologies are forcing global changes that are capturing the attention of transportation agency leaders within AASHTO; however, in order to maximize resources, there needs to be alignment in policy and approach at a national level. This project would utilize the goals and objectives of CTSO and SRM, as well as other potential AASHTO committees and councils as the basis for assessing risks. The results of the risk-based approach and prioritization would then align with meeting broader strategic objectives of the AASHTO committees.

The objective of this research is to place value and increase awareness on the greatest needs and opportunities resulting from potential implementation of emerging technologies that affect our transportation system. The desired outcome and final product includes the development of a risk-based prioritized listing of threats and opportunities that can advise state DOTs, the FHWA, and other key stakeholders of the most urgent issues and the best means for addressing them at this time. Major tasks include working with the project panel to clearly define the objectives of the risk assessment effort; assembling and facilitating one or more key stakeholder groups, subject matter experts, and potential risk owners to develop a comprehensive list of threats and opportunities; and then using the same group to rate the risks, define risk management strategies and levels of ownership for each strategy, and rate the resulting risks if the risk management strategies are
implemented. Resulting research problem statements can then be extracted and placed into a research roadmap for emerging technologies. A summary report that includes the risk assessment and resulting strategies can also be produced.

This project is expected to coordinate with the work that is being done under

- NCHRP Project B08-127, Emerging Issues: Impact of New Disruptive Technologies on the Performance of DOTs,
- TRB Forum on Preparing for Automated Vehicles and Shared Mobility’s Scenario Planning Effort, and
- PIARC Technical Committee 1.1 – Emerging/Disruptive Technologies on Transport Administrations.

This project will inform and benefit state DOT leadership, program owners, and technical experts. State DOTs as well as other key stakeholders such as government agencies, the private sector, and nonprofit areas will be able to take the results of this research, understand their ownership role, and act appropriately to identify where resources are needed both now and in the future to prepare for and implement change resulting from emerging technologies. Additional products and activities could include peer exchanges, workshops, webinars, presentations, and potential products for future phases of implementation.
As artificial intelligence (AI) and machine learning (ML) technologies are becoming more ubiquitous, it is important for state Departments of Transportation (DOTs) to evaluate, understand, and leverage them for problem solving, advanced data analytics, automation, and to anticipate disruptive change as a result of AI and ML. Data are the fuel for AI and ML; therefore, the right data management strategy is needed to increase the odds of success. State DOTs are eager to capture the potential of AI, but there is confusion around the overwhelming number of potential applications and regarding which use cases are realistic to pursue. For example, analyzing data to predict citizen preferences and behavior, leveraging AI to automatically classify complex data, AI-driven search, and autonomous vehicles are gaining gradual adoption and may soon be deployed to transportation systems. As a result, it is important for state DOTs to anticipate this disruptive change. The emergence of big data from Internet of Things (IoT) devices, UASs, and LiDAR, etc., presents additional challenges for state DOTs with limited resources to be able to consume and react to big data.

The objectives of this research are to provide the state DOTs with tools and information to implement and leverage AI and ML for the efficient, intelligent operation of a state DOT, and to facilitate evidence-based decision making. The research will look at the (a) desirability (use cases and scenarios where AI and ML are best positioned to help); (b) feasibility (model validation, pilot and other such confirmation steps); and (c) viability (focusing on ROI, and a set of readiness criteria) of using AI and ML techniques.

The proposed research will (1) illuminate the impact of AI/ML on compliance and governance; (2) generate better understanding of AI and ML; (3) identify and learn from existing implementations at state DOTs; (4) develop common use cases; (5) provide investment return analysis; (6) identify data maturity required; (7) develop common tools such as AI and ML models and code repositories that can be shared by state DOTs; and (8) generate an understanding of the skills necessary to leverage AI/ML at a state DOT. This research will benefit state DOTs by helping them chart a course to successfully pursue AI and ML program, set up key foundational elements and technologies, improve their data analytics capability, leverage existing data for insights and decision making, increase automation in state DOT functions, and anticipate disruptive change instead of reacting to it.

The desired outcomes and final products may include (a) a report outlining research methods and findings; (b) an approach to build a roadmap for an AI and ML program within a state DOT, including key foundational elements that must be considered; (c) a set of procedures to help narrow the focus toward practical use cases, with examples; (d) AI and ML case studies that were developed during research; (e) code repositories/tools that will be shared with all state DOTs; and (f) a guide to the necessary training for state DOT employees to properly utilize AI and ML.
State DOTs use metrics to measure and monitor the effectiveness of activities conducted by their organization. Recently, DOTs are starting to integrate strategic knowledge management practices and are lacking the resources and experience to monitor these new activities. However, organizations in the private sector and federal government have experience with knowledge management and many have established methods and metrics to manage their knowledge management programs.

This research will review knowledge management assessment and measurement methods carried out in the private and public sector, and will provide information to determine the value of the emergent knowledge management practice in state DOTs. Assessing and measuring these practices will support DOTs in capturing the value gained from knowledge management. Value such as increased productivity, reduced costs, institutional knowledge, and greater organizational resilience and agility.

The objective of this research is to create a guidebook for developing knowledge management assessment and measurement methods that are relevant to state DOT business interests and that reflect state DOT knowledge practices. The research will include a literature review that explores the methods for knowledge management assessment and measurement used in the public and private sectors. The literature review will then be used to define knowledge management practices and benchmarks for state DOTs and to subsequently inform the identification and selection of professionals for interviews. Lastly, the study will examine current DOT assessment and measurement methods and their application for use in knowledge management.

The boundaries of this research will not include intellectual property rights.
The AASHTO Drainage Manual (ADM 2014) provides a template and baseline for the development of state DOT highway drainage design manuals. The ADM serves as the default standard in the absence of a state DOT drainage manual for federally funded projects. Since inception, the ADM has been written in terms so that any agency can adopt and implement with their specific design criteria reflecting their specific policies, saving significant time and resources. Since the original publication in the 1970s, many DOT drainage design manuals have been developed based on the information and cumulative experience represented by this document and its subsequent editions. It is a publication reflecting the best knowledge and experience of several generations of highway hydraulic engineers.

NCHRP Project 20-07(417) evaluated various alternatives to improve the efficiency of the Technical Committee on Hydrology and Hydraulics (TCHH) in updating the ADM. The proposed reorganization suggested by NCHRP Project 20-07(417) will create smaller, more manageable publications that will permit faster implementation of research findings and emerging technology. The nimbler AASHTO drainage publications in the future will improve the TCHH’s timeliness in updating publications.

The objective of this research is to produce a new edition of the AASHTO Drainage Manual, following the detailed outlines developed in NCHRP Project 20-07(417), which will create smaller, more manageable publications that will permit faster implementation of research findings and emerging technology.

Accomplishment of this objective shall require the following tasks: (1) confirm changes identified in the revised outlines developed in NCHRP Project 20-07(417) and identify any additional deficiencies that should be updated in the new publications, such as aquatic organism passage through culverts, applying climate change, two-dimensional modeling, inlet design, and culvert and storm sewer inspection; (2) develop a work plan to evaluate the best approach to developing new publications of the AASHTO Drainage Manual and Highway Drainage Guidelines documents and propose a schedule and milestones for completion of the work; and (3) in accordance with the approved work plan, prepare draft and final publications of the new AASHTO Drainage Manual.
Some state DOTs have been conservative in their design approach and have discounted partially or completely either the estimated side or end resistance due to concerns with the effects of the various installation methods. For example, AASHTO (2014), Section 10.8, provides minimal guidance or commentary on using casing reduction factors to estimate the side friction of a cased drilled shaft. The predicted values of axial resistance for drilled shafts should be reduced accordingly when permanent steel casing is to be used along the partial or entire length of the element. AASHTO LRFD Bridge Design Specifications (2014), Section 10.8.3.5.2b (side resistance), provides the following: “Steel casing will generally reduce the side resistance of a shaft. No specific data is available regarding the reduction in skin friction resulting from the use of permanent casing relative concrete placed directly against the soil…Casing reduction factors of 0.6 to 0.75 are commonly used. Greater reduction in the side resistance may be needed if oversized cutting shoes or splicing rings are used.” For some state DOTs, the recommended factors vary from the range presented in the above-referenced section of AASHTO; for others, the factors are considerably lower or even zero, thereby eliminating any contribution from side resistance. During the past three to four decades, design demands have increased as the magnitude of axial, lateral, and flexural loadings have considerably increased due to larger superstructures, updated design codes, etc. As such, the diameter and depths to which drilled shafts can be constructed have increased substantially during this same time as a result of advancements in equipment and tooling technology and capabilities. As the methods, equipment, and tooling have evolved, there are remaining concerns regarding how the various installation methods affect the design (i.e., load transfer characteristics via side and end resistance) and the long-term performance of drilled shafts.

Experience has demonstrated that different types of installation methods, use of steel casing, and/or the drilling support fluid (i.e., slurry) may have significant effects on geotechnical load transfer characteristics (e.g., side and end resistance) and long-term performance. Given the widespread use and dependency on drilled shaft foundations, ongoing concerns regarding the effect of construction installation methods warrant a focused research investigation. Moreover, there are other construction effects that are just being recognized in the industry, such as the effect of a natural-synthetic (i.e., bentonite-polymer) blend of drilling support fluid (slurry) and the influence of rotator/oscillator-installed steel casing. FHWA GEC-10 provides emphasis on the importance of understanding the various construction methods used to install drilled shaft foundations, noting the effective use and design of drilled shafts requires knowledge of the construction methods used for these foundation elements. Drilled shaft construction is sensitive to the ground conditions encountered at the site, and the costs and magnitude of effort involved are closely tied to the ground conditions and the construction techniques that must be used for a particular circumstance. Performance is related to the effectiveness of the construction technique in preserving the integrity of the bearing materials and ensuring the structural integrity of the cast-in-place reinforced concrete drilled shaft foundation. AASHTO LRFD Bridge Design
Specifications (2014), Section C10.5.3.4, further reinforces the position statement in FHWA’s GEC-10, noting the design of drilled shafts ... should include the effects of the method of construction, including construction sequencing, whether the shaft will be excavated in the dry or if wet methods must be used, as well as the need for temporary or permanent casing to control caving ground conditions. The design assumptions regarding construction methods must carry through to the contract documents to provide assurance that the geotechnical and structural resistance used for design will be provided by the constructed product.

The AASHTO LRFD Bridge Design Specifications establish the national standard for design and construction for public infrastructure projects. However, various state departments of transportation (DOTs) have developed their own state-specific standards of practice based on experience, differences in local/regional geology, etc. Understandably, the design of and construction methods used for drilled shaft foundations vary widely across the U.S. and extend to various components of the construction methods, including dry method vs. wet method; natural vs. synthetic drilling support fluids; temporary vs. permanent steel casing (e.g., cast in drilled hole [CIDH] and cast in steel shell [CISS] including driven vs. drilled vs. spun into the ground; auger vs. bucket vs. grab methods of excavation; rotary drilling methods vs. vibratory / impact hammer, and rotator / oscillator methods).

Owens and Reese (Owens, M.J., and Reese, L.C. The Influence of a Steel Casing on the Axial Capacity of a Drilled Shaft. Report No. 255-1F. Texas State Department of Highways and Public Transportation Center for Transportation Research, Bureau of Engineering Research, University of Texas at Austin, Austin, TX) evaluated the effects on side resistance due to different construction methods of installing steel casing at two sites with different soil conditions. The authors concluded that (1) the effect of different casing installation methods on the unit side resistance was considerable (e.g., unit side resistance decreased by as much as 70 to 90% when casing was used compared to no casing); (2) vibratory means of installation caused densification of the sand deposit, resulting in an increase in unit side resistance; and (3) at one location, the loose-to-medium dense sand was densified to a degree such that the steel casing could not further penetrate. Camp et al. (Camp, W.M., Brown, D.A., and Mayne, P.W. Construction Methods Effects on Drilled Shaft Axial Performance. Deep Foundations 2002, Geotechnical Special Publication No. 116, M.W. O’Neil and F.C. Townsend, eds., ASCE, Reston, VA, 193-208) reported the results of a load testing program that was performed to evaluate the axial load transfer characteristics of three partially permanently cased drilled shafts. The authors reported significant differences in drilled shaft performance for dry, slurry, or casing methods in a cemented clay and that the unit side resistance decreased by an average of about 66% (range of 42% to 80%), as compared with uncased drilled shafts. Brown et al. (Brown, D.A., Turner, J.P., and Castelli, R.J. Drilled Shafts: Construction Procedures and LRFD Design Methods. Report No. FHWA-NHI-10-016. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., 2010) reported that polymer slurry can outperform bentonite slurry, specifically in terms of side resistance.

The LRFD Bridge Design Specifications, Section 10.8.3.5.2b (side resistance), provides minimal guidance or commentary on using casing reduction factors to estimate the side friction of a cased drilled shaft. The predicted values of axial resistance for drilled shafts should be reduced accordingly when permanent steel casing is to be used along the partial or entire length of the element. The code provides the following commentary: “Steel casing will generally reduce the side resistance of a shaft. No specific data is available regarding the reduction in skin friction resulting from the use of permanent casing relative concrete placed directly against the soil...
Casing reduction factors of 0.6 to 0.75 are commonly used. Greater reduction in the side resistance may be needed if oversized cutting shoes or splicing rings are used.”

Lee et al. (Lee, J., Basnett, C., and Muhammad, S. Case History: Effects of Permanent Casing on the Axial Resistance of Drilled Shafts. Proceedings, Geotechnical and Structural Engineering Congress 2016, ASCE, Reston, VA, 151-162) reported on the findings from a load test program on eight drilled shafts, in which the casing was installed using vibratory means. The results from the dynamic load tests were compared with predicted values of unit side resistance (using AASHTO, 2010, and Brown et al., 2010). The authors reported that the unit side resistance of the installed casing was less than the predicted values as much as 35% to 47% in both the sand and clay strata. Li et al. (Li, Q., Stuedlein, A.W., and Marinucci, A. Axial Load Transfer of Drilled Shaft Foundations With and Without Steel Casing. *DFI Journal - The Journal of the Deep Foundations Institute*, 2019, 11:1, p. 13-29, DOI: 10.1080/19375247.2017.1403074) reported that the uncased shafts outperformed the cased shafts and the uncased shafts exhibited significantly greater unit side resistances than did the cased shafts. The axial resistances for the two cased test shafts were fully mobilized prior to the completion of the testing and at loads considerably lower than the maximum anticipated test load. However, the axial resistances for the two uncased shafts were not fully mobilized (i.e., did not achieve a peak or ultimate resistance). Compared with the cased shafts, the enhanced axial load transfer characteristics for the uncased shafts were attributed to an enhanced bond at the concrete-to-soil interface than it was for steel-to-soil interface; to the rougher soil-to-concrete interface; to larger as-built shaft diameters for the uncased test shafts; and to the presence of possible gaps between the soil and casing for the cased shafts. The authors reported that the steel cased drilled shafts indicated a reduction in unit side resistance ranging from about 75% to 95%, as compared with uncased drilled shafts. Recent research performed at the University of South Florida (Mobley, S., Costello, K., and Mullins, G. The Effect of Slurry Type on Drilled Shaft Cover Quality. *DFI Journal - The Journal of the Deep Foundations Institute*, 2019, 11:2-3, p. 91-100, DOI: 10.1080/19375247.2018.1468522) suggested that drilled shafts installed with bentonite slurry exhibited more significant flaws in the concrete cover than comparison shafts installed with polymer slurry.

Unpublished load test results from the signature Harbor Bridge currently under construction in Corpus Christi, Texas, indicated that the side resistance decreased as the time of exposure of the bentonite slurry within the borehole increased. Furthermore, locally established correlations based on the results of in-situ testing tended to overpredict the side resistance of the drilled shafts. The LRFD Bridge Design Specifications do not explicitly account for some of the numerous construction effects that have already been identified herein. This proposal addresses four of the eight strategic objectives identified in NCHRP Project 20-07/Task 335. Namely, this research will enhance the AASHTO Specifications for many aspects of drilled shaft design (No. 4), accelerate bridge delivery and construction (No. 5), optimize structural systems that are affected by drilled shaft performance (No. 6), and contribute to national policy (No. 8).

The main objectives of the research program are to quantify the installation effects on side and end resistances for different types of drilled shaft foundations (e.g., uncased, cast in drilled hole [CIDH], and cast in steel shell [CISS]) in different soil conditions due to various installation methods (e.g., dry method vs. wet method; natural vs. synthetic vs. blend drilling support fluids; temporary vs. permanent steel casing; driven vs. drilled vs. spun into the ground; rotary drilling methods vs. vibratory/impact hammer vs. grab methods; etc.). Ultimately, a report will be developed that will present how the various construction techniques affect design, which will form the basis for design guidance for state DOTs regarding technique-dependent installation effects.
Bridge repair and replacement projects are required to implement measures to avoid and minimize impacts if protected bats are present. Furthermore, bats across the United States are threatened by a relatively new fungal disease known as white-nose syndrome (WNS). WNS has resulted in bat population declines of over 90% in parts of the northeastern and midwestern United States, and the fungus is continuing to spread westward. These declines most recently resulted in the U.S. Fish and Wildlife Service listing the northern long-eared bat (*Myotis septentrionalis*) as threatened under the federal 2015 Endangered Species Act, and it is anticipated that additional bat species will be listed in the coming years. Many states have protections for other bat species as well.

The northern long-eared bat, as well as other bat species, will utilize bridges and similar structures as day-time and/or night-time roosting habitat, and as places to form maternity colonies where they give birth and raise their young. State departments of transportation (DOTs) can take a number of measures to reduce impacts to bats including timing activities to avoid the season when bats are present; deterring or excluding bats from using bridges and similar structures during maintenance and construction activities; and, in some cases, providing alternate roosting locations. However, timing restrictions can be challenging to implement, especially in parts of the country with long and cold winters and short summer construction seasons. Exclusion and deterrence measures of various types are not always successfully implemented, which can result in work delays if bats continue to use the bridge. Some methods incur higher costs for materials or labor for installation and maintenance than others.

This research will focus on strategies and practices for temporarily deterring and excluding bats from using bridges to facilitate construction and maintenance activities, while minimizing harm to bats and non-target species. These may include, but are not limited to, technology such as non-lethal ultrasonic acoustic devices, physical exclusionary devices, and light devices.

Providing state DOTs with up-to-date information on exclusion and deterrence measures will make permitting, construction, and maintenance timelines more predictable and easily manageable; provide state DOTs with effective strategies for meeting current and anticipated regulatory requirements for work on bridges and similar structures where bats are present; and afford long-term cost savings for agencies. Further, the research will help state DOTs demonstrate due diligence and interagency collaboration on environmental issues and reduce the transportation sector’s impacts on imperiled bat species.

This project will collect information from published literature and from practitioners on currently used and innovative methods for temporary bat deterrence and exclusion from bridges and similar structures to facilitate construction and maintenance activities. A series of regional field tests of specific methods addressing day roosts, maternity roosts, and night-only roosts will be conducted. The field tests will allow for evaluation of the efficacy of exclusion measures on different genera of bats and monitoring bat behavior during the deployment of exclusion methods,
as well as assess whether bats return after the exclusion measures are removed. The results will be available at a webpage containing fact sheets on different methods, plan sheets where applicable, a research report, and a handbook for bat deterrence and exclusion from bridges with best practices for implementing different solutions.
On June 21, 2019, the Council on Environmental Quality (CEQ) issued the draft National Environmental Policy Act (NEPA) Guidance on Consideration of Greenhouse Gas Emissions (GHG) (84 FR 30097). This Draft Guidance follows the issuing (2016) and rescinding (2017) of past CEQ guidance. The current guidance lacks specifics on how and to what degree to analyze GHGs, and there are no other detailed federal guidance for state departments of transportation (DOT) to address this issue. Additionally, a future federal administration may reissue requirements similar to those rescinded in 2017, re-imposing requirements on state DOTs to assess project impacts on GHG emissions and climate change.

Because many state DOTs do not have the resources and expertise to develop their own GHG and climate change methodologies, they urgently need guidelines on how to develop meaningful and cost-effective documentation on climate change. More specifically, the immediate need is for a basic template that state DOTs can apply to efficiently and cost-effectively address climate change and GHG emissions in NEPA documents.

This research would create a simple guidebook and supporting templates covering two distinct elements: (1) characterizing GHG emissions from project construction, operation, and maintenance, as a surrogate for project effects on climate change; and (2) characterizing the effects of the changing climate on the project from, for example, increased precipitation or rising sea levels.

Additionally, and to the extent feasible and warranted, the basic template would account for changing climate on the project by providing alternative text or sections by region of the country.

The research will include a literature review to identify materials, analytical approaches, and resources that would be appropriate for a basic template for state DOTs through a review of current practice, published and ongoing research, and relevant methods and tools. The research will identify situations in which project-level GHG analysis is effectively supporting decision making, where the analysis is done for disclosure, and patterns in project types where a project-level GHG analysis is meaningful (e.g., comparison of typical project GHG emissions against global emissions). Based on the results of the review, identify materials, GHG emission analysis methods and resources appropriate for a basic template for state DOTs. In particular, the research will identify approaches that could streamline analyses suitable for inclusion in a basic template for state DOTs.

The research should also document best practices, recommendations, resources, and templates and compile them in a resource document that identifies completed transportation GHG and Climate Change NEPA analyses, guidance documents, and relevant tools. The research results will support development of guidelines and supporting templates that state DOTs can use to present project-level GHG and Climate Change analyses in NEPA documents (Technical Reports, Environmental Assessments, and Environmental Impact Statements) to support a variety of project types, including low-volume projects with little effect on GHG, and describe where to discuss
GHG (in air quality or energy section) and how to characterize Climate Change impacts (direct, indirect, or cumulative). The templates may present alternative text or materials by region of the country, as appropriate. The templates should be piloted with two state DOTs and refined as needed.

The project should include a virtual peer exchange with all interested state DOTs to understand the direction state DOTs are taking, share analysis experience to date, discuss best practices, and collect feedback on the draft template before it is finalized.