National Cooperative Highway Research Program

Fiscal Year 2022 **May 2021**

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 2022 is expected to include 12 continuations and 49 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 2021.**

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 2022. 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 2021; proposals will be due beginning in September 2021, and research agency selections will be made beginning in November 2021. 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 2022 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

NCHRP FY 2022

NEW PROJECTS

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Project 03-142
Evaluating the Impacts of Real-Time Warnings and Variable Speed Limits on Safety and Travel Reliability During Weather Events

Research Field: Traffic
Source: AASHTO Committee on Transportation System Operations
Allocation: $400,000
NCHRP Staff: Camille Crichton-Sumners

Road Weather Management (RWM) involves use of solutions and strategies that minimize the impact of weather events on transportation system operations to increase safety and travel reliability. It has advanced significantly with new sources of road weather data and the opportunity for more active management of roadways through various Transportation Systems Management and Operations (TSMO) deployments that enable more direct communication with drivers. As a result, during the past decade there has been growth and experimentation with RWM safety applications and strategies that have proven to yield high payoff benefits during weather events. A survey of TSMO practitioners conducted in 2019 revealed six strategies that would have the most positive impact on system safety and reliability during weather events. Actively managing the system using real-time data on the road conditions to provide variable speed limits (VSLs) and real-time motorist warnings (RTWs) for road weather hazards were both identified as high priority strategies. However, there is a need for additional research on the safety and travel reliability benefits as well as systems engineering processes to advance VSL and RTW for road weather. Notably, each of these solutions depend on actions by the driver, requiring a greater understanding of the related human factors in order to optimize the systems and measure the safety and travel reliability payoff of these strategies.

In order for VSL to be effective in changing driver behavior and increasing roadway safety and reliability, the infrastructure owner/operator (IOO) must have a detailed understanding of both the operational environment and the anticipated responses of drivers. In order for RTW to be effective, the IOO must know the current and anticipated environmental conditions and have a mechanism at their disposal to alert drivers. As with VSL, the IOO should have a detailed understanding of how drivers will react to RTW during different weather events, how they receive and interface with the messages, whether they respond differently based on advisory or regulatory messaging, and many other human factors and driver behaviors. The IOO also needs to understand the ideal ways to capture the driver's attention to the message/warning and needs to have approved standards/consistent messaging to deliver.

In June 2019 a peer exchange identified several gaps in the existing body of knowledge connected to effective VSL and RTW operation and the understanding of driver behavior. These include:

- Safety and travel reliability benefits.
- Baseline and document driver understanding of VSL and RTW.
- Detailing the current understanding of anticipated driver response and level of compliance to messages during all potential operating conditions.
- Documenting the effectiveness of different visual cues and messaging on driver response.
- Documenting the effectiveness of in-vehicle messages versus messages generated via roadside or overhead signage on driver response.
- Detailing the impact of other operating restrictions (e.g., commercial vehicle restrictions such as lane restrictions and chain requirements) on driver response to messages.
- Understanding of the impacts of agency and partner regulatory and enforcement authority for violations on driver behavior (including automated enforcement options).
- Investigating potential design modifications needed to account for human factors and driver behavior.

The objective of this research is to advance the RWM strategies of VSL and RTW that lead to safer and more reliable roadways through a better understanding of driver behavior. Specifically, this research aims to (1) provide a detailed understanding of the anticipated driver behavior impacts from VSL and RTW on safety and travel reliability; (2) identify and convey best practices in VSL and RTW messaging including message locations, content, platform, and timing; and (3) strengthen the ability of agencies to plan for and/or optimize VSL and RTW functions that maximize impacts on driver behavior for improved safety and travel reliability outcomes.

The anticipated products of this research will offer immediate benefit to IOOs dealing with roadway safety and travel reliability challenges due to weather. It will also promote the use of beneficial and cost-effective RWM strategies among state DOTs and other IOOs to increase network safety and security.

Direction from the AASHTO Special Committee on Research & Innovation: Coordinate with an ongoing Transportation Pooled Fund project. Include consideration of return on investment in the scope of work. Consideration should be given to including pedestrians and cyclists within the right-of-way.

Project 03-143
Warrants for a Pedestrian Traffic Control Signal and for Other Pedestrian Traffic Control Devices

Research Field: Traffic
Source: AASHTO Committee on Traffic Engineering
Allocation: $600,000
NCHRP Staff: Leslie C. Harwood

Greater uniformity throughout the country with respect to pedestrian crossing treatments can be achieved when criteria are available regarding when to use a class of pedestrian treatments. The different classes of pedestrian treatments can range from no treatment, to pavement crosswalk markings and a sign (side or in-roadway mounted) to yellow flashing devices (e.g., rectangular rapid flashing beacons, border LED warning signs, in-pavement warning lights, etc.) or devices that display red indications (e.g., pedestrian hybrid beacons or traffic control signal). In particular, the current Manual on Uniform Traffic Control Devices (MUTCD) warrants for a pedestrian traffic control signal currently do not permit consideration of additional pedestrians that would likely begin using the crossing if a signal were present. For example, pedestrians may avoid a crossing because they do not feel safe in attempting to cross a road at that location (resulting in using a less direct route or mode, such as car). A warrant that is based primarily on the *existing* number of crossing pedestrians limits the ability to adequately account for demand that would be expected if a safer crosswalk treatment were present. Given the physical limitations of some pedestrians, such as the very young, very old, or persons with disabilities, should the warrants better address the needs of these groups? Should the pedestrian signal warrant not be based on number of pedestrians but rather on the characteristics of the land uses, such as type and size, represented on either side of the street? Should it incorporate equity considerations of long spaces without safe crossings of large, high-volume, high-speed roadways?

There is a growing interest from agencies in having information that guides them in choosing from the increasing variety of pedestrian crossing treatments to have a better understanding of the characteristics of each treatment and how they might be beneficial for a given location. In addition, as more agencies and programs promote walking and walkable communities, the interest (and need) for such guidance is growing. Issues of the standard of care in the logical and prudent progression of pedestrian crossing treatments (rather than a cumulative assembly of all treatments anywhere) is a growing local agency need. Guidance on treatment selection will provide practitioners with the ability to more confidently provide an improvement to a crossing with reduced concern about over-treating or under-treating those crossings or introducing unintended effects from a treatment or multiple overlapping treatments. If the project is not performed, agencies will continue to approach the selection of treatments with the same information currently available, which can vary widely from one jurisdiction to another or commonly not exist, leading to inconsistent application of treatments and less expectancy by drivers and pedestrians and a less safe outcome.

The objective of this research is to develop MUTCD warrants for pedestrian traffic control devices, especially for the pedestrian traffic control signal. Characteristics that could be considered include vehicle volume, operating speed, available gaps in the vehicle stream, pedestrian demand (including forecasted demand), crossing distance, posted speed limit (target vehicle speed), pedestrian walking speed, and neighboring land use. Additional characteristics will likely need to be considered based upon the reviews and surveys of practice. As part of this project, guidance will be developed to provide explanations on how to use the procedure to identify the appropriate treatments for the conditions present at the location.

There is a growing interest from agencies in (1) having information to guide them in choosing from the increasing variety of pedestrian crossing treatments and (2) having a better understanding of the characteristics of each treatment and how they might be beneficial for a given location. In addition, as more agencies and programs promote walking and walkable communities, the interest (and need) for such guidance will grow and be more regularly used if available. Guidance on treatment selection will provide practitioners with the ability to more confidently provide an improvement to a crossing with reduced concern about over-treating or under-treating those crossings or introducing unintended effects from a treatment.

Currently, the approach to selection of treatments can vary widely from one jurisdiction to another or may be largely non-existent, leading to inconsistent application of treatments and less expectancy by drivers and pedestrians. Without this guidance regarding the prudent progression of safe pedestrian crossing treatment, overlapping devices will continue to be installed with unintended consequences and increased risk and liability to public agencies and private roadway owners.

Direction from the AASHTO Special Committee on Research & Innovation: given the amount of research in this area, the project panel should take care not to duplicate other efforts.

Project 03-144
Leveraging Existing Traffic Signal Assets to Obtain Quality Traffic Counts

Research Field: Traffic
Source: North Carolina DOT
Allocation: $450,000
NCHRP Staff: Edward Harrigan

State DOTs, Metropolitan Planning Organizations, and counties manage extensive traffic count programs and continue to have a need for adequate coverage of traffic count data, including bicycle and pedestrian counts. These counts support decision-making with the aim of enhancing safety and mobility for the traveling public. Meanwhile, there are thousands of existing traffic detection devices throughout the nation that serve traffic management operations. However, many other customers of traffic count data such as traffic engineers, traffic monitoring staff, transportation and active transportation planners, data scientists, and other non-transportation stakeholders need traffic counts to combine data sets in new ways to support various business processes.

As sensor detection technologies mature in assisting traffic operations and intelligent transportation system (ITS) programs, traffic count program providers recognize the potential benefits of using existing infrastructure and data to supplement their counts. However, issues arise concerning the diverse efforts underway that are not summarized, publicized, or leveraged. Furthermore, there are concerns associated with using the data from traffic signals gathered for traditional traffic volume measurement that are not fully understood. Typical issues often encountered with capturing and harnessing data from traffic signal equipment include (a) inconsistency in data quality that varies across vendors and technologies; (b) inconsistency in availability of sensors at all intersections; and (c) variable configuration of sensor equipment causing possible gaps in data availability and quality even though the equipment itself may be capable of counting vehicles, bikes, and pedestrians.

This research will determine if existing traffic equipment can be used to collect, store, and disseminate data for purposes other than traffic operations and how suitable are traffic count data from already installed and existing traffic devices. The research will evaluate a minimum of five types of currently installed traffic devices and provide an assessment of traffic count data suitability for non-operational traffic data usage evaluation. Further, the research should address the following questions:

1. Is it possible to obtain accurate (±10%) traffic count data from existing traffic signal assets? If yes, the method of obtaining traffic counts should be documented. If not, the reason why traffic count data cannot be obtained should be documented.
2. What is the quality and completeness of traffic count data obtained from existing traffic signal assets?
3. What is the appropriate use of traffic count data obtained from existing traffic signal assets?
4. Is the traffic signal data limited to operation usage only, why or why not?
5. What methods of data handling, storage, and quality assurance and quality checking (QA/QC) need to be implemented to obtain traffic counts from existing traffic signal assets?
6. What challenges exist in obtaining traffic count data from existing traffic signal devices?
7. What agencies are currently collecting traffic count data from existing traffic signal devices?
8. What are the incremental costs for these efforts?

The objectives of this research are to (1) gather the active support and participation of agencies across the nation that include city, county, state, federal, and private entity partners; (2) identify and summarize existing and in-development methods for obtaining traffic counts from existing traffic signal assets including, but not limited to, signalized intersections, cross walk signals, video, loops, magnetometers, radar, and traffic detection cameras; (3) identify good practices that can be adopted by the traffic monitoring community; (4) identify challenges associated with leveraging the data from these

devices; (5) summarize improvements or solutions to these challenges including, but not limited to, standards, pooled fund studies, or additional research needs; and (5) prepare a final report documenting the results of the research in a form to be used as a best practice guide for obtaining traffic counts from existing traffic devices and disseminate the results through webinars, training, and peer exchanges.

Direction from the AASHTO Special Committee on Research & Innovation: Include consideration of a cost-benefit analysis in the scope of work.

Project 07-32
Future-Proofing Automatic Traffic Signal Performance Measurement Systems for Scalability, Transferability, and CAV Integration

Research Field: Traffic
Source: Iowa DOT
Allocation: $500,000
NCHRP Staff: Christopher T. McKenney

In the United States, more than 300,000 traffic signals are currently in operation. According to the Federal Highway Administration, the operation and performance of most of these signals are assessed through citizen complaints. Historically, agencies have been forced to rely on manual counts input into software and simulation models to develop timings, with the presumption that if there are no public complaints, then everything is working acceptably, often compromising on performance and efficiency as user demand changes.

Automated Traffic Signal Performance Measures (ATSPMs) started in the mid-2000s with the collection and analysis of high-resolution event-based data for traffic signal performance. Since then, researchers at Purdue University along with practitioners at the Indiana Department of Transportation, Georgia Department of Transportation, and Utah Department of Transportation have evolved the use of event-based data into a method of assessing and improving the performance of traffic signals, traffic signal systems, and traffic signal system business practices. From a technical standpoint, the suite of ATSPMs can allow an agency to monitor capacity, progression, multimodal, and maintenance performance measures without the added expense of a central or adaptive traffic signal system. These performance measures can be developed through robust communication and typical traffic signal detector information, though additional detection is required to take advantage of all the performance measures. For the sake of consistency, introduction of commonly used terminology throughout this proposal include high-resolution controller data schema, geo-spatial metadata, and signal timing plans.

The experiences of users of ATSPMs and those who have been actively developing the methodology have revealed the following limitations of the current high-resolution data scheme on which the performance measures are founded:

- Lack of common methods for describing geo-spatial information ("metadata").
- High resolution controller data only stores changes in states.
- Unavailability of data management and archival process.
- Lack of holistic performance measurement.

The purpose of this research is to address shortcomings of the current conceptions of high-resolution data on which ATSPMs are founded. This will "future-proof" the data and the systems that rely on it by enabling it to integrate new data streams and enhance its scalability and transferability to multiple agencies and jurisdictions. The main objectives of this research should include:

- Reconcile the diverse approaches taken to the intersection metadata problem: for example, the conception of an intersection in SAE J945 standard as compared to methods of describing detector layouts for signal control.
- Develop a standard schema for saving geospatial information required for current ATSPM systems.
- Develop an open-source tool for easily generating the geospatial information for a given intersection.
- Expand dynamic data storage standards, schema, and format to include storage of short-term trajectories available via BSM message or advanced sensors.
- Design data compression and aggregations methods to enable long-term storage of critical information to manage economics and processing speed of the system.
- Enhance the performance measures to provide a more holistic view of the system.

The results of this research will be used by Traffic Operations and Traffic Signal Management of agencies. The tool and recommendation developed during the course of this research will make it easier for DOTs to implement a scalable system which will consume data from Connected Vehicles in the future. The tools could be immediately applied by agencies and vendors implementing the ATSPM system.

Project 08-150
Valuation of Transportation Equity in Active Transportation and Safety Investments

Research Field: Transportation Planning
Source: AASHTO Council on Active Transportation
Allocation: $650,000
NCHRP Staff: Leslie C. Harwood

Historic methods of transportation decision-making led to the design and construction of transportation facilities oriented toward the use of motorized vehicles, without full consideration of all road users. Redlining practices led to placement of roads and highways that severed or boxed in neighborhoods with majority Black, Indigenous, people of color (BIPOC) populations, concentrating and deepening both poverty and environmental health impacts from transportation-related pollutants. Roadway designs and operations emphasized higher speed throughput of drivers often without facilities for safe walking and bicycling, creating the context for greater exposure to serious injury and fatal crash involvement of active transportation modes in these communities. Driver behavior and potential biases, as well as land use and transportation infrastructure, have exacerbated the disparity in outcomes from a social equity perspective. Gaining a deeper understanding of the causes of and solutions to the disproportionate burden on historically marginalized groups requires a multi-sectoral and multi-step approach.

With data-driven safety, it is important to understand how data can be used in performance analysis to inform tradeoff decisions during planning, the project development process, maintenance, and operations. The premise with this research is that, without the ability to analyze and evaluate social equity considerations, there will be limited ability for use of this critically important information throughout planning, project development, maintenance, and operational processes within transportation agencies. The results and products of this research would be incorporated into systemic safety analysis, prioritization of investments, evaluation of the existing system, and improvement of current mobility performance metrics. Tools to incorporate a systemic, risk-based approach to safety prioritization with a focus on promoting socially equitable outcomes would bring jurisdictions along in a twofold industry evolution: away from chasing hot spots to proactively promoting pedestrian safety, and with a renewed focus on equity. Such a tool would help to ensure that traditionally underserved communities, who are disproportionately involved in collisions, benefit from safety investments. This tool could build off of the foundation provided by both *NCHRP Report 893: Systemic Pedestrian Safety Analysis* and *NCHRP Research Report 803: Pedestrian and Bicycle Transportation Along Existing Roads–ActiveTrans Priority Tool Guidebook*.

The objective of this research is to advance the use of social equity considerations in planning, programming, design and operation of transportation systems. This research will develop data driven tools and guidelines for use by practitioners in safety decision-making and in supporting Safe System principles, considering modal priorities and in performance tracking to reduce the potential for fatal and serious injury crashes. This research recognizes that past decisions have created system inequities for BIPOC populations and intends to address the overrepresentation of these communities in severe crash outcomes. This research also recognizes that by addressing these system inequities all road users benefit as system gaps are overcome. The tools may include models, checklists, worksheets, and processes that will assist practitioners in how to consider and account for social equity in safety projects, as well as projects related to mobility, preservation and operations. The knowledge created as part of this effort will also inform data driven tools such as the *Highway Safety Manual* (HSM) and will include updates to appropriate chapters of the HSM to include equity in safety.

The ability to serve all communities, particularly those that need adequate transportation systems to perform daily tasks is critical. The ability to provide an approach will provide value, not only in safety programs, but mobility projects and in environmental impact statements where environmental justice considerations are required. Past system approaches that redlined through communities of color and lower incomes created significant gaps in the transportation system for these communities. Not only do gaps exist, but people of color and lower incomes are overrepresented in crashes at all levels: the research attempts to address this problem. The new guidelines and tools will be used in data driven safety analysis as well as in performance-based approaches to planning, project development, maintenance, and operations. This research will help local and state agencies optimize existing resources to reduce roadway fatalities and support Safe Systems outcomes and

the broader sustainable benefits of modal priority. This research will help local and state agencies optimize existing resources to reduce roadway fatalities, support Safe Systems outcomes and the broader sustainable benefits of modal priority, and benefit Toward Zero Deaths, Vision Zero, and Road to Zero efforts in the US.

Project 08-151
Building Risk-Management Momentum in Agencies

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $350,000
NCHRP Staff: Ann M. Hartell

Formal risk management is becoming a best practice in the private sector. Many federal agencies now have functional risk-management programs as well. The current challenges of disruptive changes to state DOT operations due the COVID-19 pandemic and resulting decreases in revenues for transportation funding further emphasize the need for proactive risk management in order to identify response strategies that will manage potential risks to strategic objectives. Disruptive technologies, a changing workforce, and the ongoing requirement to develop and maintain risk-based asset management plans drive the relevance and requirement of adoption of formal risk management within transportation agencies.

A few agencies do have effective formal risk-management programs in one or several areas of their business, but only a few have implemented risk management agency-wide. Other agencies have piloted risk management specific purposes but did not implement it fully or sustain it. Many others have not yet attempted formal risk management.

The objectives of this research are to:

- Identify and evaluate potential barriers to adoption and sustained implementation of formal risk-management practices and a risk-informed culture in state DOTs.
- Identify best practices of risk management from the private sector that can translate to state DOTs.
- Identify effective approaches to overcome those barriers and increase the momentum among state DOTs in adopting and sustaining the use of formal risk management.

The research effort should build on previous efforts and guides and include activities such as CEO and risk practitioner workshops, peer exchanges, and other outreach.

Direction from the AASHTO Committee on Research & Innovation: this research should build on NCHRP Project 08-113, “Integrating Effective Transportation Performance, Risk, and Asset Management Practices.”

Project 08-152
Strategies for Advancing Equity in Transportation Planning by Increasing Diversity, Equity, and Inclusiveness in the Transportation Planning Profession

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $350,000
NCHRP Staff: Ann M. Hartell

Understanding the actual and potential negative impacts of transportation decisions on minority populations, low-income households, women, and other historically underrepresented populations and taking meaningful action to resolve inequities are critical functions of transportation agencies.

Transportation planners are central to the work of changing the trajectory of inequality in transportation. Transportation plans document the urgent needs of the community and lay out a blueprint for transportation investment and policies. These plans are based upon the data gathering, modeling, analysis, and public engagement conducted by planners working in or for state DOTs, metropolitan planning organizations (MPOs), and transit agencies. Planners make fundamental choices about which questions are important to ask, how to ask them, and what to do with the answers, and they structure the

planning process accordingly. If they are unaware of, misunderstand, or dismiss the questions that are important to underrepresented populations, a plan is less likely to address those concerns, and, at worst, could set the stage for investments and policies that harm these communities. If the planning team members are all from similar backgrounds and hold similar perspectives, it may be difficult for them to spot the presence of their own cultural biases, and to counter the potential negative effects of those biases on the development of a plan that meaningfully advances equitable transportation goals.

The transportation planning and analysis field has been slow to incorporate racial/cultural and gender-related concerns into its methods meaningfully, and to identify potential biases and disparities within the practices of travel data collection, analysis, engagement, and plan development. Meanwhile, women and Black, Indigenous, people of color (BIPOC) have been, and continue to be, underrepresented in the field. They are less likely to study fields leading to transportation planning careers, less likely to promoted to leadership roles, and more likely to be subject to racism, sexism, and exclusion in the workplace. The extent and distribution of that underrepresentation with the planning field have not been consistently and clearly documented, and there is not a clear understanding on how it manifests itself and permeates the workforce. In order to address inequities in transportation decision-making, the industry needs a clear understanding of the extent to which women and BIPOC are excluded from meaningful roles in transportation planning; the ways in which this imbalance impacts the quality of equitable planning, analysis, and decision-making; and potential strategies for improving diversity, inclusiveness and equity within the transportation planning profession.

The objective of this research is to fully understand the scope and causes of the lack of diversity, equity, and inclusion within the transportation planning field, and to make clear and actionable recommendations to employers, leaders, professionals, and academics for effective strategies to achieve meaningfully greater diversity throughout the industry. The desired outcomes of this project include:

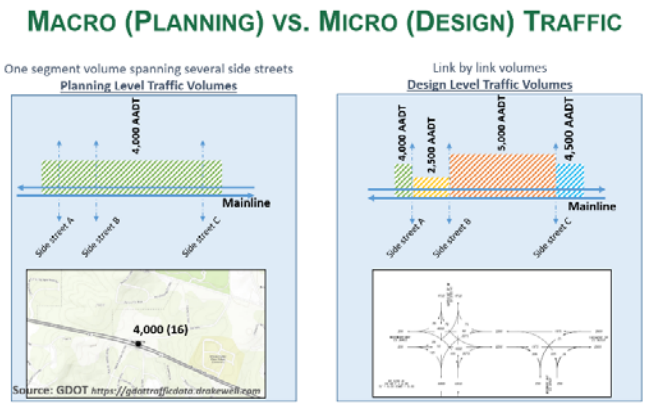
- Defining the extent to which women and BIPOC are underrepresented within the transportation planning field
- Analyzing hiring, retention, pay equity, employee satisfaction, and professional development practices by dimensions such as person characteristics (gender identity, race, ethnicity, etc.), employer characteristics (public, private, academic), location/geography, tenure, seniority, and areas of focus within transportation planning.
- Identifying the potential impacts of underrepresentation of women and BIPOC within the professional ranks of planners on the ability of agencies to develop plans and programs that address historic inequities in their jurisdictions.
- Identifying the ways in which increased workforce diversity, equity, and inclusiveness can improve the development of equitable transportation plan analyses, engagement, decision-making on investments and policies, and long-term outcomes.
- Identifying potential causes and correlations associated with the underrepresentation of women and BIPOC in the transportation planning field.
- Understanding the trajectory of the industry by assessing trends in agency workforces and in the pipeline of transportation professionals earning credentials through higher education and professional development programs.
- Identifying potential strategies and measures of success for improving the representation of women and BIPOC within the transportation planning profession, and associated strategies for improving the process of equitable transportation planning and decision-making.
- Proposing applications of these strategies and measures of success within public- and private-sector transportation planning agencies, institutes of higher education, and professional development organizations.

Direction from the AASHTO Special Committee on Research & Innovation: This research should build on *NCHRP Report 798 The Role of Planning in a 21st Century State Department of Transportation—Supporting Strategic Decisionmaking* and NCHRP Project 02-25, "Workforce 2030—Attracting, Retaining, and Developing the Transportation Workforce: Design, Construction, and Maintenance."

Project 08-153
Guidance on Improving Truck Traffic Estimates in "Design Traffic" Forecasts

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $425,000
NCHRP Staff: Jennifer L. Weeks

The 2020 "INVEST in America Act" directs state department of transportation (DOTs) to develop tools and databases for better informed passenger and freight planning. The current practice on determining "Design Traffic" forecasts to assess roadway design elements stands in contrast with "Planning Level" forecasts used for identifying possible deficiencies that also form input to determining roadway design elements.



Planning forecasts use historical traffic counts, existing and future land use, road network changes, population and employment estimates. Design level traffic analysis requires a much more precise level of detail at the link level and should include turning-movements data as shown in the figure to the left.

Furthermore, a model's truck traffic forecast is generally a secondary step that is represented as a percentage of traffic after the overall traffic is determined. When projecting future truck volumes under the design forecast, often the same percentages of truck traffic identified under the existing conditions are applied to future Annual Average Daily Traffic and Design Hourly Volumes to forecast future truck volumes.

This research is intended to explore the best practices of "design level" forecasting of truck volumes in the roadway project development process. The results should facilitate better project evaluation, prioritization and implementation, traffic estimation, and design of roadway improvements.

Improvements in truck volume forecasts in "Design Traffic" Forecasting will enhance state and regional freight system planning, improve the project-level analysis on truck traffic management, and better accommodate the rapid growth in truck volumes due to a variety of reasons including online shopping. Traffic and design planners in state DOTs and MPOs will benefit from the outcome of the research and the resulting guidelines.

Project 08-154
Guidebook/Toolbox for Agencies to Incorporate Uncertainty into Long-Range Transportation Planning

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $600,000
NCHRP Staff: Trey Joseph Wadsworth

State departments of transportation (DOTs), metropolitan planning organizations (MPOs), and other planning agencies increasingly face the challenge of developing meaningful plans and making thoughtful investment decisions during a time of uncertainty. These uncertainties are composed of a confluence of trends including changes in demographics, the economy and workforce, land use and development patterns, and other social, cultural, and geopolitical trends; the impact of rapidly changing technologies including automated, connected, electric, and shared vehicles; a growing number of risks ranging from extreme weather and climate change to cybersecurity concerns; and continued uncertainty about future funding for transportation. There is also significant uncertainty regarding the short-term duration and recovery from the pandemic and the long-term impacts of COVID-19 on travel behavior.

Recent research has helped agencies understand potential trends and disruptions and helped develop scenario planning and risk analysis tools to assess the potential impacts of these changes. However, additional research and guidance are needed to help state DOTs, MPOs, regional and other planning agencies incorporate these uncertainties into statewide and metropolitan long-range transportation plans (LRTPs), statewide and metropolitan transportation improvement programs (STIPs/TIPs), and other planning documents. Agencies often face challenges related to introducing greater flexibility into

existing planning and programming processes, particularly where existing processes rely on specific types of data, forecasts, and modeling tools; must remain consistent with local land-use decisions; must demonstrate fiscal constraint; and must demonstrate progress toward transportation performance management targets.

The objective of this research is to identify examples of how agencies are incorporating uncertainty into their planning and investment decisions; develop a framework for how DOTs, MPOs, and other planning agencies can address uncertainty in their plans; and provide guidance and a toolbox for use by DOTs, MPOs, and other planning agencies consistent with this framework. The framework and guidance should be flexible to address different scales or contexts for specific types of agencies. This guidance should focus on incorporating uncertainty into LRTPs, and, through these plans, inform investment decisions as documented in TIPs at multiple scales. The guidance is intended to augment prior or ongoing research regarding incorporating risk into asset management and other performance-based planning processes. The guidance should reflect the unique characteristics of DOTs, MPOs, and other planning agencies, and provide approaches that would be appropriate to incorporate into different types of planning processes with consideration for the level of resources available.

Direction from the AASHTO Special Committee on Research & Innovation: The project should build on the *NCHRP Report 750 "Strategic Issues Facing Transportation"* (Foresight Series)

Project 08-155
Researching and Responding to Racial Disparities in Construction

Research Field: Transportation Planning
Source: Minnesota DOT
Allocation: $400,000
NCHRP Staff: Camille Crichton-Sumners

During the construction of the United States Interstate System, an estimated one million people were uprooted (Schwartz, 1976). Because planning for the interstates and other roadways occurred at a time of significant racial change in American metropolitan areas, the interstates were tied to racial politics. Harms varied by state and metropolitan area, and marginalized communities often bore a disproportionate share. Their losses included neighborhoods central to community life and direct financial harms to individuals and their families that have compounded over time. The pain and anger in these communities is still alive today, evidenced most recently by articles that appeared in 2020 in California, New York, Michigan, Louisiana, Connecticut, and elsewhere. To concerned citizens and activists, the expressways are "monuments to racism" (Fleischer, 2020). Negotiations among federal, state, and local officials produced the expressways. Top officials gathered in 1958 to promote cooperative approaches, agreeing that "A community which displaces large numbers of people through activities designed for the general benefit has a responsibility to help these persons adjust satisfactorily to the new conditions. This responsibility is greatest where the potential injury is greatest—that is, among lower income and minority groups, the elderly, and others least equipped for what may be for them a major crisis" (Sagamore Report, 1958). State highway departments used eminent domain and displaced people from their homes, businesses, and community institutions.

The objectives of this research are to (1) increase knowledge among government officials and the public about disparities associated with highway construction; (2) develop tools for state DOTs and local staff to help build accountability and trust as communities confront the truth about the disparate racial impacts of past decisions; and (3) provide successful practices for transportation professionals in the treatment of groups affected by construction activities.

Direction from the AASHTO Special Committee on Research & Innovation: The scope of work will include all facility types but focus only on the construction phase of project delivery.

Project 08-157
Best Practices for Data Fusion of Probe and Point Detector Data

Research Field: Transportation Planning
Source: Ohio DOT
Allocation: $200,000
NCHRP Staff: David M. Jared

Data fusion is defined as the process of integrating multiple data sources to produce more consistent, accurate, and useful information than that provided by any individual data source. Research is needed to define the types and characteristics of data for entry into a data fusion engine. This research should delineate the challenges, issues, and best practices for performing data fusion by agencies to estimate or predict travel time, speed, and reliability on road networks. Road traffic datasets of interest include traditional inductive loop detectors; Bluetooth; GPS devices embedded in smartphones, personal navigation devices, taxis, fleets, and other sources; third-party travel time data; and emerging connected vehicle data sets.

The objective of this project is to identify the data and data fusion algorithms that will enable road operators to better understand the traffic state on their network for both operations and planning applications. This will be achieved by fusing data from multiple traffic data sources that have differing spatial and temporal characteristics. The project will develop a clear pathway from data selection to fusion model selection that is implementable in the field by agency staff or their contractors. The research will promote the adoption of data fusion technology for improving the safety and efficiency of traffic management by developing (a) a data characterization catalog that assesses the suitability of sensor data as an input into a data fusion process; (b) a decision process that enables the choice of data fusion model and provides guidance on the expected information gain; and (c) methods to estimate the traffic state and the reliability of the estimate considering various traffic flow and data availability scenarios.

By enabling better knowledge of the network state, the outcomes of the proposed research will enable improved traffic management and planning decisions. Even a 5% reduction in congestion will produce large economic savings. The economic cost of traffic crashes was estimated at $871 billion in 2013. Improved network state estimates will enable enhanced safety outcomes by identifying locations with high crash rates and anomalous traffic flow conditions.

Project 08-158
Communicating the Value, Interactions, and Impacts of Freight to Stakeholders

Research Field: Transportation Planning
Source: Texas DOT
Allocation: $350,000
NCHRP Staff: Christopher T. McKenney

Freight is a critical component of the national and international transportation system, though its importance is not always recognized. The relevance of the freight transportation system is further accentuated by increasing e-commerce: deliveries to households in an average month that doubled between 2009 and 2017. Despite the importance of freight to local communities and the economy, many planning, transportation, and government professionals and the general public do not understand its value, its connection to land use and other transportation uses, or how best to address impacts of the freight system.

Many local and regional planning and transportation initiatives focus primarily on the movement of people, without adequate consideration of the movement of goods. With increasing urbanization and changing technologies driving both growing freight volumes and disruption of the transportation system, it is imperative for freight officials to effectively communicate the importance of freight to stakeholders and the general public. While there are some resources and toolkits available to support freight professionals with implementing specific freight strategies, resources are needed to improve public dialogue about the importance, impacts, and interconnectedness of freight with our day-to-day lives to make visible, and understandable, a part of our transport system that sometimes goes unnoticed.

The proposed project would provide departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local agencies with visually-engaging and research-based resources, such as factsheets and presentations that identify why freight is important and provide examples of how jurisdictions have effectively communicated the role of freight in their communities. By considering the impacts of freight as part of the transportation system, planners, engineers,

elected officials, and other stakeholders will all be able to maximize the efficiency of the transportation system and minimize the negative impacts of freight on their community.

The objective of this research is to present resources and best practices for public-sector practitioners, including, but not limited to, (1) conducting a comprehensive literature review to document the economic, equity/environmental justice, and infrastructure impacts of freight. This object includes, but is not limited to (a) freight impacts on non-motorized traffic in major urban areas, and conflict between user groups on streets and at the curb; (b) land-use decisions and policies on freight pickup and delivery needs, including, but not limited to, alley network development and preservation; off-street or actively managed curbside loading and unloading zones for postal, freight, ride-sharing, and waste collection; and connections to intermodal facilities, like ports, airports, and rail facilities; (c) Methods of integrating freight with passenger modes including transit, transit hubs, ride-share services, bike and scooter sharing, and freight-multimodal centers; (2) developing a briefing book and corresponding factsheets for the public, elected officials, and public-sector practitioners, ranging from staff level to director level, on the impacts of freight, the interaction of freight and the community, and the need to consider freight in community development and policy decisions; (3) documenting case studies that tell the stories of specific regions with differing geographies (e.g., urban, suburban, rural) and industries that enable other agencies to apply lessons learned; and (4) creating a series of short (2-minute maximum) videos or animation/motion graphics to explain the role of freight for presentation and online use.

Project 08-159
Understand How Accessibility to Employment, Health Care, Education, and Other Vital Needs Varies for Different Population Groups in Different Settings, and Methods for Effectively Assessing Mobility and Accessibility Needs

Research Field:	Transportation Planning
Source:	AASHTO Special Committee on Research and Innovation
Allocation:	$500,000
NCHRP Staff:	Jennifer L. Weeks

State DOTs are seeking guidance on how to assess and address the transportation needs of the full spectrum of diverse populations they serve within their jurisdictions. Understanding transportation needs in the context of equity requires an understanding not only in the gaps in access to quality transportation infrastructure and services but specifically how those gaps limit the access of some populations and communities to key destinations that provide health and wellbeing. Traffic models have long used home-based work trips (commute trips) to forecast travel needs and design infrastructure and transit operations, oriented around “peak periods.” And while there is considerable research on access to employment, common methodologies do not fully represent the full range of challenges faced by many low-income, minority, and other vulnerable populations whose commute patterns do not fit traditional commute work hours or travel patterns. More importantly, to ensure more equitable transportation service it is important to gain a better understanding of the specific transportation challenges faced with respect to providing underserved populations with access to critical goods and services such as health care, active transportation, recreation and outdoor destinations, religious services, healthy food, and more.

The objectives of this research are to (1) better understand transportation equity issues in all transportation modes related to accessibility to employment, health care, and education; (2) identify opportunities for state departments of transportation as well as other transportation agencies to minimize inequities caused by transportation decisions that impact low-income, minority, and other vulnerable populations; and (3) develop methodologies to help decision-makers better understand the differences and factors that influence the needs in different geographic contexts and for different groups.

Project 08-160
Understand the Role of Transportation Infrastructure Investment in Gentrification and Displacement and Identify Effective Policies and Strategies to Address These Effects

Research Field: Transportation Planning
Source: AASHTO Special Committee on Research and Innovation
Allocation: $400,000
NCHRP Staff: Jennifer L. Weeks

Some types of transportation investments in older urbanized areas designed to create a more accessible and attractive community often lead to the displacement of existing residents and businesses as wealthier residents and businesses move in, attracted by the new public investment, and land values and rents increase. *Gentrification*, as this phenomenon is known, is frequently associated with investments in rail transit and associated transit-oriented development (TOD), although other infrastructure investments can lead to similar market forces. The overall outcome of gentrification and displacement on low-income and minority communities can be housing, job and local business instability that result in longer commutes as well as disruption to social connections and community institutions.

Research is needed to examine the role of transportation investment in creating gentrification and the investment decision-making processes that lead to them. Specifically, this research should identify strategies, policies, and data that state departments of transportation can utilize to avoid displacement and the other adverse impacts of gentrification on low-income and minority communities.

Project 08-161
Identify Emerging Approaches for Public Engagement to Meaningfully Involve Minorities, Low-Income, and Other Vulnerable Populations

Research Field: Transportation Planning
Source: AASHTO Special Committee on Research and Innovation
Allocation: $500,000
NCHRP Staff: Jennifer L. Weeks

In light of recent public emphasis on diversity, equity, and inclusion, there is a renewed urgency to reconsider transportation decision-making practices and policies that lead to inequity in transportation outcomes and identify how new approaches or models might positively impact transportation planning and decision-making. Notably, there is the need to examine the strategies, methods, and techniques for effectively engaging more vulnerable populations in transportation decision-making, including but not necessarily limited to, low-income and minority populations and communities.

While several studies and guidebooks have focused on effective public involvement supporting transportation decision-making, including methods to engage low-income, minority, low-English literacy and other vulnerable populations, there is a need to focus research on those methods and strategies that provide *meaningful* involvement. This is particularly important for low-income and minority communities that often are not engaged in the political process and stand to lose the most if their needs are not considered. .

This research shall seek to identify and define what meaningful public engagement consists of and the outcomes that can be achieved in the decision-making process by practicing effective engagement. In so doing, it will seek to identify the most pressing challenges in obtaining the meaningful involvement of minority, low-income, and other vulnerable populations in transportation decision-making. It will build on and reflect the well-documented research on this topic through the lens of recent experience, particularly in light of the effects and challenges that all-virtual public engagement, an outgrowth of COVID-19, has created for agencies and communities. The research should then assess and identify what are determined to be effective approaches for engagement that respond to those challenges that facilitate a more successful decision outcome for state departments of transportation and the full array of communities that they serve.

Project 08-162
Identify Practices and Policies to Advance Social Justice and Equity into Transportation Decision-Making

Research Field: Transportation Planning
Source: AASHTO Special Committee on Research and Innovation
Allocation: $750,000
NCHRP Staff: Trey Joseph Wadsworth

Institutional racism is widespread, infiltrating transportation planning and decision-making. By examining systemic racism in transportation historically and today, injustices can be identified with the intent to provide pathways for strategies to be adopted to eliminate racism and injustice from planning and decision-making. Transportation decisions made in the past, such as in the period of the development of the interstate highway system, still contribute to inequities and adverse impacts to low-income and minority communities. Freeways constructed through the heart of communities destroyed social fabric, divided spaces physically, or created barriers to access for low-income and minority communities with profound and lasting impacts. Also, land use and housing policies at all levels of government, including redlining and exclusionary zoning, played an important role in limiting access to opportunities for minority communities. To not repeat these mistakes, it is necessary to understand the lessons of the past and to then mitigate the negative outcomes, particularly as transportation decisions are made concerning the rehabilitation of aging transportation infrastructure and deployment of new mobility options.

As transportation decision-making is an ongoing practice of planning, evaluating, implementing, and measuring, new policies and practices can become best practices over time. This research is intended to identify the most effective ways to incorporate equity into ongoing transportation practice at all levels. Beyond statewide and regional planning, sometimes local decisions on operations and maintenance or where to add bus shelters, crosswalk improvements, and other infrastructure, as well as traffic calming, are structured in response to public concerns raised about needs. However, this approach often disadvantages low-income neighborhoods and communities of color, who are not always actively engaged in the decision-making process. This research will also identify how and why current decision-making practice fails to consider equity appropriately, across all aspects of transportation decision-making—planning, project selection, project design and development, operations, and maintenance—and how this outcome can be changed. For example, rapid transit lines have been shown to cause displacement through gentrification. Additionally, operational issues like those employed in policing strategies of mobility (for all modes, in cars, in active transportation with harassment of bicyclists and pedestrians, and even the criminalization of transit fare evasion). The decision of where to build infrastructure and how to operate it has had positive or negative long-term outcomes for the affected neighborhoods.

The research objective is to understand transportation infrastructure's intentional or unintentional role through history in enabling systemic inequities, failure to close access gaps for all users—both in urban and rural communities—and causes of long-term community impacts such as gentrification and displacement. Additionally, the research will identify practices and policies that enabled mobility injustice in transportation policy and investment decision-making. Finally, the research will identify effective policies and strategies that evolve from well-intentioned policy gestures and toward actionable mechanisms to eliminate systemic racism, reverse impacts, and ensure equity in future transportation investments, both operational and capital, and for new mobility and innovative technologies. Although this is a complex problem and will require extensive effort, it is important to start immediately as the understanding of transportation's role in the history of racism and inequity is foundational to other research. This information will inform transportation policies and decision-making to hopefully end systemic racism in transportation decision-making and reverse impacts for communities of color and low-income individuals and households.

The research will develop a historical summary of racism and inequity related to transportation planning and decision-making, including practices and policies that enabled mobility injustice, and identify strategies to overcome this history. Institutional racism will be described in transportation sufficiently to underpin this research. Patterns of structural racism and inequities in both urban and rural contexts will be articulated, matrixed over capital and operational policies and practices to provide a sufficiently informative illustration of the magnitude of the issue impacting communities of color and low-income mobility users. How racism is different for Native Americans will also be documented and describe how equity issues are different from those affecting other minority and underrepresented racial groups in the transportation planning and decision-making process.

The research will identify the best approaches to adopt and implement new practices related to equity and develop strategies to address and mitigate injustice and harms caused by past transportation decisions, particularly about community disruption and barriers to access. Actions that are needed to dismantle institutional racism in the transportation sector will

be identified. Lessons learned from equity research that can be more effectively translated into practice will be articulated. Additionally, effective approaches to enhance access and quality of life in areas adversely impacted by past infrastructure projects will also be identified. They will elaborate on how these strategies can be integrated into and prioritized in infrastructure rehabilitation. Finally, a demonstration of clear connections for when policies and practices have been established between equitable transportation policies, priorities, decision-making, and investments will be evaluated and shared.

Project 09-68
Considering Binder Availability of Recycled Asphalt Materials

Research Field: Materials and Construction
Source: AASHTO Committee on Materials and Pavement
Allocation: $500,000
NCHRP Staff: Edward Harrigan

To promote sustainability and ensure adequate performance, there is a need to consider the amount of asphalt binder available from asphalt-based recycled materials, such as reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS). The use of recycled materials is growing due to economic and environmental benefits, yet there is no accepted method to quantify or account for the effective binder content available from these materials. AASHTO guidance on the design of asphalt mixtures with RAP and/or RAS assumes that 100% of the recycled binder is available to blend with virgin binder and any additives such as recycling agents or warm mix asphalt products. The actual availability of recycled binder varies between 0% and near 100%, with lower availability for heavily aged RAP or RAS binder and mixtures produced at lower temperatures. Thus, the assumption of 100% availability leads to less overall effective binder content, yielding a dry mixture with insufficient coating that may be difficult to compact and that may exhibit inadequate durability and cracking performance in-service. These poor-performing pavements cost agencies due to their reduced life and increased maintenance expenditures. This research will identify or develop a method to quantify or account for binder availability from recycled asphalt materials and provide guidelines for their efficient use.

The objective of this research is to identify or develop a method to quantify or account for binder availability from recycled asphalt materials that can be used by agencies to improve mix design procedures and specifications. Important factors affecting the active binder inherent in recycled materials and/or the available binder that contributes to the recycled mixture include the following to be considered when producing guidelines for efficient use of RAP/RAS: (a) the type and source (aging state), content (%), binder content, and gradation of the recycled material; (b) the performance grade and flexibility of the virgin binder; (c) the gradation of the virgin aggregate; (d) the type and dose of optional additive(s) including recycling agents or warm mix asphalt additives; and (e) production plant type and mixing and storage times and temperatures.

Accomplishment of this objective shall require the following tasks: (1) review current practices of U.S. and international agencies to estimate and incorporate recycled binder availability; (2) evaluate coatability and rutting and cracking performance of typical dense-graded mixtures considering 100% recycled binder availability and 0% recycled binder availability to assess the impact on mixture performance; (3) identify or develop a method to quantify or account for recycled binder availability that is sensitive to the factors listed above; and (4) develop a reporting format for characterizing RAP/RAS in terms of binder availability. Project deliverables shall include the following: (1) a user-friendly method to incorporate binder availability factors for RAP and RAS into mix design processes and (2) proposed revisions to specifications and mix design procedures for recycled mixtures to account for recycled binder availability.

Direction from the AASHTO Special Committee on Research & Innovation: The scope of this research should not include evaluation of rutting and cracking.

Project 09-69
Recommended Procedures for Verifying Material Quantities at Asphalt Mix Plants

Research Field: Materials and Construction
Source: AASHTO Committee on Materials and Pavements
Allocation: $400,000
NCHRP Staff: Amir N. Hanna

Asphalt mixtures produced in the United States in 2018 contained over 82 million tons of reclaimed asphalt pavement (RAP) and over 1 million tons of reclaimed asphalt shingles (RAS). Public transportation agencies typically specify maximum percentages of RAP and RAS that can be used to produce asphalt mixes, based on factors such as mix type and application. These maximums are needed to ensure good performance of the pavement. These maximum values can be based on total percentage of the RAP or RAS by weight, or on a calculated value such as reclaimed binder ratio. Regardless of the specification method, it is necessary to verify the percentage of RAP or RAS being introduced into the asphalt mix plant in order to determine specification compliance. This is further complicated with the fact that RAP and RAS contain both asphalt binder and aggregate, so, the verification process must include the quantity added as well as the percentages of asphalt binder and aggregate included in each material. Verification of RAS content can be especially challenging because it often does not flow freely when using traditional cold feed bins, so is often mixed with another material (such as RAP or sand) before introduction into the plant. Excess RAP or RAS in a pavement can lead to insufficient new binder and increased stiffness of the mastic, potentially resulting in reduced mixture durability.

States have used various approaches to verify RAP and RAS percentages using techniques such as stockpile measurements or plant recordation. Also, plant manufacturers have introduced new equipment to monitor flow from individual cold feeds or improved plant calibration equipment, but there are no national guidelines in the use of these approaches. In addition to RAP and RAS, materials introduced at asphalt plants include asphalt binder, aggregate, and many additives such as latex, ground tire rubber, warm mix additives, anti-strip additives, fibers, and mineral fillers. Addition of these materials is done with many different types of equipment and control systems. The additions must be accurately controlled and interlocked in order to meet job mix formula requirements and agency specifications. Often, these additives are introduced using systems that do not provide good means to verify the quantity being added. Transportation agencies and asphalt mix producers would benefit from guidelines recommending best practices for verifying quantities of materials including RAP, RAS, and other additives into asphalt mixtures. Improved information will lead to better specification compliance and potentially improved pavement performance.

The objective of the research is to develop recommended practices/standards updates to verify quantities of materials being introduced into asphalt mixtures at production facilities. Tasks include (1) literature review of public transportation agency specifications and inspection procedures related to asphalt mix plant and production requirements and AASHTO M 156, *Standard Specification for Requirements for Mixing Plants for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures*; (2) survey of public transportation agencies asphalt mix producers and plant manufacturers to determine current procedures for verifying raw material quantities including RAP, RAS, and other additives during mix production; (3) identify best practices for verifying raw material quantities used including RAP, RAS, and additives, as well as any knowledge gaps in this area; (4) develop suggested specification language and inspection procedures, including plant calibrations and procedures, accuracy requirements for various additive types, and documentation/recordation procedures for both batch plants and drum mix plants—staffing, timing, and frequency of these activates should be addressed (there may not be one approach, there may be a variety of approaches from which a state could choose; and (5) prepare a guide for agencies to use to develop specifications and inspection procedures for verification of materials including RAP, RAS, and additive content of asphalt mixes. Develop proposed updates to AASHTO M 156.

Project 10-111
Evaluation and Selection of 3D Model Viewers for Construction Inspection

Research Field: Materials and Construction
Source: AASHTO Committee on Construction
Allocation: $400,000
NCHRP Staff: Christopher T. McKenney

In the past decade, we have seen advances in technology that have introduced equipment and tools to leverage 3D engineered models for construction. Most notably is the use of automated machine guidance (AMG) for grading and excavating, fine grading and base preparation, and concrete paving. Until most recently, contractors had been using the contract plan sets to create their own 3D models. Although there has been a shift to deliver digital data as a supplement to the plan sets, only a few states have started piloting model-based deliverables by changing the medium of construction contract documents from paper or 2D PDF plans to include 3D model-based, digital information that is contractually binding.

While more state departments of transportation (DOTs) are interested in expanding the benefits of the model-based approach to project delivery, there are two distinct, but related barriers: (1) a lack of understanding of the tools currently available in the market to support the use of 3D models for inspection and (2) a lack of guidance for setting technical requirements for the procurement and selection of commercial off-the-shelf (COTS) tools or development of custom mobile applications.

Previous research has identified the wider issues related to the creation and use of 3D models. However, these prior studies have not examined how to perform detailed quality assurance checks without the use of plan sheets. Some efforts have been made to understand how high accuracy equipment (e.g. GPS) can be used to check location and elevations of specific points and record those points to create surfaces that are used for cutting cross-sections in the office for verifying earthwork quantities. However, to date not much has been done to use tablets with mobile applications that show the 3D model in a way the inspector can read the same information he/she was getting from the plan sheets.

The objective of this research is twofold: (1) Perform an evaluation of current COTS tools for viewing 3D engineered models in the field to inspect highway and bridge projects and (2) develop recommendations for procurement and selection of 3D model viewing mobile applications to perform construction inspection of highway and bridge projects. While there is progress towards using 3D engineered models for project delivery, technology is changing rapidly so it is important to conduct this study under an accelerated timeline.

State construction engineers would use the research to provide tools that construction inspectors and construction management staff can use for model-based inspection. The research should provide a thorough assessment of the software currently available, its capabilities and limitations. Understanding what is commercially available will enable state DOTs to procure and select tools that meet their immediate needs for viewing 3D models in construction for inspection tasks.

Project 10-112
Guidelines for Digital Technologies and Systems for Remote Construction Inspection for Highway Infrastructure Projects

Research Field: Materials and Construction
Source: AASHTO Committee on Construction
Allocation: $500,000
NCHRP Staff: Christopher T. McKenney

Over the past few decades, many state departments of transportation (DOTs) have been experiencing an expanding highway construction program concurrently with a reduction in the amount of construction project staff that are available to administer these projects. Existing state inspection personnel have to rely on innovative technologies and strategies for addressing the increasing demand and discharge their responsibilities in an efficient way. The adoption of mobile devices and modern surveying equipment for construction inspection have proven timely and beneficial for state DOT inspectors, who play a critical role overseeing and managing several moving parts of a construction job. A wide variety of digital tools are available to support construction inspection activities while offering numerous benefits, including improved data quality and consistency, enhanced communication, improved transparency, and improved safety of the site personnel.

Most of the recent research efforts have focused on developing guidelines and documenting effective practices for digital inspection. Emerging technologies such as small Unmanned Aerial Systems (sUAS) and remote imaging and video tools provide opportunities for enabling visual inspection (both offline and in real-time) that can be conducted remotely. Remote inspection can offer safety and efficiency enhancements while providing accurate digital data for verification and as-builts. It is important to note that the construction inspection on federally funded projects is often governed by federal regulations that offers oversight guidelines for state DOTs. There is need to develop guidelines for state DOTs in evaluating and successfully integrating the tools enabling remote inspection while meeting verification and acceptance requirements for various elements of highway construction and complying with governing regulations.

The objectives of this research are to (1) evaluate the state-of-the-art technologies and systems available in the market for remote inspection; (2) identify the activities and elements of highway construction that can be inspected remotely using the technologies; (3) document potential implementation challenges from a technological, procedural, and legal standpoint and propose mitigation strategies; and (4) develop an implementation framework for state DOTs to incorporate remote inspection technologies.

Digital technologies offering remote inspection capabilities provide opportunities to offset the challenges faced by the state DOTs owing to resource constraints they face with limited inspection personnel. Guidelines for systematically evaluating and integrating these tools to support inspection requirements would benefit SHAs considerably by equipping their personnel with skillsets required to transition to efficient digital workflow. It will also act as a valuable reference for other stakeholders including contractors and consultants that work with the state DOTs.

Project 10-113
Design Review and 3D Model Quality Management for Model-based Design and Construction

Research Field: Materials and Construction
Source: Iowa DOT
Allocation: $450,000
NCHRP Staff: Waseem Dekelbab

The 3D model-based design approach is close to market saturation for roads and continues to gain market penetration for bridges. 3D model-based design is reframing how we design, review, communicate, and coordinate project details in our organizations, with the public and to contractors. The model-based approach could produce optimal designs, improve information transfer, manage project data better, and improve overall efficiency of the road and bridge project delivery process.

State departments of transportation (DOTs) have also begun a process to change the medium of construction contract documents from paper or 2D PDF plans to include 3D model-based, digital information that is contractually-binding. The drivers of this major change are the ability for contractors and inspectors to consume 3D design data directly to support their activities and the opportunity to more comprehensively define, evaluate, and communicate the design intent. However, changing the medium of construction contract information also creates a procedural challenge. More state DOTs are interested in expanding the benefits of the model-based approach to project delivery. Two distinct, but related barriers are (1) a lack of a robust approach to 3D model-based design reviews (including review documentation) and (2) a lack of holistic quality control (QC) and quality assurance (QA) processes for 3D model-based contractual information. The procedures are well established for executing design checks using 2D plans (either paper or PDF-based), but do not translate easily to digital 3D models.

The objective of this research is to provide guidance to agencies on how to develop design review QC and review documentation QA procedures for a 3D model environment, as well as to provide guidance for QC of the digital, 3D model-based construction contract documents.

While there is progress towards resolving technological challenges to replacing the medium of roadway and bridge design contract documents, a lack of rigorous processes for 3D model-based design reviews and 3D model QC and QA is a serious concern for many agencies and engineering consultants. Owners are unable to scale the practice of contractual 3D models until these two issues are resolved.

Project 10-114
Developing Performance and Safety Specifications for Rejuvenating Seals

Research Field: Materials and Construction
Source: Rhodes Island DOT
Allocation: $300,000
NCHRP Staff: Camille Crichton-Sumners

Pavement preservation is an important tool departments of transportation (DOTs) use to maintain and enhance the conditions of their highways. Pavement preservation treatments do not improve the structural capacity of a pavement; rather they delay pavement deterioration by sealing cracks, preventing pavement oxidation, and, in the case of surface fog seals, rejuvenating the existing pavement surface layers. Rejuvenating fog seals consist of a rejuvenator, which is delivered as an emulsion; however, recently non-emulsion based seals have also been introduced to the industry. Traditionally petroleum-based rejuvenators have been used in such applications, though in recent years bio-based rejuvenators have also been increasingly utilized. Preservation treatments utilizing asphalt emulsions as the binder have generally been considered secondary to hot mix asphalt (HMA) technologies. As such, these treatments have not been researched to the same extent as HMA technologies. Over the past 5 years, however, the AASHTO TSP2 Emulsion Task Force (ETF) has made a concerted effort to improve the state of the science in emulsion technology and to create consistent, performance-based standards (specifications, test methods, design practices, etc.) that are sponsored by AASHTO and are not vendor specific. To date, twelve standards have been approved.

Rejuvenating fog seals are believed to have the ability to modify the surface binder of aged, cracked pavement surfaces. If they can rejuvenate the surface, they may be able to restore functionality to old pavements and allow them to function for longer without total reconstruction. This is an area that has not received adequate investigation. There are new materials on the market that warrant a review of those materials and the efficacy of rejuvenating seals.

The objectives of this project are to (1) determine the extent that rejuvenating fog seals penetrate and rejuvenate the asphalt pavement; (2) determine how the different rejuvenating compounds impact the underlying pavement; (3) determine how the impact and the desired performance for rejuvenating seal are measured and quantified in the laboratory and in the field; and (4) determine the optimum dose of rejuvenator required to provide the desired performance and friction properties.

The ETF recently prioritized its efforts to reestablish rejuvenator seals as standard preservation practice and views this research project as critical to both DOT materials (emulsion purchase specifications) and maintenance (application performance specifications) and to divisions wishing to safely extend pavement life at minimal cost.

Direction from the AASHTO Special Committee on Research & Innovation: Consider coordination with NCHRP project 09-63, “A Calibrated and Validated National Performance-Related Specification for Emulsified Asphalt Binder.”

Project 12-124
Improved Demand Predictions on Shear Studs for Composite Steel Bridge Design

Research Field: Design
Source: AASTHO Committee on Bridges and Structures
Allocation: $900,000
NCHRP Staff: Waseem Dekelbab

To ensure full composite action in a steel-girder bridge, shear studs must be provided along the length of a bridge at the interface between the concrete deck and the steel section to resist the interface shear and prevent slip along the interface. Currently, designers determine the stud proportions and the required stud pitch to satisfy both the fatigue and strength limit states. There have been instances where some designs have appeared to have an excessive number of shear studs. Shear stud quantity and subsequent installation increases steel bridge fabrication cost. In addition to undesirable increases in costs, an excessive number of shear studs produces unsafe conditions since the studs can pose a tripping hazard for iron workers.

In addition, further research is necessary to understand the demand on shear studs for steel-girder bridges at the fatigue limit state. It is anticipated that the demand on shear studs at the fatigue limit state will be reduced, which will reduce the quantity of required shear studs without compromising the safety of steel girder bridges. A reduction

in the number of shear studs will also increase the efficiency of fabrication and erection as well as decreasing the number of tripping hazards during construction.

The objective of this research is to develop more accurate demand predictions on shear studs for composite steel bridge design. Proposed changes from this research should further reduce the number of shear studs required on steel girder bridges, which will reduce engineering costs, improve fabrication and construction efficiency, and improve erection safety.

Project 14-47
Tools and Technology for Roadside Landscape Asset Management

Research Field: Maintenance
Source: AASHTO Committee on Maintenance
Allocation: $350,000
NCHRP Staff: Christopher T. McKenney

The design, construction and ongoing maintenance of linear roadside landscapes is one of the most complex and least understood aspects of highway system asset management. It is one of the most critical and unexplored opportunities is the application of geographic information systems, data recording tools, and data management systems in the management of roadside landscape assets. There are an estimated 1,000,000 acres of unpaved land within the nation's state and federal highway systems, which can be referred to as the natural infrastructure, supporting our built systems and blending these systems into the surrounding landscape. By planning work and tracking accomplishment and results in a geographic inventory system over time, we can better understand and explain the continuously evolving process of roadside vegetation growth and maintenance treatment.

This project would bring together and build on several key pieces of recent national study and would support the integrated research strategies of the TRB Standing Committees focused on Roadside Maintenance Operations (AKR20), and Landscape and Environmental Design (AKD50). This effort would leverage technology and digital media to create a national model for roadside asset management, and establish a recommended foundation for sustainable state DOT program development. It would serve as the basis for an ongoing dialogue and discussion with regard to health and resilience of our nation's roadsides, and facilitate our national quest to create the most integrated, locally adapted, sustainable roadside landscapes.

The objective underlying this entire proposal is the establishment of an organized and ongoing national dialogue regarding best practices for highway roadside asset management and the project's design would be to engage the states in implementing recommendations by establishing an ongoing discussion forum for state and local transportation organizations to best manage roadside landscapes. This research would be documented into a series of webinars highlighting the project and progress throughout.

A primary objective is for discovery and analysis of information on roadside asset management tools currently used by the various states. This survey and analysis would show the current state of the art with regard to design, construction, and maintenance practices for roadsides. The other objective will result in an ongoing dialogue and communication network on the topic of roadside asset management. This will facilitate the development of tools and techniques to be customized and applied within the context of the various state and local governments.

Because the topic of roadside management extends to the subject areas of ecology, social equity, sustainability, and climate change, there are many overlapping research efforts and interest from a number of other transportation research committees. It is important to note that many state departments of transportation have developed and published best management practices on this subject and comparative analysis of recent individual state approaches would be advantageous. One of the outcomes of this project would be an appendix of all relevant research and local case study data for reference.

Urgency has increased in recent years with emerging concerns over endangered species impacts, pollinator decline, increased roadside fire starts, climate change, and increasing invasive species pressures on our native ecosystems. It is also heighten by the rapid developments in mapping and data analysis technology, and the application of previously unavailable tools and innovative data management systems.

Project 14-48
Construction Guide Specifications for Pavement Treatments—Sand Seals and Ultra-thin Bonded Surface Treatments

Research Field: Maintenance
Source: Rhodes Island DOT
Allocation: $200,000
NCHRP Staff: Amir N. Hanna

Pavement preservation is an indispensable component of asset management that departments of transportation use to maintain and enhance the conditions and performance of their highways. Pavement preservation treatments do not improve the structural capacity of a pavement; rather they extend pavement life through delayed pavement deterioration by sealing cracks, preventing pavement oxidation, and, in the case of surface seals, rejuvenating the existing pavement surface layers. Preservation treatments utilizing asphalt emulsions as the binder have historically been underutilized and therefore considered secondary to hot mix asphalt (HMA) technologies. As such, these treatments have not been upgraded or researched to the same extent as HMA technologies. Over the past few years, however, the AASHTO Transportation System Preservation Technical Services Program (TSP-2) Emulsion Task Force (ETF) has made a concerted effort to improve the state of the science/engineering in emulsion technology with the goal of creating national performance-based standards (specifications, test methods, design practices, etc.) that are adopted by AASHTO and are not vendor specific. All the emulsion treatments except for sand seal and ultra-thin bonded wearing course (UTBWC)treatments have or are in the process of having their construction guide specifications developed through NCHRP projects. Therefore, to close the" gap" and have a full complement of standards for all emulsion preservation treatments it is critical that these two treatments have their construction guide specification developed. Some agencies have developed construction specifications for local jurisdictions, but standardized nationwide construction guide specifications do not exist.

Sand seal is a sprayed application of asphalt emulsion followed by a covering of clean sand or fine aggregate. A pneumatic-tire roller is often used after applying the sand. Excess sand is removed from the road surface after rolling. A sand seal is used to fill existing pavement cracking and even out surface smoothness defects as either a preparatory treatment for other maintenance treatments or as a wearing course. AASHTO materials specifications and design practices exist for sand seals (AASHTO MP 34-18 for Materials, and AASHTO PP 90-18 S for Design practices).

Ultra-thin bonded wearing course (UTBWC-Nova Chip) is a preventative maintenance tool used to help extend the life of a road. This UTBWC is an open graded hot mix asphalt placed over polymer modified asphalt emulsion through a special, self-priming paver and compacted with a roller. The treatment improves skid resistance and reduces hydroplaning and noise. UTBWC can be used in pavement maintenance activities or in new construction. TSP-2 ETF has submitted to AASHTO COMP, material specifications and design guides for UTBWCs.

The objective of this project is to produce recommended construction guide specifications for the application of sand seals and ultra-thin bonded surface treatments. This will assist highway agencies in adapting these specifications to the local conditions and environments and will aid DOTs in implementing these treatments in their pavement/asset management programs. The construction guide specification will address the construction operations required, with possible adjustments for local materials and experience. Quality assurance protocols and incentive/disincentives will have to be addressed. The research will include a review of previous work in the area, including construction standards, construction specifications, and construction practices both national and internationally. Deliverable documents will be in conformance with AASHTO COMP standards format.

Project 15-81
Guidelines for Depicting Existing and Proposed Utility Facilities in Design Plans

Research Field: Design
Source: AASHTO Committee on ROW, Utilities and Outdoor Advertising Control
Allocation: $550,000
NCHRP Staff: David M. Jared

Utility information varies in degree of accuracy, source and timeframe collected, making it difficult to depict correctly and with an indicated level of confidence. The proper denotation and use of utility information eliminates substantial

risk from construction projects. State Departments of Transportation (DOTs) are highlighting the importance of utility coordination just as more utilities are being installed within the right-of-way (ROW). These standards are needed before these trends exacerbate the previously defined problems. Without best practices and specifications in collection, management, and the depiction of utility information, many state DOTs may simply force utilities that might not truly be in conflict with the project to relocate. Research is needed to document a sound understanding of utility data, managing that data, and documenting confidence in data obtained from various sources. This would combat the practice of relocating utilities unnecessarily, reduce risk to the delivery of timely projects, and save millions of dollars in unnecessary costs.

Data management investigated in SHRP2 R01A, "3D Utility Location Data Repository," proposed to implement a state-of-the-art 3D storage and retrieval data model to accommodate data, interface with existing design software, and provide designers a tool to use captured data on underground utilities. Moreover, FHWA has promoted the appropriate use of utility investigations and depiction of utility information in proposed project design plans, as explained in the American Society of Civil Engineering (ASCE) 38 Guidelines. If the proper utility data is collected and depicted, products like SHRP2 R15B, "Identifying and Managing Utility Conflicts" and the concept of the Utility Conflict Matrix (UCM) can be leveraged, which can improve cooperation among highway agencies and utility companies for faster and more efficient project delivery. Finally, some state DOTs who do use advanced utility investigations do not clearly delineate a confidence level of the utility information collected.

The objective of this research is to develop guidance for state DOTs on best practices for retrieving data, depicting data, and identifying conflicts for all of the collected information about utilities. The research should have a primary focus on how information is depicted. The research should help define approaches to (a) reconcile conflicting utility information from various sources; (b) prioritize the depiction of data from multiple sources; (c) depict existing, proposed, and relocated facilities; and (d) depict data indicative of confidence level with design standards. The practice of better utility records, proper depiction, and conflict analysis will allow for better decision-making for state DOTs and their consultants who perform design and utility coordination for transportation projects.

Project 17-102
Safety Performance for Active Transportation Modes using Exposure Models

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $700,000
NCHRP Staff: Inam Jawed

The need to develop a modally integrated and well-functioning transportation systems is clear. It is in the interest of agencies to provide safe, accessible, and reliable systems for all, including users who walk, bike, and use mobility assistive devices. At the same time, the financial resources for local and state agencies operating these systems are dwindling, and many agencies are having difficulty maintaining their current assets at a state of good repair, let alone funding for new infrastructure. This often leads to projects being built that prioritize motorized vehicle mobility over facilities that move people and advance the use of active transportation modes (walking and biking) as part of accessible, healthy, and connected communities. In addition to funding challenges, facilities that support active transportation modes often receive less priority because the data and decision-making tools are not available to assess the potential safety performance tradeoffs when evaluating alternatives that includes facilities for walking and biking.

This research will investigate a means to assess the safety performance of projects for multiple modes of transportation in the suburban and urban environments. To fully support all modes and to improve the safety and equity of the system, it is critical to develop a method to determine potential use of the system by those who bike, walk and use mobility assisted devices. Counts of people walking and biking are often unavailable in these environments or have not been collected in a manner that is usable for crash prediction or for a comparisons of the needs of all users to support equitable decisions. Because of this lack of information, the benefits and opportunities for active transportation are often overlooked. This research will look at key factors simultaneously to evaluate the safety performance of urban and suburban facilities using characteristics such as speed, roadway width, (lanes/shoulders/medians), sidewalks, bicycle lanes/tracks, land use, network connectivity, and access management. These factors will be used to determine current and future system usage by the active transportation modes if compatible land use, or walkable and bikeable facilities were to be provided. In addition, various design treatments for active users in different contexts will be evaluated using proven exposure prediction methods for active transportation modes to examine how these designs effect the likelihood of crashes.

Exposure models allow organizations to incorporate predictive information into decisions when volume data for those who walk or bike are not available and organizations do not have the funds to collect data at every location where a project might be developed. Even if data are collected in some locations for individual projects, state and local transportation agencies are unlikely to have sustainable funding available for regularly collecting active transportation volume data; therefore, these critical modes lack the necessary data to justify their consideration during project planning and development. This lowers the potential for inclusion of transportation facilities for active transportation modes, particularly in lower income areas where significant gaps for active transportation modes exists. It is intended that this research advance a decision-making framework that considers how best to achieve an integrated multimodal approach on the public roadway system. The proposed research would develop methods for using exposure volumes that could be used in other tools, such as the models currently under development in NCHRP Project17-84, "Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual" and other systemic safety tools. In addition, this research would develop additional safety performance functions to supplement the NHCRP Project17-84 models with additional functional classes and contexts. This proposal is developed with the intent to supplement other ongoing predictive modeling and systemic tools for active transportation.

The objective of this research is to advance the predictive methodologies for pedestrians and bicyclist by using exposure (e.g., pedestrian any bicyclist volume) prediction. These exposure models can then be used to develop multivariate safety performance functions and systemic analysis tools for use in planning, design and operational decision-making. The safety performance functions will address additional functional classes and contexts to supplement those developed being develop under NCHRP Project17-84. This proposed research will develop models and predictive methods that can be used by state and local agencies of all sizes to determine potential exposure, which will allow this information to be used to determine the likely safety performance at a given location. The multivariate nature of this approach allows for the necessary planning, design, and operational considerations in different combinations and contexts upfront, so the needed information related to potential safety performance can be used in decision-making throughout planning and the project development process for active transportation modes. This research will also develop guidance for determining appropriate considerations and modifications to the public right of way to provide for an equitable system for people biking and walking in a manner that reduces the likelihood of crashes involving these users and the likelihood of death or serious injury of these users in the event of a crash.

The research will be conducted in two phases. Phase I will include at least the following tasks: Task 1—*Review safety literature* to identify the pedestrian exposure factors associated with highway safety; Task 2—*Identify data needs and potential data sources* for developing exposure models and safety prediction models for the identification of appropriate multimodal roadway locations, as well as development of a data collection plan; Task 3—*Prepare a Phase II work plan* indicating a methodological framework for developing exposure and safety prediction models; and Task 4—*Prepare an interim report* documenting the literature review, datasets, and proposed work plan. Tasks to be performed in Phase II will include at least the following: Task —*Execute the work plan* developed in Task 4 and approved by the NCHRP panel; Task 6—*Conduct the statistical analysis (i.e., exposure and safety prediction)* using the proposed methodologies that have been approved by the NCHRP panel; Task 7—*Develop a user-friendly guideline* to facilitate the implementation of research outcomes and how these models can be used to inform multimodal decision-making in different design contexts and for different modal priorities, including a discussion of how changes in the road environment may change safety outcomes for all users and how roadway (mitigation) strategies can be applied to address the respective changes; and Task 8—*Prepare final deliverables and guidelines* documenting the research development process, including all assumptions, research results, and the guidelines on incorporating exposure factors in safety research. The final set of deliverables should include the research datasets with a data dictionary, and the program code used for the development of any statistical models to support future research and reproducibility of research results.

The AASHTO Committee on Safety and the TRB Highway Safety Performance Committee have identified this research as a high priority. This research will have a significant influence on how the state departments of transportation analyze pedestrian and bicyclist accommodations and will provide the ability to make use of additional analytical tools.

Direction from the AASHTO Special Committee on Research & Innovation: Consider adding elements from the FY 2022 problem statement G-06, "Improving Bicyclist and Pedestrian Safety Using Perceived Risk and Surrogate Safety Measures."

Project 17-103
Developing Multidisciplinary Safety Strategies from Understanding Roadway Fatality Trends During the New Millennium

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $500,000
NCHRP Staff: Leslie C. Harwood

Traffic fatality trends in the United States in recent years have raised questions concerning how to continue the decline in fatalities experienced from 2005 to 2011. *NCHRP Research Report 928, Identification of Factors Contributing to the Decline of Traffic Fatalities in the United States from 2008 to 2012* successfully identified major contributors to the decline in fatalities during this period. The research indicated that the most significant contributors to the drop in traffic fatalities were the substantial increase in teen and young adult unemployment, decreased alcohol consumption, and reductions in GDP/capita income. Vehicle design improvements also contributed to the decline significantly, as did the decline in rural vehicle-miles traveled (VMT) and increased strictness of DUI laws.

There is a need to more fully explore the relationships identified in *NCHRP Research Report 928* to reveal information that can be used by states to target safety programs and projects. As traffic fatalities have risen since 2011, there is a need to examine additional information related to factors contributing to fatality trends and to develop strategies to recreate and expand decreasing trends. Exploration of this data and relationships could create other data sets for consideration such as socioeconomic or regional behavioral opportunities. Achieving safety targets will necessitate the use of multiple types of strategies and programs that aim to reduce traffic fatalities, since there is not a single discipline that is expected to be able to produce the desired reductions in fatalities and serious injuries. The effectiveness of many individual strategies has been studied, but it is not clear the effect a combination of multiple strategies using engineering, enforcement, education, and emergency medical service approaches will have on crashes. This project would allow for the potential creation of strategies and countermeasures that would more intertwine the work of the "4 E's" (Education, Enforcement, Engineering, and Emergency Response).

The objective of this project is to develop multidisciplinary strategies for making significant reductions in traffic fatalities through the investigation of the quantitative impact of combined behavioral, infrastructure, and or other mitigation strategies. The first phase of the project would build on earlier research and use experiences and knowledge gained from recent trends to determine the effectiveness of external factors as well as combined countermeasures in previous mitigations. The research will consider specific geographic, temporal, and/or functional areas of the highway system. The second phase will be to develop guidance for identifying and customizing specific combined mitigations for individual jurisdictions, regions, or states.

A more detailed understanding of data from individual states and data related to individual crash types and contributing factors will allow safety professionals to more aggressively use the strategies that have worked and to identify new strategies to fill gaps in the tool box. A better understanding of economic and social factors will contribute to the development of programs that change traffic safety culture. In addition, the changes in travel due to the 2020 pandemic and related economic changes may have an effect on fatalities, and an analysis of related data can add to the knowledge regarding potential "4E" and traffic safety culture strategies that would help maintain and continue fatality reductions. This research would help safety professionals more fully understand the relationships between economic, regulatory, vehicle, and infrastructure factors and traffic fatalities and the mechanisms by which they operate to provide states with insights that can be used to target fatality reduction programs and projects. Moreover, strategies that combine domains will be important for using state resources efficiently to maximize fatality reductions.

Project 17-104
Enhancement of Roadside Design Features Safety Performance Models for the Highway Safety Manual

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $500,000
NCHRP Staff: Edward Harrigan

The AASHTO *Highway Safety Manual* (HSM) is a tool that allows safety practitioners to consider safety fully and quantitatively in project decisions. The first edition of the HSM (HSM1) provides a method for considering roadside conditions in analyses of two-lane facilities that is based on a qualitative and visual index. The user selects a factor, called a Roadside Hazard Rating (RHR), using a series of photographs and descriptions to represent the roadside on the existing or proposed facility undergoing analysis. This rating is used in a limited number of safety performance functions (SPFs) and/or crash modification factors (CMFs) to account for roadside features on two-lane rural roads in crash predictions. Roadside information is limited to side-slopes on undivided multi-lane roadways and is not incorporated into analyses for other multi-lane divided facility types addressed in the HSM1.

Since publication of the HSM1 in 2010 there has been research to fill in the knowledge gaps in the associated SPFs and those used in the Roadside Design Guide (RDG) for roadside features. NCHRP Project 17-54, "Consideration of Roadside Features in the *Highway Safety Manual*" developed models to quantitatively consider the roadside in safety analyses. Upon completion of this work, the AASHTO Highway Safety Manual Steering Committee, TRB Committee on Safety Performance, and others reviewed the research results and proposed a draft chapter for the second edition of the HSM (HSM2) that is currently being developed.

Because the NCHRP Project 17-54 models were of a different form than the existing HSM1 models, using exposure versus predictive models, the AASHTO HSM Steering Committee undertook a demonstration project to determine the ability to use the models in the HSM context. In a separate effort, results from NCHRP Project 17-82, "Proposed Guidance for Fixed Objects in the Roadside Design Guide" were reviewed. . This analysis was also considered by the AASHTO committee. The TRB Committee on Highway Safety Performance also provided input to AASHTO on these analyses and all the analyses were discussed with the panel for NCHRP Project 17-71, "Proposed AASHTO Highway Safety Manual, Second Edition."

In summary, the NCHRP Project 17-54 findings for SPF and CMFs could not be validated by small sample testing by several states in the AASHTO HSM Steering Committee. Of particular concern was the shape (reduced road departure crash rates) of the SPF at higher volumes and the associated effects of roadside fixed objects and their offsets to the travel way.

Research is needed to collect additional data and validate proposed models and then determine whether improvements are needed for the roadside-related crash prediction tools proposed for future editions of the HSM. If new data are available or readily collectable, then the model improvements could be performed. The same validation and model development would also benefit the existing and future efforts to develop a performance-based RDG.

The objectives of this research are to (1) validate and/or develop enhanced roadside safety performance functions including associated design element variables that are appropriate for inclusion in the HSM and (2) prepare appropriate draft text for AASHTO to consider for inclusion in appropriate HSM chapters. The research will include a review of available roadway and roadside design element inventory and associated crash data. Both the roadway departure SPFs and related CMFs for design elements will be provided for the roadway facility types prioritized by AASHTO members based on available or collected data.

Accomplishment of these objectives shall require the following tasks at a minimum: (1) conduct a review of recent roadside-related safety research to determine if data exist to validate the recent safety performance research findings and/or develop refined SPFs and CMFs, and if additional roadway data are needed, propose data collection methods; (2) conduct a survey to determine the critical roadway facility types that require more detailed models for roadside elements (e.g., rural two-lane versus urban multi-lane) and validate those types based on the Task 1 findings and proposals; (3) prepare a work plan to validate and/or develop new SPFs and CMFs, validate the relationship between the HSM and RDG methods and the data collection required, and develop a design for data collection, statistical methodology, analysis, and reporting; (4) collect data, select methodologies and an analysis approach, and prepare a technical memo that addresses potential risks, recommended solutions, possible modification to the work plan, and the estimated cost of proposed work; (5) develop a final work plan using the Task 4 technical memo feedback; (6) prioritize the selected facility types and conduct feasibility analysis per final work plan outcome; (7) conduct data analysis to develop and validate SPFs and CMFs for inclusion in the HSM; (8)

produce a technical memo for SPF and CMF development outcomes including identifying risks/needs/opportunities; and (9) prepare (a) a final report with recommended SPFs and CMFs and associated updated text for inclusion in the HSM, (b) an application spreadsheet to conduct the safety analysis and a reference guide for training materials for users understanding in selecting roadside models in conjunction with other HSM models, (c) research problem statements for continuing and complementing the findings, and (d) documentation of the project data for future use.

Project 17-106
Motorist Behavior and Safety Impacts on Bicyclists from Centerline and Shoulder Rumble Strips on High-Speed Two-Lane Highways

Research Field: Traffic
Source: California DOT
Allocation: $400,000
NCHRP Staff: Inam Jawed

Shoulder and centerline rumble strips provide significant safety benefits to motorists. However, contact with rumble strips is very jarring to bicyclists, making safe riding upon them unlikely or impossible. States are increasingly installing rumble strips on roads frequented by bicyclists, particularly rural two-lane roads with speed limits over 50 miles per hour, and often with less than 4 feet of shoulder space. As a result, the bicyclist community is increasingly experiencing challenges when rumble strips are installed in rideable shoulder space and bicyclists are forced to ride in the lane with high-speed mixed traffic.

The Federal Highway Safety Improvement Program (HSIP) is a major funding source for rumble strip projects. Federal law (23 USC 148(a)(4)(B)(iii)) allows HSIP use for such projects "if the rumble strips or other warning devices do not adversely affect the safety or mobility of bicyclists and pedestrians…." However, there is a lack of available research quantifying the safety effects for bicyclists with the use of rumble strips in shoulders and center lines.

Another problem with rumble strips affecting bicyclist safety is the motorist behavior when passing cyclists riding on roadways with centerline rumble strips. A study by the Michigan Department of Transportation's Traffic and Safety Division suggests that motorists are less likely to cross centerline rumble strips when passing cyclists due to vibration and noise. This may induce unsafe behaviors such as motorists passing too closely, increasing risk of a motorist-cyclist crash.

At present, there are only a few studies that explore motorist and bicyclists interactions with rumble strips, and there is no research assessing the safety impacts of motorist-bicyclist interactions caused by rumble strips. In addition to public safety concerns, these impacts have repercussions for compliance with the federal law.

Installing centerline and shoulder rumble strips on rural, two-lane high-speed roadways without sufficient rumble-free clear zone has an impact on the safety of bicyclists that needs to be studied. Motorists interacting with on-road bicyclists are also affected, to a lesser degree.

Research into the design of rumble strips on high-speed roads and its effects on bicyclist and motorist behaviors and interactions would determine and quantify the safety impacts that may exist. The results of this research could be used to improve design and inform potential policy modifications, ensuring transportation departments are compliant with federal law when using HSIP funding for rumble strip projects.

With the national rise in the number of serious injuries and fatalities for people who walk and bike, the AASHTO Council of Active Transportation has prioritized bicycle and pedestrian safety and has developed a number of goals and strategies to address risk to the most vulnerable road users.

The objective of this research is to determine and quantify safety impacts on bicyclists for the use of centerline and shoulder rumble strips on high-speed rural roadways. Primarily using a simulator, the researcher would compare motorist behavior passing bicyclists traveling in the same direction, using consistent rumble strip design dimensions that follow best practices for accommodating bicyclists (see Adventure Cycling's *Solutions for Making Rumble Strips Safer for Bicyclists: Best Practices for Transportation Decision Makers*) on 50+ mph roadways with 12-foot lanes. For roadways with no centerline rumble strips, the scenarios to be considered will include (1) bicyclist riding in the far-right of the travel lane on a roadway without paved shoulders and no rumble strip; (2) bicyclist riding in the center of a 5-foot paved shoulder with at least 4 feet of rumble-free clear zone to the right of rumble strips; and (3) bicyclist riding in the far right of the travel lane on a roadway with paved shoulders that are not usable due to rumble strips and a lack of sufficient rumble-free clear zone. For roadways *with* centerline rumble strips, the scenarios will include (1) bicyclist riding in the center of the 5-foot paved shoulder and (2) bicyclist in the far-right travel lane with no paved shoulder.

In addition to simulation results, based on data availability, historical crash data can be used to understand crash rates for cyclists on high-speed two-lane rural roadways with shoulder and centerline rumble strips and discover possible contributing factors. The results should present the five cases' crash rates and/or lateral passing clearance statistics as suggested. If the results warrant, guidance for Crash Modification Factors should be developed. Design recommendations should be provided for shoulder and centerline rumble strips.

With the growing nationwide use of rumble strips to reduce motorist run-off-road and head-on crashes, knowledge of whether there are unintended bicyclist safety impacts from specific design policies is needed. Depending on the research's outcome, state departments of transportation using or funding rumble strips could (1) adjust rumble strip installation and design parameters through Federal Highway Administration guidance and recommendations; (2) ensure compliance with Federal Highway Safety Improvement Program law; and (3) confidently respond to bicycle community concerns on shoulder and centerline rumble strips

Project 17-107
Work Zone Intrusion Frequency and Characteristics

Research Field: Traffic
Source: Federal Highway Administration
Allocation: $600,000
NCHRP Staff: Leslie C. Harwood

Traffic intrusions into work zones, when they occur, present a significant safety risk to construction, maintenance, and utility workers. According to the Bureau of Labor Statistics Census of Fatal Occupational Injuries, "struck-by" crashes are a major cause of roadway construction worker deaths. Motorists are also at risk when intruding into a work zone, potentially colliding with work equipment and materials. Unfortunately, the rate at which intrusions occur, and the factors that influence that rate, are not well understood at this time. As a result, it is difficult to quantify possible benefits of intrusion mitigation strategies (e.g., use of positive protection, intrusion alarms, etc.) or determine when and where such strategies are cost-effective. Recent advancements in sensor technology (such as 360-degree Lidar, thermal cameras, machine vision, and others) now allow vehicle trajectories to be tracked and could be used to monitor work zones and systematically collect intrusion data. Research is needed to determine which technologies are best suited for this purpose, and then to quantify and characterize intrusions that occur into work zones when using that technology.

The objectives of this research are to (1) perform an assessment of the technologies and methods available to detect work zone intrusions; (2) use appropriate technologies and methods to collect data on work zone intrusion frequency and characteristics at a sampling of work zones nationally; and (3) develop predictive models and methods to estimate intrusion likelihood as a function of key roadway, traffic, and work zone variables based on the collected data to improve work zone safety management decision-making.

Current regulation (23 CFR 630 subpart K) requires consideration and management of road user and worker safety in work zones. The processes, procedures, and/or guidance shall address the use of positive protection devices, exposure control measures, other traffic control measures including uniformed law enforcement officers, and the safe entry/exit of work vehicles onto/from the travel lanes. Data on actual intrusions is urgently needed to assist agencies in making work zone safety management decisions.

Project 17-108
Developing Crash Modification Factors for Alternative Intersections

Research Field: Traffic
Source: Texas DOT
Allocation: $600,000
NCHRP Staff: David M. Jared

Alternative intersection designs, including Displaced Left Turn (DLT), Median U-Turn (MUT), and Restricted Crossing U-Turn (RCUT), have been implemented in the United States to reduce congestion. The reduction in the number of traffic signal phases and conflict points at these intersections results in improved traffic operations and safety. Various research has been conducted to develop crash modification factors (CMFs) for typical intersections as well as conversion of traditional intersections to roundabouts. Additional studies have been conducted to evaluate the safety benefit of different intersection configurations.

In the past 10 years, the number alternative intersections have increased substantially in the U.S. The operational improvements of the alternative intersections over conventional intersections have been proven. The total number of conflict points for alternative intersections are lower than traditional intersections, and, as a result, offer safety advantages over conventional intersections. Studies show significantly lower crash rates with MUTs and RCUTs for both corridor-wide and intersection related data. Lower crash rates for DLT's are also supported by intersection data following DLT installation; however, there are safety concerns, especially for older drivers and those unfamiliar with alternative intersections.

The objective of this research is to develop CMFs for alternative intersection types, to include but not be limited to DLT, MUT, and RCUT configurations, and hence a tool for estimating crashes with and without alternative intersections. The research would inform engineers, transportation agencies, and the public of the safety benefits of alternative intersections by quantifying the reduction in crash frequency and severity resulting from conversion of traditional signalized intersections to DLT, MUT, RCUT, or other alternative configuration. Ultimately, it would help transportation professionals *evaluate* alternative intersection strategies in terms of safety benefits. The estimation/evaluation tool could be included in *Highway Safety Manual*, state DOT manuals and guidelines, and in the CMF Clearinghouse, and it could support progress towards Vision Zero goals across the U.S.

Direction from the AASHTO Special Committee on Research & Innovation: The scope of work should focus on Safety Performance Functions before CMFs, and coordinate with active, related NCHRP research. The results should be applicable across the country, although these intersections may not yet be widely used. Additional intersection types may be of interest in addition to those listed.

Project 17-109
Crash Modification Factors (CMFs) for Automated Traffic Signal Performance Measures (ATSPMs)

Research Field: Traffic
Source: Utah DOT
Allocation: $400,000
NCHRP Staff: Edward Harrigan

Automated traffic signal performance measures (ATSPMs) offer an alternative approach to traditional signal retiming. They are developed using second-by-second data that can be collected over several months or years. The Federal Highway Administration (FHWA) included ATSPMs in Every Day Counts 4, and since then, dozens of agencies have installed this new technology. ATSPMs have been shown to help agencies improve operations at signalized intersections through reduced split failures, arrivals on red, red-light running, and delay.

The right-of-way time that is allocated to different modes and movements can significantly impact behavior–drivers willing to take smaller gaps, pedestrians waiting for the walk signal, or bicyclists clearing an intersection. While not a true adaptive solution, ATSPMs give agencies the opportunity to make near-real-time adjustments based on data from the field. There has been previous research on the safety impacts of Adaptive Signal Control Technology (ASCT), but the same level of research has not been completed for ATSPMs.

This research would quantify reductions in crash frequency and severity resulting from the deployment of ATSPM signal retiming. It would inform public agencies about the safety benefits and help them make funding decisions related to ATSPM systems.

The objectives of this research are to (1) identify and organize ATSPM signal retiming and/or associated operational improvements with respect to site characteristics (e.g., geometry, volumes, etc.), (2) quantify crash modification factors and/or functions associated with ATSPM signal retiming (for all modes for specific conflict types and severity) at a quality that could facilitate inclusion in the *Highway Safety Manual* or *Crash Modification Factors Clearinghouse*, (3) develop guidance for the use of ATSPM signal-retiming-related CMFs, and (4) document case study costs and benefits associated with safety improvements resulting from ATSPM signal retiming (expanding on information in FHWA-HOP-20-003).

Direction from the AASHTO Special Committee on Research & Innovation: The scope of work should focus on traditional systems and implications for safety.

Project 19-19
Sustaining a Zero Fare Public Transportation Program in a Post COVID-19 World

Research Field: Administration
Source: AASHTO Council on Public Transportation and MTAP
Allocation: $300,000
NCHRP Staff: Ann M. Hartell

The coronavirus outbreak continues to create numerous challenges to public transportation providers and the communities they serve. Stay-at-home orders, social distancing regulations, and the heightened demand of essential workers are forcing public transportation providers to adapt to extraordinary circumstances and consider new approaches to make transit functional yet safe during the COVID-19 pandemic response.

One strategy deployed by transit systems throughout the nation is a temporary zero fare system: a fare collection policy aimed to limit interactions between operators and riders, remove human bottlenecks at ticketing locations, and provide relief to essential workers depending on transit throughout the pandemic. Before COVID-19, many communities were embracing a zero fare structure as a way to improve personal mobility and quality of life for their public transit riders. The pandemic, however, sped up this fare policy shift drastically, with both urban and rural transit agencies beginning to operate on zero fare. As more businesses open and people begin returning to work, policy makers are now facing key decisions to remain on zero fare, begin transitioning back to the old fare system, or create a new collection policy that more effectively limits interactions.

To understand the associated tradeoffs, policy makers need to have a proper analysis of the benefits and risks associated with remaining zero fare. A key element of this effort is to catalog the changes in ridership and the societal, economic, and public health benefits of implementing a zero fare policy. *TCRP Synthesis 101: Implementation and Outcomes of Fare-Free Transit Systems*, captured examples of transit agency implementation of zero fare programs and their associated outcomes. As more agencies have implemented zero fare programs during the pandemic, the current state of practice and documented outcomes is in critical need of an update with a more detailed and comprehensive analysis of the impact of these programs during a public health crisis as well as the possibility of sustaining a zero fare structure as communities adapt and recover.

The objective of this research is to analyze the costs and benefits of sustaining zero fare transit programming, including impacts to ridership and societal, public health, and economic benefits. The research will explore existing approaches to fare structure decision-making, a potential development of a scenario-planning tool based on actual implementation outcomes, a cost-benefit analyses and evaluation of risks associated with implementation of zero fare transit approaches. The purpose is to provide state departments of transportation with the information necessary to evaluate zero fare approaches, post pandemic, on their transit systems. Potential research deliverables include the following:

- A report of pandemic-related findings,
- A scenario-planning tool for evaluation, and
- Recommendations for presenting the findings to the transit community and its partners.

Project 19-20
Interdependence of Federal, State, and Local Transportation Funding and Ownership

Research Field: Administration
Source: AASHTO Committee on Funding and Finance
Allocation: $450,000
NCHRP Staff: Trey Joseph Wadsworth

Transportation infrastructure is built, maintained, and operated by multiple levels of government and each level plays a role in delivering an integrated transportation system to serve national, state, and local needs. Components of the transportation system are owned and operated by all levels of government, creating a complex network of entities that plan, build, and operate roads, bridges, and transit systems. Current funding mechanisms consist of a mix of funding from all levels of government. This multi-layered system of ownership and funding can present challenges for project development and delivery. While there is a desire on the part of some policymakers for more "local control" of federal funding, the complexities and requirements of the federal-aid programs can prove burdensome to local entities.

The objective of this research is to document the different scales and complexities of owning, funding, building, and maintaining the transportation system for all levels of government. Additionally, this research will investigate the interdependence of funding sources and flexibility and system ownership and responsibility. Research tasks and activities could include (1) a detailed analysis of ownership and operational control of transportation system elements and how different needs and functions of the system are met in different states and at different levels of government; (2) an exploration of non-federal funding issues including a compendium of state methods for state and local government revenue generation; (3) an identification of the reasoning for differences in transportation system ownership, project delivery responsibilities, and funding; and (4) an examination of how federal funding flexibility is used currently to improve efficiency and accommodate these differences.

Research into the complex and interdependent funding mechanisms for transportation is important to state departments of transportation and local transportation agencies as they face constrained budgets and shortfalls in federal funding. If local governments are encouraged to accept more responsibility for project delivery and funding to meet highway and transit needs, this research will benefit policymakers and stakeholders at all levels of government.

Project 20-129
Best Management Practices to Address Encampments on State Highway Rights of Way

Research Field: Special Projects
Source: AASHTO Committee on Maintenance, Washington DOT
Allocation: $350,000
NCHRP Staff: Amir N. Hanna

Many urban areas throughout the country are experiencing a dramatic increase in the number of people living without permanent residence. For these people, state highway rights of way through cities are often some of the most accessible areas to set up temporary encampments. This growing trend of encampments on state rights of way has presented a series of unprecedented challenges and liabilities for state departments of transportation (DOTs), in the design, construction, and maintenance of urban freeway roadsides and bridges. An NCHRP synthesis study on the issues facing state DOTs along urban freeway sections was completed in 2019. NCHRP 20-05/Topic 49-06 "Landscape Development and Management for Urban Freeway Roadsides" provides information on the scope of issues and current magnitude of the issues throughout the country. The report identifies urban freeway encampments as one of the most significant challenges facing state agency operations and maintenance of highway systems throughout our nation's cities. An organized comparison and discussion of agency experience in relation to this topic would benefit all state DOTs and provide a basis for the development of recommended best management practices for tolerance, prevention, and cleanup of encampments.

The primary objective of the research is to document the current scope of the impacts and solutions and to comparatively study the approaches taken by state transportation agencies in response to encampments along the highways and under bridges. Specific issues to explore include:

- State agency policy and procedures.
- Processes for developing location inventories and activity data.

- Agency liability issues/instances of legal actions/local agency coordination.
- Data sharing agreements with local agencies.
- FHWA restrictions/potential solutions/cases where encampments are permitted.
- Allowed types of alternate land uses on limited access rights of way/equivalent value issues with leasing.
- Agency training materials specific to this issue.
- Policies and practice specific to construction projects.
- Tracking and documentation of campsite occurrence and cleanup.
- Cost and funding of cleanup and prevention efforts.
- Planting design and maintenance impacts and solutions.
- Application of Crime Prevention thru Environmental Design (CPTED) principles.
- Bridge and wall design impacts and solutions.
- Bridge and drainage infrastructure maintenance impacts and solutions.
- Environmental regulatory impacts and solutions.
- Employee safety training for dealing with camp removal/clean up.
- Employee interaction with encampment residents in daily operations.
- Holding personal property following cleanup.
- Local laws and coordination with law enforcement.
- Adjacent neighborhood safety issues.
- Partnering with local businesses and advocacy groups.
- Use of contractors for cleanup.
- Use of corrections crews for cleanup.
- Use of state employees for cleanup.
- Camping in Safety Rest Areas.
- Parked/abandoned RVs.

A secondary objective is the development of recommended best management practices based on comparative case studies throughout the country. Recommendations would answer as many as possible of the specific issues listed above. Another objective is the establishment of a forum to facilitate ongoing dialogue between state transportation agencies as adaptive practice evolves nationally in response to the economy and combined societal pressures. This project would include efforts to communicate and discuss the issues with the larger national audience. Webinar discussions would be conducted to collect initial information and data and provide periodic input on analysis and recommendations. An ongoing peer-exchange working group would be established in conjunction with the project to participate in information gathering efforts, facilitate the national discussion, and continue the discussion upon completion of the project.

Project 22-52
Development of a Crashworthy Tangent End Treatment for Low Speed Curbed Roadways

Research Field: Design
Source: AASHTO Committee on Design, Technical Committee on Roadside Safety
Allocation: $750,000
NCHRP Staff: Ann M. Hartell

With the increasing interest in multimodal transportation, the demand for appropriate barrier solutions to address roadside safety issues in low-speed urban and suburban conditions has increased. These environments often have closely spaced intersections/driveways, improvements intended to encourage bicycle and pedestrian travel, physical limitations to the available lateral offset, and commonly involve curbed roadways sections. Because of the physical space limitations, barriers have been installed without a crashworthy end treatment (e.g., sloped end treatments on concrete barrier). Systems that have not been evaluated for use in combination with curbs (e.g., crash cushions) and/or those that involve compromises with respect to length of need (i.e., use of gating hardware) have also been installed. Because barriers in these locations are normally installed in combination with curbing, terminals commonly cannot be flared to avoid conflicts with adjacent pedestrian or bicycle accommodations.

As a result of these constraints, a viable end treatment for barriers in these environments—whether for new construction or retrofits of existing barriers—should minimize:

- Length—to allow for installations along roadways with longitudinal constraints (i.e., discontinuities for intersections, driveways, predestination crossings, etc.).
- Width—to reduce impacts on infrastructure and adjacent pedestrian pathways.
- Height—to reduce impacts on sight distance and allow for use with low profile barriers, guardrail, and typical concrete barriers/bridge traffic railings shapes.

The objective of the research is to develop an AASHTO Manual for Assessing Safety Hardware (MASH) TL-2 Tangent End Treatment that minimizes the required length, width, and height of the system, and can be used in common conditions found in urban and suburban areas—specifically in combination with 6" vertical curb (minimum height)—and that can be transitioned into either TL-2 low profile, TL-3 F-shape concrete, and semi-rigid w-beam barrier systems. The end treatment should be evaluated using a combination of ISPEs, computer simulation, and full-scale crash testing. The final product will be non-proprietary system drawings and specifications that will allow for component manufacturing and installation.

Potential tasks include:

- Comprehensive literature review to determine critical design elements, evaluate potential components, and establish baseline for system design concepts.
- Review related current and expired patents to ensure a non-proprietary system can be developed.
- Determine appropriate curb heights.
- Develop design concepts.
- Perform component/material testing.
- Perform computer device simulations of selected concepts.
- Proof of concept crash testing.
- Validation of computer simulations.
- Full scale crash testing to MASH TL-2 terminal/crash cushion testing matrix.
- Development of design drawings and construction specifications needed for the manufacturing and installation of the system.
- Develop design drawings of concepts for commonly needed transitions.
- Submit drawings for inclusion in the Task Force 13 Hardware Guide.
- Presentation of final design to AASHTO Technical Committee on Roadside Safety and TRB Roadside Design Committee.

(AKD20)

Direction from the AASHTO Special Committee on Research & Innovation: Consider the use of simulation to minimize crash testing to develop a generic system. Consider NCHRP project 15-53, "Roadside Barrier Designs Near Bridge Ends with Restricted Rights of Way" and avoid duplication of effort.

Project 22-53
Development of Guidance for Enhanced Delineation of Barriers and other Roadside Safety Hardware, Slopes, and Hazards

Research Field: Design
Source: AASHTO Committee on Design, Technical Committee on Roadside Safety
Allocation: $450,000
NCHRP Staff: Amir N. Hanna

Roadside safety hardware is crash tested to assess the crashworthiness of the device. The current crash test criteria are contained in the AASHTO Manual for Assessing Safety Hardware (MASH) and all transportation agencies are in the process of implementing MASH hardware on their highway systems. However, like all hardware assessment, MASH testing is conducted within the sterile, idealized environment of a laboratory test deck and does not encompass human factors

regarding perceived danger and consequent driver behavior to specific delineation practices of safety barriers or other roadside hazards. Transportation agencies have encountered situations where enhanced continuous delineation of the face of existing roadside barriers seem to be playing a significant role in the reduction of crashes and injury severity. Examples of such situations could be related to the reduction of motorcycle impacts at strategic locations where a metal rub-rail was added to the guardrail system and painted yellow. Similar crash reductions were noticed when the yellow colored DR-46 motorcycle attenuator rub-rail was added to existing guardrail systems.

This research will develop guidance for enhanced delineation of roadside barriers and other hazards such as steep slopes in order to provide increased visibility and improved safety performance. Such guidance will also address delineation applications for reducing vehicle interaction with pedestrians and bikes on multi-modal roadways.

The objectives of this research are to (1) identify best practices of enhanced delineation of roadside barriers and steep slopes, as currently adopted by transportation agencies; (2) identify the effectiveness of such delineating practices, as reported by existing transportation agencies data/studies; (3) develop guidance that agencies can apply to delineate roadside hardware systems, slopes, and multi-modal facilities adjacent to roadways; and (4) propose any needed updates of appropriate sections of the AASHTO Roadside Design Guide (RDG) and the Manual on Uniform Traffic Control Devices Recommended (MUTCD), and the AASHTO MASH standards.

Direction from the AASHTO Committee on Research & Innovation: No crash testing is anticipated.

Project 22-54
MASH Hardware Evaluation with New Proposed Test Vehicles

Research Field: Design
Source: AASHTO Committee on Design, Technical Committee on Roadside Safety
Allocation: $1,000,000
NCHRP Staff: David M. Jared

The AASHTO Manual for Assessing Safety Hardware (MASH) requires full-scale crash testing of roadside features using worst practical impact conditions, which should be representative of the composition of vehicles involved in run-off-road crashes and of the roadside departure speeds and angles. Previous NCHRP projects have driven changes in standard test conditions and test vehicles. In the mid-2000s, MASH was introduced and updated the criteria for selecting passenger car and pickup truck standards. Also, a mid-size test vehicle was introduced. After exploratory crash-testing programs for each of these changes in test vehicle selection criteria, a narrow number of selected makes and models were informally adopted as the "preferred" test vehicle types, offering economical and reproducible outcomes.

Recently, NCHRP Project 20-07, Task 372, "Evaluation of MASH Test Vehicles," indicated a significant decline in new passenger car sales and a rise in new light truck sales since 2014, driven primarily by "compact" or "crossover" utility vehicle (CUV) sales. Hence, updates for the selection criteria used for standardized passenger car and light truck test vehicles were recommended, as was an exploratory full-scale testing program to evaluate roadside hardware using the CUV class of test vehicle. A pilot testing program evaluating existing, MASH-approved hardware using the new proposed vehicles, with emphasis on the CUV vehicle class, is needed to ensure that testing criteria remains representative of the "practical worst-case" impact conditions.

The objectives of this research effort would be to (a) conduct a series of full-scale crash tests of MASH-approved, non-proprietary roadside safety hardware using test vehicles consistent with recommendations provided in NCHRP Project 20-07 Task 372; (b) compare results of the full-scale crash testing using the new proposed vehicles with correlated MASH full-scale crash testing results; and (c) identify preferred vehicles and recommend the configurations, trim levels, or sizes needed for developing new vehicle models using finite element analysis (FEA) methods.

The outcome of this research would be (a) guidelines for selecting preferred standardized vehicles for the light truck, small car, and mid-size vehicle classes, as a basis for recommending updates to MASH evaluation criteria and (b) selection of characteristics of the preferred mid-size test vehicle. This research would provide the first indications of the likelihood that existing, successfully-tested hardware will continue to be perform acceptably with the updated test vehicles. Also, the research would identify recommended vehicles to be developed into FEA models in future studies which could augment evaluation of hardware using the updated vehicles.

Project 22-55
Develop, Fabricate, and Test Surrogate Bogey Vehicles and Pendulum Masses with Noses for Evaluating MASH Breakaway Performance of Luminaire Poles, Signs, and Work Zone Devices

Research Field: Design
Source: AASHTO Committee on Bridges and Structures
Allocation: $850,000
NCHRP Staff: Waseem Dekelbab

Historically, roadside safety features have been subjected to crashworthiness evaluations using a variety of impact test specifications and/or guidelines. With the AASHTO Manual for Assessing Safety Hardware (MASH) guidelines, elimination of surrogate vehicle testing, the addition of a pickup truck test condition, the existence of numerous luminaire poles, sign supports, and work-zone traffic control devices, and the increased cost to certify these devices, crashworthiness evaluations and innovation have stagnated for many of these devices. As a result, there exists a need to re-examine the use of surrogate vehicle testing in the crashworthiness evaluations of luminaire poles, sign supports, and light-weight, work-zone traffic control devices. The development of robust, surrogate bogey vehicles, with an ability to largely capture vehicle deformation and penetrations as well as accurate system behavior, would reduce crash testing costs and promote greater innovation for new products for manufacturers and state departments of transportation (DOTs). Motorist safety of U.S. roadways would be enhanced as more AASHTO MASH-compliant systems become available and are implemented.

The main objective of the research study is to develop, fabricate, test, and evaluate surrogate bogey vehicles and pendulum masses (referred to a surrogate devices) for determining Test Level 3 MASH 2016 crashworthiness with passenger vehicles for breakaway luminaire poles, sign supports, and work-zone traffic control devices used in permanent and temporary applications.

State DOTs are required to install crashworthy safety hardware along freeways, interstates, highways, and roadways. In recent years, AASHTO and FHWA agreed to a roadside safety hardware implementation plan corresponding to AASHTO's Manual for Assessing Safety Hardware (2016), which included breakaway luminaire poles, sign supports, and work-zone traffic control devices. Each hardware category consists of hundreds, maybe even thousands, of combinations that require crashworthiness testing and evaluations. The development of surrogate testing devices would reduce complaint testing costs, increase innovation, and promote testing and evaluation of a greater number of devices in the noted roadside safety hardware categories. Over time, more MASH-compliant devices would be placed along U.S. highways and roadways, thus benefiting the motoring public and helping to reduce roadside fatalities and serious injuries.

Project 22-56
Development of Prefabricated Concrete Barrier Systems for Accelerated Bridge Construction

Research Field: Design
Source: AASHTO Committee on Bridges and Structures
Allocation: $1,000,000
NCHRP Staff: Waseem Dekelbab

A major knowledge gap in the world of Accelerated Bridge Construction (ABC) is prefabricated barriers. The knowledge gap is a combination of limited pre-existing prefabricated barriers and the new AASHTO Manual for Assessing Safety Hardware (MASH) crash testing requirements.

Precast concrete barriers were previously crash tested to *NCHRP Report 350* requirements. Some of these barriers were evaluated for Test Level 3. States are moving to higher level designs. Test Level 4 is common. Some agencies are moving to Test Level 5. The MASH provides current crash-testing requirements.

The goal of this research is not to develop a "new barrier shape." The concept is to identify and MASH crash-test prefabricated versions of existing *NCHRP Report 350* approved barriers. During the preliminary phases of the project, a questionnaire can be sent to owner agencies to determine which barriers are commonly used and what test levels are being specified. From that knowledge, the project panel can select the three most appropriate barriers and test levels for the crash testing portion of the project.

Due to durability concerns with exposed concrete surfaces, the researchers and panel may consider the use of non-corrosive reinforcing bars in one of the specimens. The major challenges to address in this research include: (1) accommodating various geometric configurations such as vertical curves, horizontal curves, and variable cross slopes; (2) accommodating tolerances; (3) developing durable (waterproof) connections; and (4) accommodating accelerated construction schedules (operational in under 12 hours).

The objective of this research is to identify and MASH crash-test three non-proprietary prefabricated concrete barriers that can be used on ABC projects. The barriers need to be crash worthy, easy to install, practical, durable, and be able to accommodate variations in geometry.

Virtually every state DOT is using ABC at this time and has a need for MASH-tested prefabricated concrete barriers. This work will potentially be a value to all DOTs. Current ABC designs have had to resort to prefabricating barriers integral with prefabricated decks. There are currently no MASH-tested prefabricated concrete barriers on the market. Having several barrier designs that are crash tested and versatile will help fill a major gap in the ABC world.

Project 23-22
Increasing Competition on Projects Delivered by Alternative Methods by Defining and Assessing Contractual Risk Profiles

Research Field: Administration
Source: AASHTO Committee on Construction
Allocation: $500,000
NCHRP Staff: David M. Jared

While the COVID-19 pandemic has put a near-term damper on the availability of public infrastructure funding, the impact of current public project risk profiles on competition remains a significant issue, and public transportation agencies still need the major industry players to build infrastructure projects. The number of firms that are financially capable of competing for billion-dollar plus contracts is relatively limited, and if “business-as-usual” procurement practices continue to perpetuate a lopsided risk profile and/or if the market slowly but steadily attempts to transfer more and more risk the to the private sector on a go-forward basis, the pool of available, qualified contractors will continue to shrink. Therefore, practical guidance is needed for public agencies to be able to assess their procurement models and appropriately allocate the risk profile for a given project with consideration of the perspective of potential bidders. Public agencies are being encouraged to re-evaluate the assigning of risk per the concept of “best-able to manage” the risk in the best interest of the taxpayers. In other words, if the small pool of contractors is assigning extreme contingency values to unbalanced risk/reward structures, it is not in the best interest of the taxpayers to transfer such risk levels.

The research objective is to develop a rigorous methodology based on empirical data for identifying, assessing, and measuring the perceived risk to industry in the solicitation for projects delivered using alternative project delivery methods such as Design-Build (DB), DB-Finance, and Public-Private Partnerships (P3). To support this objective, the scope would include (a) investigating different risk management arrangements used in the transportation industry and linking them to state department of transportation (DOT) project goals and objectives; (b) examining the industry perception of those used by state DOTs and other countries in the delivery of transportation infrastructure; (c) documenting lessons learned; and (d) making implementation recommendations that will improve U.S. policy and practice.

This project would produce an empirical guide based on effective practices regarding the selection of performance measures for P3 projects and provide guidance on selecting different P3 arrangements/structures given state DOT goals and objectives, as well as effective practices for implementing performance measures. Moreover, the guide would enable agencies to make structured risk analysis of the procurement and contractual framework embodied in the solicitation for a given project. Upon completion of such analysis, the guide would provide a menu of options for the agency’s consideration to make changes in the solicitation that would make its resultant risk profile more attractive to industry and thereby enhance potential competition.

Direction from the AASHTO Special Committee on Research & Innovation: The results should be implementable by most state DOTs.

Project 23-23
Data Governance Design and Implementation—Links Between Governance Approaches and Performance Effects in DOTs

Research Field: Administration
Source: AASHTO Committee on Data Management and Analytics, California DOT
Allocation: $350,000
NCHRP Staff: Sid Mohan

Cross-functional data governance design and implementation that have been optimized for different organizations is a recognized challenge for the transportation community. The experience with data governance approaches is varied among state departments of transportation (DOTs) and there is an ongoing need for greater understanding of the most effective approaches and for process improvement as feasible. Key trends such as the accelerating increase in the amount of data created/collected every year, and the growing variety of data from different sources, both internal and external to state DOTs, have exacerbated the traditional challenges of data quality, access, security, and suitability for state DOT requirements. The 2018 FHWA report, "Data Governance & Data Management: Case Studies of Select Transportation Agencies" highlighted that many of the agencies surveyed for the report did not have official data management or data governance policies.

The objective of this research is to advance the application of data governance to increase the value of data as an enterprise asset, while minimizing data-related costs and risks associated with poorly governed data, or low quality data. The proposed research will examine existing best practices for data governance and conduct further qualitative and quantitative research on the complexity of state DOT data ecosystems, including, but not limited to, existing governance approaches, data sources, data-related costs, data-related risks, data supply and value chains, enterprise data warehouses and data lakes, technology platforms, performance metrics, and user demands.

The outcomes of the proposed research will (1) fill gaps in our understanding and application of different data governance approaches in state DOTs; (2) identify key areas of data governance to gather data from state DOTs on the performance effects of different approaches across time; (3) optimize the design and implementation of data governance approaches for different organizational contexts; and (4) prepare an implementation document to deploy the data governance approaches.

Direction from the AASHTO Special Committee on Research & Innovation: Consider refining the scope of work to focus on enterprise data warehouses and data lakes. The use of GIS and spatial data may be used to identify gaps in service; make use of enable data links.

Project 23-24
Develop Methods to Allow Agencies to Incorporate Quantitative Risk Assessment at Project and Network Level

Research Field: Administration
Source: AASHTO Committee on Performance Based Management
Allocation: $500,000
NCHRP Staff: Camille Crichton-Sumners

Managing risk is a critical component of asset management. On a day-to-day basis transportation asset managers spend much of their time responding to or mitigating a large number of risks, which may range from external events that damage transportation infrastructure to unplanned changes to budget or workloads resulting from unexpected events. Various recent and on-going research efforts aim to improve approaches for risk management for transportation agencies. However, most of these efforts treat risk management as a high-level activity. Further research is needed to develop quantitative, repeatable approaches at the appropriate staff level, to assess and identify the highest priority risks that state departments of transportation face in managing physical assets and allow risk and resilience to be on par with traditional performance measures. High-risk threats to be studied include, but are not limited to, extreme events (e.g., earthquakes, fires, hurricanes, avalanches, tornadoes); asset failure (structural and operational); financial, strategic, political, environmental (e.g., sea level rise, flooding); technological; and social justice risks.

This project aims to develop such approaches to assess risks (e.g., financial, strategic, operational, political, environmental, technological, social justice risks) and incorporate them into life-cycle analysis and planning efforts. Specifically the project objectives are to (1) generate risk identification techniques to determine high-risk threats at project and network levels; (2) develop quantitative, repeatable approaches for assessing likelihood and consequences for these threats; and (3) develop visual, interactive characterization methods (e.g., dashboards) to reflect an agency's level of risk and the effectiveness of proposed mitigation actions.

While existing reporting mechanisms allow agencies to see the parts of their network that are in good and poor condition, risks associated with different threats and the impact of failure are not reported as an explicit performance measure. Competing design documents, financial implications, legal concerns, maintenance practices, focus on building new capacity rather than managing existing infrastructure, and other factors that affect decision-making procedures may counteract risk-based Transportation Asset Management (TAM) practices. Issues related to social justice and equity, and consequences of failures make risk-based TAM even more important. Creating harmony in the TAM decision-making space in consideration of risk and resilience represents an urgent need. A practical, quantitative, and repeatable risk assessment process could play a major role in addressing this need.

Direction from the AASHTO Special Committee on Research & Innovation: This research should consider NCHRP Project 08-118, "Risk Assessment Techniques for Transportation Asset Management", NCHRP Project 23-09, "Scoping Study to Develop the Basis for a Highway Standard to Conduct an All-Hazards Risk and Resilience Analysis," and NCHRP 20-125, "Strategies for Incorporating Resilience into Transportation Networks."

Project 23-25
Interstate Information Sharing of State Truck Regulatory Requirements

Research Field: Administration
Source: AASHTO Committee on Transportation System Operations
Allocation: $400,000
NCHRP Staff: Amir N. Hanna

The goal of trucking industry is to move goods safely, quickly, and profitably. From 2012 to 2018, freight movement on trucks increased 11%, or nearly 2% per year according to the U.S. DOT Bureau of Transportation Statistics (BTS). BTS reported that two-thirds of all U.S. freight was moved by truck in 2018. BTS predicts a 21% increase in truck tonnage between 2018 and 2045, driven by the world economy and consumption within the U.S. In 2045, trucks are expected to still haul two-thirds of all freight. Regulatory functions like safety inspections are important to take unsafe vehicles off the road and to verify compliant companies' safety record. State agencies, who are expected to handle increases in trucking without corresponding increases in staff, have used technology—such as electronic screening, tire anomaly checking, thermal brake inspection, over-dimension detection, and automated permitting systems—to keep pace. State agencies share truck size and weight and safety inspection information within their own boundaries and report to the Federal Motor Carrier Safety Administration, but rarely share directly with neighboring states.

Sharing information with neighboring states could reduce the cost and workload for size, weight, and safety enforcement. If each state could bypass trucks that have satisfied the mutual requirements of both states, recently processed trucks would not have to be detained again. Arizona and Utah already share information at Utah's I-15 St. George facility, located just 70 miles upstream from a planned Nevada site. A data-sharing arrangement with Utah could save Nevada the cost of the I-15 site they have planned. Conversely, Nevada cold save Utah costs on northbound I-15 traffic. The value to the states would be much greater than data sharing through federal databases because the shared information would have immediate operational value.

Sharing real-time data requires an information architecture, data standards, and enabling technology. For example, the information system technology that supports the International Registration Plan (IRP) is AAMVAnet, developed by the American Association of Motor Vehicle Administrators (AAMVA). Institutional arrangements are also necessary. One potential mechanism is the interstate compact. An interstate compact is an agreement established by legislatures of two or more states to enable states to act jointly outside the constraints of the federal government. Interstate compacts were used before the establishment of the federal government and are referenced in Article 1, Section 10 of the U.S. Constitution. The Council of State Governments describes interstate compacts as "the most powerful, durable, and adaptive tools for ensuring cooperative action among the states." Each state is already a member of on average 25 compacts. Four compacts related to

trucking—the IRP, the International Fuel Tax Agreement (IFTA), the Driver License Compact, and the Vehicle Title Compact—have operated for more than 35 years. IRP and IFTA include 49 States and the 10 Canadian provinces. The need, benefits, technology, and institutional arrangements related to sharing interstate data using standard messages need to be studied nationally. Full regulatory harmonization will never be found using the state by state approach, with statutes that vary from state to state. The entry point to harmonizing starts with data sharing between states. After data sharing is proven on regulatory processes, multi-state permits and other harmonization could be added.

The objectives of this research are to (1) evaluate the need, feasibility, and benefits of establishing real-time commercial vehicle data sharing among states; (2) design an information architecture, including data elements and standards, to support data sharing among states; and (3) propose an institutional arrangement to establish and sustain ongoing data sharing among states.

Direction from the AASHTO Special Committee on Research & Innovation: The scope of this research should have a domestic focus while acknowledging the potential to coordinate with Canadian counterparts. Motor vehicle agencies should be included. The scope should also address the hosting and ongoing maintenance requirements of potential solutions.

Project 23-26
Measuring Impacts and Performance of State DOT Resilience Efforts

Research Field: Administration
Source: AASHTO Committee on Transportation System Security and Resilience
Allocation: $300,000
NCHRP Staff: Camille Crichton-Sumners

State departments of transportation (DOTs) increasingly focus on resilience as a key solution to the impacts of short-term events and long-term stresses, including climate change. The frequency and severity of damaging weather events, sea-level rise, wildfires, and other climate impacts are forcing state governments to seek more long-term solutions. Economic shifts, demographic changes, and other disruptions also cause state DOTs to adapt and modify their practices to accommodate uncertainty.

State DOTs need more/better tools and approaches to track resilience efforts, investments, and progress towards improving resilience of the transportation system. There is no clear standard for tracking goals, effectiveness, and outcomes of resilience efforts and past research does not provide a comprehensive approach to evaluate the effectiveness of policies, programs, project implementation, and other resilience actions from state DOTs.

The objectives of this research are to (1) identify and establish resilience performance measures for transportation agencies; (2) identify methods to incorporate resilience into DOT business; (3) develop resources to help state DOTs evaluate progress, identify gaps, and prioritize investments to improve resilience.

Currently, state DOTs may be asked to justify additional expenses on projects that improve the resilience of transportation projects even when these investments are forecasted to reduce long-term costs and disruptions. Having a consistent set of performance measures will accelerate the cost-effective use of resilience-related funds and incorporation of resilience into standard DOT practices and programming.

Project 25-65
Successful Approaches in Preparing Convincing Section 106 Effect Determinations

Research Field: Transportation Planning
Source: AASHTO Committee on Environment and Sustainability
Allocation: $150,000
NCHRP Staff: Ann M. Hartell

Concluding Section 106 (of the National Historic Preservation Act of 1966) has ramifications for other environmental requirements in transportation project development including National Environmental Policy Act (NEPA), Section 4(f) analyses, and environmental permits. The outcome of the Section 106 consultation process is an effect determination,

i.e., what effect will a federal action have on historic properties. Federal regulation (36 CFR 800) makes a distinction between undertakings that adversely affect historic properties and those that do not. The basis for this distinction is whether a federal action will alter or diminish those properties that make a property eligible for listing in the National Register of Historic Places. In other words, not every alteration or change constitutes an adverse effect from a Section 106 perspective. Conducting an analysis of potential effects and effectively crafting a no-effect or no-adverse effect determination requires both a detailed understanding of regulatory definitions and specialized skill in communication.

While Section 106 training is available to state department of transportation (DOT) cultural resources practitioners, it often covers the general requirements of law and regulation, focuses on the nuances of writing Memoranda of Agreement, or specialized topics like tribal consultation. Further, many Section 106 practitioners at both state DOTs and their State Historic Preservation Officer (SHPO) partners may have imprecise, colloquial understanding of the regulatory definitions involved in making effect determinations. At the same time, many skilled and experienced Section 106 practitioners are reaching the end of their careers and newer employees may not possess the knowledge, skill, and ability to develop robust effect determinations.

The objective of this research is to identify, analyze, and document examples of accurate, high-quality, no-effect, and no-adverse effect determinations. This will be accomplished by identifying the qualities and characteristics of accurate, high-quality determinations from state DOTs and synthesizing the findings in a manner that is implementable among cultural resources practitioners.

Potential tasks include to:

a. Define the regulatory basis and definition for effect, especially pertaining to alteration vs. diminishment of historic characteristics, tests of integrity, and any situations where a certain effect determination is prescribed.
b. Identify and collect examples of no-effect and no-adverse-effect determinations developed by state DOTs and concurred with by the state DOT's respective SHPO.
c. Interview cultural resources practitioners for recommendations about making effect determinations.
d. Synthesize the aspects of the examples, especially pertaining to the basis of the no-effect or no-adverse-effect finding.