To: DISTRIBUTION - see below

From: Lori L. Sundstrom
Manager, NCHRP

Subject: Panel Members for FY 2019 Projects in the National Cooperative Highway Research Program (NCHRP)

## → → → Immediate Action Requested by *June 15, 2018* ← ← ←

On March 27and 28, 2018 the AASHTO Special Committee on Research and Innovation (R&I) formulated the NCHRP's FY 2019 program. We are forwarding the research problem statements (see attached) to you and asking for your help in identifying individuals with relevant expertise and experience to volunteer to serve on each project oversight panel.

- *Nominations can be submitted online at this link*: Online Panel Nomination Form.

- This year we are also asking if the nominee is a member of an AASHTO Committee or TRB Committee; we are also interested in panel members who are connected to their national community of practice to help with moving research results into practice when research is completed.

Although the FY 2019 projects are tentative (they have not yet been approved by States' ballot), we are soliciting now for nominees to meet future deadlines. We appreciate anything you can do to identify or nominate qualified individuals by **June 15, 2018.**

- Please note that this solicitation for panel nominations is for new regular NCHRP projects EXCEPT for new NCHRP Synthesis of Practice topics. The solicitation for panelists for Synthesis topics will be sent separately.

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

If you would prefer to submit a nomination via email instead, you may use the attached form (in WORD) and send it with a resume to Mr. Joseph Snell at jsnell@nas.edu.

We encourage the nomination of members of historically underrepresented groups, including women, young professionals (age 35 and younger), and members of minority groups.

Contacts to determine an individual's interest in serving will be made from this office after we have matched available expertise with that required by the nature of the project.

- Panels for the new projects are scheduled to meet beginning in August through October. Panel members are prohibited from submitting or participating in preparation of proposals on projects under their jurisdiction. They serve without compensation but are paid travel and subsistence expenses. Travel insurance is provided at no cost to the members. In many cases, three meetings are held in the life of a project, and these normally occur in Washington, D.C. The first meeting is to develop a request for proposals that is used to solicit proposals; the second meeting is to select a research agency from among those submitting proposals. Typically, a third meeting will be held to review progress with the research team while the research is active.

- Membership on each panel will number approximately eight, and panels operate under the guidance of a chair--see attached "Your Role as an NCHRP Panel Member ". The NCHRP staff serves as the secretariat.

We are grateful for your support of the NCHRP by providing nominees each year. With the nominees continuing to outnumber the available positions by about four to one, we have been able to establish panels outstanding in their ability to play a critical role in the accomplishment of successful research. Please realize that if your nominee(s) is not selected, that there are several factors to be considered when forming well balanced and objective panels. Although expertise is the primary factor, we also attempt a proper balance in terms of geographic areas, organization or agency types (e.g., public and private agencies, universities, associations, local and state government), and gender and ethnic diversity.

Attachments:
Summary of FY 2019 Research Program
NCHRP Panel Nomination Form
"Your Role as an NCHRP Panel Member"

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Executive Director, National Association of County Engineers; CEO & President, National Urban League; President, National Council of Negro Women; President, Blacks in Government; Directors, University Transportation Centers; Chairman and Members, TRB Executive Committee; Chairmen, NCHRP Panels and Committees; Chairmen, TRB Group Councils and Sections; TRB Liaison Representatives, State Highway & Transportation Departments; TRB University Representatives; TRB Sustaining Associates; Chairman, Subcommittee on NRC Oversight; TRB Staff.

**National Cooperative Highway Research Program**
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**Project 02-25**
***Workforce 2030: Recruiting and Training the Next Generation Transportation Construction Workforce***

Research Field: Administration
Source: AASHTO Committee on Construction
Allocation: $700,000
NCHRP Staff: Lawrence D. Goldstein

The U.S. DOT spends $51 billion annually on construction, repair, and operation of our Nation's public transportation systems—a significant investment benefitting multiple dimensions of society. Every $1B invested in the transportation infrastructure produces 13,000 jobs across multiple industry sectors (US Dept. of Education, US Dept. of Transportation, and US Dept. of Labor, 2015). Much of this investment is in highways and bridges developed, constructed, and maintained through state transportation agencies (STA). An increasing challenge is the availability of the construction and maintenance workforce within the agencies to keep pace with the annual $51 billion expenditures; agencies will need over 550,000 new staff within their construction and maintenance programs. However, due to current and anticipated budgeting challenges, STA will likely be working with a smaller workforce, and many new workers will require significant training to meet present and future demands.

The need for this research aligns with the objectives of the Environmental, Safety, and Workforce Section within the AASHTO Subcommittee on Construction. An in-depth discussion took place on several occasions on the topic of workforce issues and workforce development at the AASHTO Subcommittee on Construction Annual Meeting in August 2017 with the result the development of this much-needed problem statement.

The objective of this research is to address two primary goals:

1. Produce a 'roadmap' of the current workforce development system for STAs and identify critical areas for improvement to attract both the quantity and quality of individuals needed to increase representation of the next generation among the state transportation construction workforce; and
2. Identify the policy and training framework to allow state transportation agencies to develop the process for moving the workforce into the 2030 competency level.

The research objective will be achieved through the completion of research tasks to be described by the research team that best addresses the research questions and goals.

The U.S. transportation system was historically the envy of most other countries, from its construction of the transcontinental railroad to the interstate highway system. Somewhere along the way, we have allowed our nation's transportation system to slip; the quality of our roads is now rated 16th in the world. All future transportation innovations hinge on the assumption that a qualified workforce will be there to build and maintain our infrastructure. Reversing the workforce shortages requires new investment and innovations as well as a new workforce. The research described here develops the basis for growth to occur.

**Project 02-26**
***Implementation of Programmatic Life Cycle Cost Analysis in a Transportation Asset Management Framework***

Research Field: Administration
Source: AASHTO Committee on Performance Based Management
Allocation: $500,000
NCHRP Staff: Lawrence D. Goldstein

Federal and state policies are increasingly directing the owners of transportation assets to manage the performance of their assets and networks, using this information to minimize the long-term cost of providing service. Life cycle cost analysis considers how the overall cost of an asset, as it is incurred from planning and design through construction, operation, maintenance, and decommission phases, can be optimized. It also often includes costs experienced by transportation system users and stakeholders. It evaluates projects, programs, and policies in light of these economic outcomes, often in combination with other non-economic aspects of performance.

Over time, the costs of routine maintenance and programmed repair work tend to increase as condition deteriorates. Agency policies and actions attempt to slow the rate of deterioration, or interrupt it entirely, by means of rehabilitation and replacement. If major agency expenditures can be delayed, this may be an attractive option in order to free up resources for higher priority uses. However, delayed maintenance or rehabilitation means further expenditures in future to bring the condition of those assets to an acceptable level of service. This implies that there is a time value of money and that data-driven decisions should be made about when to intervene in the life of an existing asset. In addition, future costs are subject to considerable uncertainty, which can have a significant effect on the relative attractiveness of various scope and timing alternatives.

The objective of this research project is to develop guidance and one or more example tools to demonstrate quantitative asset-level, project-level, and network-level models for predicting the life cycle costs associated with preservation, replacement, and risk mitigation activities on the full range of highway assets. These costs may include agency, user, and non-user stakeholder costs. They may be associated with condition, risk, mobility, safety, or any other quantifiable aspect of transportation system performance. The guidance will address major issues such as:

- How to reconcile fiscal limitations with agency and stakeholder performance goals, while minimizing long-term costs;
- Incorporating risk management in its relevant forms, including uncertainty of planning metrics and the potential impacts of unpredictable natural and man-made hazards;
- Considering multiple competing objectives affecting multiple asset classes.
- Recommending a mutually compatible set of quantitative life cycle planning performance measures for use in various decision-making scenarios, including needs identification; comparison of project scope and timing alternatives; prioritization and resource allocation; tracking of the performance of individual assets and groups of assets; comparing investments across asset categories; evaluating projects that affect multiple classes of assets in a corridor; retirement or other disinvestment alternatives; network target-setting and tracking; establishment of level-of-service standards; establishment

of treatment selection policies; negotiating funding levels; and public reporting of network performance.

- Documenting commonly used analysis parameters and the rationale for establishing and using these parameters, including deterioration rates, unit costs, indirect costs, treatment application criteria and effectiveness, discount rates, program planning horizons, long-term cost horizons, fiscal scenarios, and inflation projections.

The model will enable assessment of trade-off decisions to help asset owners understand how investment at one point in the asset's life cycle can impact on the whole.

Life cycle cost analysis is an integral part of management systems for major constructed facilities, such as pavements and bridges. It is not yet routine for other types of assets such as signs, traffic signals, and geotechnical assets. Consideration of life cycle cost, especially in combination with the analysis of uncertainty, may identify opportunities to optimize preservation and replacement policies to reduce life cycle costs.

**Project 02-27**
***Making Targets Matter: Effective Practices by Transportation Agencies to Establish, Monitor and Adjust Performance Targets***

Research Field: Administration
Source: AASHTO Committee on Performance-Based Management
Allocation: $650,000
NCHRP Staff: Andrew C. Lemer

The AASHTO Committee on Performance-Based Management is seeking to support the implementation of a strategic approach that uses system information to make investment and policy decisions to achieve performance goals. An increasing number of transportation agencies are adopting Transportation Performance Management (TPM) principles to ensure the right investment decisions surrounding transportation projects are made and delivered to produce the performance outcomes desired by the agency, external partners, elected officials, and the public. TPM helps determine what results are to be pursued, using information from past performance levels and forecast conditions to guide investments, measuring progress toward strategic goals, and making adjustments to improve performance. TPM is grounded in sound data management, usability, and analysis as well as in effective communication and collaboration with internal and external stakeholders. The key to successful implementation of TPM practices lies in the organizational support and agency embrace of data-driven decision making; connecting employee actions to results; motivating and focusing staff; increasing accountability; guiding the allocation of resources; and tracking the efficacy of adopted strategies. TPM uses performance information to create links among an agency's strategic direction, resource allocation decisions, individual employee activities, and external stakeholders' priorities.

A core element of TPM is defined performance targets that connect investment decisions to system results in a transparent manner for all stakeholders. Targets are used to assess progress toward achieving strategic goals, guide planning efforts, inform programmatic decisions and adjustments, and communicate with stakeholders. Setting targets has become more common with the requirements outlined in MAP-21 and the FAST Act, but what remains missing is the establishment of a feedback loop to adjust planning, programming, and future target setting decisions. This research will address this challenging yet critical piece of TPM: the relationship between actions taken and performance results and an assessment if targets are practical and reasonable. This research will go beyond how agencies are setting targets by examining closely how agencies are establishing, monitoring, communicating, and adjusting performance targets in both the short and long term.

The objectives of this research are to (1) document successful practices of transportation agencies establishing and communicating performance targets related to both the national regulations and individual state-based goals and objectives, (2) identify and fill gaps between the needs of transportation professionals and current resources related to target setting, and (3) develop a collection of resources agency professionals can use to track progress and adjust actions taken to achieve performance targets and adjust those targets as appropriate to achieve agency goals and objectives.

The research may be conducted in two parts, with the first part focused on organizing a series of workshops and peer exchanges that will bring together state DOTs, MPOs, and

transit agencies that have been involved in the implementation of the national-level performance management regulations in order to share, document, and learn from each other how they have established performance targets for the various performance and asset management areas. These in-person meetings could focus on agency experience with target setting, for example (1) challenges (e.g., lack of forecasting tools), (2) benefits (e.g., collaborating with stakeholders), (3) keys to success (e.g., new data sources identified), and (4) how targets are linked to agency decision making. The workshops will also delve into the business processes around target setting: agency staff roles and responsibilities, purpose of the target, information gathered through benchmarking, and external stakeholder roles. In essence, what worked, what didn't, key lessons learned, and keys to success. The products of this work could include a compendium of case studies; analysis of the strengths, weaknesses, opportunities and threats transportation agencies face in establishing and implementing performance targets as part of a performance management program; and identification of resources needed by transportation agencies to better establish, monitor, and adjust performance targets.

The second part of this research would focus on developing resources for monitoring and adjustment of targets as part of a comprehensive performance management program. These resources would likely include robust monitoring and adjustment strategies; guidance on feedback and management adjustment practices; clearly defined steps for linking system level and program/project level targets; and guidance for achieving maximum benefits of monitoring, feedback, and target adjustment with respect to system performance.

Note: The AASHTO Special Committee on Research and Innovation suggested that the project panel should consider whether all of the allocated funds are required for the research described.

**Project 03-134**
***Determination of Encroachment Conditions in Work Zones***

Research Field: Traffic
Source: AASHTO Technical Committee on Roadside Safety
Allocation: $500,000
NCHRP Staff: William C. Rogers

There were 96,626 crashes in work zones in 2015. This equates to one work zone crash every 5.4 minutes. Every day, 70 work zone crashes occurred that resulted in at least one injury, and every week, 12 work zone crashes occurred that resulted in at least one fatality. Previous research regarding work zone encroachments has also indicated that there is a higher frequency of fatalities in work zone crashes than non-work zone crashes. Thus, work zones may be an area where significant safety improvements can be made.

While current data on work zone crashes suggests that work zones are at higher risk for crashes and fatal injuries, accurate data on the impact conditions associated with work zone crashes does not exist. Development of accurate encroachment data for work zones would indicate areas for improvement in the design of work zones and the safety barriers used therein and raise the level of safety in work zones for the travelling public and workers. Furthermore, if encroachments for work zones are significantly different than non-work zones, designers could balance temporary features and cost in work zones against use of higher cost features to provide the best use of state funds.

The objective of this research program is to determine encroachment conditions associated with work zone crashes, including speed, angle, and vehicle mass, and determine if they are consistent with those previously determined for freeways. It is anticipated that the research effort to meet this objective would encompass the following tasks:

1. Review existing literature on encroachments and work zones crashes.
2. Review states practices in work zones and include speed reductions, separation of traffic, barrier use, temporary geometrics, etc. through work zones that could correlate to the encroachments.
3. Analyze encroachment data collected.
4. Review methods to collect encroachment data or determine whether engineering analysis could be used to analyze data collection.
5. Develop a data collection plan for work zone encroachments, taking into account that most work zones are reset as soon as possible by field staff after a crash event.
6. Provide analysis of work zone encroachment conditions and recommendations for future research.

**Project 03-135**
***Wrong-Way Driving Solutions, Policy and Guidance***

Research Field: Traffic
Source: Idaho
Allocation: $600,000
NCHRP Staff: William C. Rogers

Since the beginning of the interstate highway system in the 1950s, crashes related to driving the wrong way on freeways have posed a problem for transportation officials. To this day, even though wrong way collisions are infrequent (only about 3 percent of all crashes on high-speed, divided highways) wrong-way driving (WWD) remains a serious problem because the resulting crashes almost always result in death or serious injury to the persons involved.

According to the National Highway Transportation Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) database, nationally 1,566 fatal WWD crashes occurred on divided highways over a 6-year period from 2004 to 2009, resulting in 2,139 fatalities. On average, about 360 people are killed each year as a result of WWD.

WWD events continue to occur due to many factors. Many of the approaches so far have accomplished some reductions. New more advanced technologies are forthcoming in the market place and need to be evaluated and included in an overall approach to the problem. The development and compilation of clear guidance into a single document that could be included in DOT design manuals would foster a more systematic and uniform installation of roadway geometries, signs, striping, and technology. A more uniform method for monitoring, measuring, and reporting the effectiveness of these installations would also help in demonstrating the results of the overall program.

The objectives of this research are to (1) develop guidance for retrofitting existing interchanges and design of new interchanges to reduce the likelihood of WWD incidents and crashes, and (2) evaluate the potential for active WWD warning technologies that are now becoming commercially available or in development to reduce WWD incidents and crashes.

**Project 03-136**
***Evaluating the Performance of Right-Turn-On-Red Operation at Signalized Intersections (with single and dual right-turn lanes)***

Research Field: Traffic
Source: Arkansas
Allocation: $300,000
NCHRP Staff: Camille Crichton-Sumners

Right-turn on red (RTOR) has been used since the 1970s as an efficient strategy to reduce delay and fuel consumption at signalized intersections. Most studies on this subject focused only on safety concerns, dedicating little attention to its operational benefits. In the absence of a country-wide accepted methodology, alternative tools are often the only resource to estimate traffic behavior on arterials where RTOR is permitted. Empirical models, however, are still necessary in order to verify if the results produced by alternative tools are compatible with field conditions.

This strategy is widely accepted as an effective approach to reduce control delay at intersections, especially for high demands on right-turn movements. However, the conflicting movement of pedestrian crossing is a critical issue to be addressed, from both operational and safety standpoints. Although a reference methodology to evaluate and plan RTOR operations is desired, it is unlikely that it will be widely implemented if it will bring significant negative impacts on pedestrians and vehicle safety. Additionally, high density pedestrian flows may undermine the benefits of RTOR implementation. This trade-off between operations and safety can be found in empirical studies throughout the literature, but a reference methodology to evaluate this issue is still not present.

The *Highway Capacity Manual* (HCM), in its 6$^{th}$ edition, lacks a methodology to estimate the RTOR flow volume and its effect on delays, leaving field counts as the only option for obtaining this input, which is then subtracted from total right-turn movements. This may be feasible for operational analyses on existing intersections, but it is not reliable for either planning- or operational-level applications.

Some of the main gaps in the HCM methodology and aspects that need to be addressed are:

- The lack of a volume prediction model for resulting right-turn delay. In the current method, input values must be obtained through field observations and subtracted from the right-turn volumes. The suggested default value for right-turn volume on red is 0 veh/h, due to the difficulty to estimate it without the support of field data. This is a conservative estimate, and may lead to inaccurate performance estimations.
- The RTOR flow rate should also be used as input for pedestrian methodology and may be affected by pedestrian volumes.
- No guidelines are provided on whether RTOR should be implemented or not.

Agencies throughout the country have performed their own research on this topic, probably due to the lack of a reference methodology to evaluate RTOR operations. The development of an HCM methodology is expected to assist agencies and practitioners, especially those who do not have a consolidated body of knowledge on RTOR analysis.

The objective of this research project is to develop methods to evaluate right turn on red (RTOR) operation that can be implemented in the Highway Capacity Manual methodology for signalized intersections and urban arterials.

The following tasks are proposed in order to achieve this goal:

*Task 1. General Work Plan*. The objective of this task is to develop a general work plan that targets the objectives of the study and validates the project objectives, desired deliverables, and project schedule.

*Task 2. Literature Review and Current Practice.* The objective of this task is to review relevant literature and current RTOR practice adopted by agencies throughout the country.

*Task 3. Draft Methodologies*. The objective of this task is to develop draft methodologies on proposed RTOR analysis, describing the expected inputs, outputs, strengths, and limitations. Motorized and non-motorized modes must be included.

*Task 4. Data Collection Plan*. This task aims to develop plans to guide the collection of data. The research agency is expected to develop a comprehensive list of study locations in a manner that the data reflects different traffic scenarios throughout the country, as well as the key parameters to be collected and which approaches or sources will be adopted to collect data.

*Task 6. Data Collection and Preliminary Results*. The objective of this task is to implement the approved data collection plan developed in Task 4. The task also includes the preliminary analysis of the data against the proposed draft methodology from Task 3, indicating needs for method review, additional validation, and others.

*Task 7. Validation and Methodology Refinement*. The objective of this task is to comprehensively analyze and validate the data collected in Task 6 and perform any methodology refinement needs previously identified.

*Task 8. Report.* The Report shall summarize the work performed on the previous tasks, along with significant conclusions and recommendations for implementation. It must include but not be limited to:

- Methods for estimation of RTOR flow rate;
- Methods for the estimation of the effect of RTOR flow rate on approach delays;
- Recommendations on the adaption of the current pedestrian methodology to the developed method;
- Evaluation of any impacts to vehicle and pedestrian safety that may derive from the proposed methods.
- Recommendations on criteria regarding the implementation of RTOR;
- Guidance for operations on both pre-timed and actuated signal controls;
- Case examples of the proposed methodology application;
- A user-friendly guide that will assist traffic signal engineers in state and local agencies to implement the proposed practices;
- Guidelines for development of a computer engine for software developers.

The development of a method comprising RTOR effect on operations can benefit researchers and practitioners by providing an analytical method for RTOR evaluation, serving as a resource for safety studies, and supporting software development. Ultimately, better understanding of the effect of right turn on red and its consideration on existing methodology may contribute more cost-efficient systems where the use of this measure is

permitted. Also, the development is of great value for agencies and municipalities, especially those without any guidelines on the subject. This may allow those agencies to direct research resources for different issues. It is envisioned that this research will lead to the incorporation of the produced methodologies into a future version of the HCM. Any changes or updates to the HCM will need to be formally adopted by the TRB Highway Capacity and Quality of Service (HCQS) Committee (AHB40). Based on the updated HCM methodology and recommendations from the research team, guidelines for RTOR implementation by public agencies will be established.

**Project 03-137**
***Algorithms to Convert Basic Safety Messages into Traffic Measures***

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

The USDOT has invested in research on Vehicle to Infrastructure (V2I) connected vehicle applications. For example, the USDOT has funded the Collision Avoidance Metrics Partnership (CAMP) to develop prototype applications for Red Light Violation Warning, Curve Speed Warning, and Reduced Speed/Work Zone Warning. Similarly, several federal and state-funded projects have developed prototype Signal Phase and Timing (SPaT) safety and eco-driving applications. All of these V2I applications require software inside the vehicle and at the roadside that is specific to the application. The chicken-and-egg problem hinders operational implementation of these applications in that the application cannot be sold as a feature of the vehicle if the infrastructure to support it is not widely available, and justifying deployment of the infrastructure is difficult without any guarantee that any vehicles will have support for the applications. The current NHTSA Notice of Proposed Rulemaking would only require that vehicles be capable of sending and receiving a Basic Safety Message (BSM) using Dedicated Short Range Communication (DSRC). It will not require support for any V2I application.

Because the NHTSA rule will require all new vehicles to broadcast a BSM, V2I applications that depend only on listening to the BSM from the vehicle will be the most likely V2I applications to be deployable in the near future. The BSM will contain information such as the car's location, speed, and heading. Installing DSRC roadside units will allow agencies to listen to the messages the cars are broadcasting and calculate estimates of traffic measures such as travel time and travel time reliability, end of queue in a work zone, queue lengths at traffic signals, intersection delay, etc.

Under the NHTSA rule, each vehicle will be required to broadcast a BSM 10 times per second. As a result, a stream of traffic will produce a large number of point measurements of speed and heading. Converting this large number of point measurements into estimates of traffic measures will require algorithms and processing. The problem this research will address is developing, validating, and publishing these algorithms so that agencies and vendors can incorporate the algorithms into software to estimate the traffic measures.

Research Objectives include:

*Objective 1 Document Algorithms from Previous Research.*
Previous research reports may include algorithms similar to the subject of this research project. Also, existing research prototype software may contain embedded algorithms. This objective will collect and analyze these algorithms for potential to address the research problem statement.

*Objective 2 Identify Candidate Traffic Measures*
Identify performance measures required by federal regulations as well as additional performance measures commonly used by transportation agencies. Describe how BSM messages could support the measures. Identify the specific measures to be included in this research effort.

*Objective 3 Develop Algorithms*
Develop algorithms to convert BSMs into the identified traffic measures. The USDOT Open Source Application Development Portal (OSADP) includes some open source software applications that attempt to develop traffic measures from Basic Safety Messages as well as plug-ins to traffic models that allow creating BSMs that would be generated by vehicles modeled in the traffic model, which could be used to help develop the algorithms envisioned by this project.
*Objective 4 Validate Algorithms*
Validate the developed algorithms using simulation and using recorded BSMs from the USDOT data portal.
*Objective 5 Publish Algorithms*
Publish the final validated algorithms in formats that provide for easy use within software as well as in formats that support easy documentation of software algorithms.

Travel times and end of queue information are important in work zones for safety and mobility, and knowing queue lengths at traffic signals could enable smarter traffic signal control. Listening to vehicle BSM broadcasts is a means to gain early benefits from connected vehicles. Other vehicle-to-infrastructure connected vehicle applications will require additional capabilities in the car beyond what NHTSA is requiring, whereas generating traffic information from BSMs will be possible in the nearer term when vehicles may only have the vehicle to vehicle BSM broadcast capability on board.

Many transportation agencies have a large investment in physical infrastructure to measure traffic flows. Examples include vehicle detectors measuring speeds and volumes and Bluetooth devices or toll tag readers measuring travel time. Arterial roadways off the freeway typically are not measured. Work zones in areas without instrumentation or where instrumentation has been disrupted by the construction are difficult to measure but may have more need of the measures due to non-typical traffic patterns.

Utilizing permanent or temporary DSRC roadside equipment to capture BSMs could provide a lower cost approach to estimating traffic measures where they are currently unavailable, but this research is not intended to focus solely on DSRC roadside equipment as a means to listen for vehicle BSMs. Rather, the algorithms to convert BSMs into estimates of traffic measures are intended to operate independently, regardless of communication method.

A lack of the algorithms to convert BSMs to traffic measures would result in a missed opportunity to utilize a potentially lower cost and more geographically complete approach to estimating the needed measures.

**Project 04-41**
***Deterioration Rates and Unit Costs for Geotechnical Assets***

Research Field: Materials and Construction
Source: Colorado
Allocation: $400,000
NCHRP Staff: Waseem Dekelbab

Federal rules in 23 CFR 515.9 encourage transportation agencies to incorporate in their Transportation Asset Management (TAM) Plans all infrastructure assets within the highway right of way. This may include geotechnical assets such as retaining walls, unstable slopes, embankments, and other asset classes whose functionality may affect the whole life cost and/or performance of the network. AASHTO guidance on asset management notes that best practice is the use of deterioration and cost models as central tools in forecasting future preservation needs and estimating life cycle cost.

Agencies implementing geotechnical asset management (GAM) will need to develop consistent quantitative tools to forecast deterioration and costs for best practice asset management and to provide accurate investment plans in the TAM Plan. The deterioration of unstable slopes, embankments, and retaining walls increases the likelihood each year that transportation service in a road corridor will be disrupted by rockfall, slope movement, frost heaves, washouts, and other damage. These problems then require an agency response—either proactive risk mitigation or preservation, or reactive emergency repair—to maintain continuity of service.

The objective of this research is to develop measurable, consistent, broad-based deterioration and cost models for the three most significant types of geotechnical assets; retaining walls, embankments, and unstable slopes. The models will be developed mainly using existing condition assessment data already gathered by transportation and other agencies and may be supplemented by field surveys conducted by the researchers, particularly to follow up on earlier surveys or to fill in asset classes not covered by available data. Agency data on quantities and costs of past risk mitigation, preservation, and reconstruction projects will also be used.

One value of conducting the research proposed here is to provide DOTs some of the tools to improve progress to GAM implementation. The tools developed with this research are expected to be useable as created or could be readily adapted to an agency's specific needs. There is some benefit to uniformity of approach that will make it easier and less expensive for state DOTs to develop GAM programs without re-inventing the approaches that have already been developed.

**Project 06-18**
***Update the AASHTO Guide for Snow and Ice Control***

Research Field: Maintenance
Source: AASHTO Committee on Maintenance
Allocation: $300,000
NCHRP Staff: Amir N. Hanna

The AASHTO Guide for Snow and Ice Control, prepared under NCHRP Project 20-7(83) and published in 1999, provided a comprehensive guide for snow and ice control. As environmental awareness associated with snow and ice control grew, an update to the Guide was made in 2008 under NCHRP Project 20-7(250) to add content addressing environmental implications and impacts. Winter weather affects nearly every state not only by snowfall, but also ice events, freezing rain, freezing fog, and other weather events that impact mobility and require a maintenance effort to mitigate these effects. The range of winter maintenance operations is not limited to northern climates but includes weather regimes in moderate and maritime climates that require special considerations not currently addressed in the current AASHTO Guide.

Advancements have been made in research and state of the practice in several areas, including (1) equipment: wing plows, belly plows, tow plows, liquid deployment systems, and brine making facilities; (2) strategies: Maintenance Decision Support Systems, plowing alternative lane configurations such as roundabouts and diverging diamond interchanges, and the utilization of fixed automatic spray technologies for specific locations and critical infrastructure such as structures; (3) deicing technology: liquids and liquid-only routes, utilization of slurry, various solid-liquid and liquid-liquid blends to enhance deicing performance; (4) RWIS and sensor technology: non-contact sensor technology, mobile RWIS, grip sensors; and (5) sustainability and resiliency in the delivery of service and procurement, storage, and deployment of materials.

The objective of this research is to prepare, for publication by AASHTO, an updated guide for snow and ice control that addresses the advances in the state of the practice across a variety of climatological regions and provide guidance in the long-term planning necessary to be responsive to changing conditions. This objective will be accomplished by the following tasks: (1) Evaluate each existing chapter of the AASHTO Guide for Snow and Ice Control and include the best methods, practices, equipment, and technologies that have been developed; (2) Consider new sections in the Guide to address new strategies, tactics, and technologies that have been developed and are routinely utilized during winter maintenance operations, and (3) Ensure that the Guide covers strategies that address all weather regimes across the United States from northern snow belt to windswept plains to moderate/maritime ice belt states.

**Project 07-26**
***Highway Capacity Manual Methodologies for Analyzing Freeway Merging and Diverging Bottlenecks Considering Different Geometric Characteristics and Mitigation Strategies***

Research Field: Traffic
Source: California, Texas
Allocation: $500,000
NCHRP Staff: Waseem Dekelbab

Freeway congestion typically generates at freeway merge and diverge segments, which have the potential to serve as bottlenecks. To alleviate or mitigate the impacts of congestion at these segments, a number of active management operational strategies such as ramp metering, hard shoulder running, etc. have been implemented. The current freeway merge and diverge methodologies in Chapter 14 of the 6th edition of the Highway Capacity Manual (HCM) were developed over 25 years ago using limited field-collected data. In addition to limited data, the methodology does not conform to the fundamental relationship of traffic flow, namely that flow is the product of speed and density. Also, contrary to literature findings, the methodology overestimates the capacity values at both merge and diverge segments. In addition, the HCM does not offer any methodology for lane drops or additions, which often occur in the vicinity of freeway merge/diverge segments.

The objectives of this research are to (1) evaluate the current HCM freeway merge and diverge methodologies and propose methodology improvements or changes, (2) consider the effects of commonly implemented freeway management tools and strategies on capacity and quality of service, and (3) evaluate different geometric configurations that have not been adequately described in the HCM, such as lane drops/additions or long acceleration/deceleration lanes for multilane ramps, and recommend modifications to the proposed methodologies accordingly. The research will evaluate the use of emerging data sources for model development and provide guidance on incorporating such datasets for validation of analysis results. The new methodologies should be developed with close consideration to the HCM weaving and basic segment methodologies to ensure compatibility.

This research will produce new analytical methodologies and tools for improving the Highway Capacity Manual merge and diverge segments' existing procedures. The proposed research will address several limitations of the current methodologies, which include different geometric configurations and implementation of active traffic management operational strategies. Failure to fund this problem statement will result in cost-prohibitive use of microsimulation.

**Project 07-27**
***An Update of the Green Book Design Vehicles and Minimum Turning Paths***

Research Field: Traffic Planning
Source: AASHTO Technical Committee on Geometric Design
Allocation: $400,000
NCHRP Staff: B. Ray Derr

The current design vehicle classifications in AASHTO's *A Policy on Geometric Design of Highways and Streets* (Green Book) have been developed over a 40+ year period. These design vehicle dimensions and minimum turning radii, while providing full coverage of the general vehicle fleet, are difficult to support and verify. This difficulty is a result of the limited or nonexistent supporting data and research for these vehicles.

Questions have been raised about the steering angles for some of the Green Book design vehicles that appear small for the modern vehicle (e.g., 13 degree steering angle for the WB-92D and WB-109D). This can result in overly conservative or large geometric layouts and striping plans. Further, with the increased usage of modern roundabout designs, accurate vehicle steering angles and swept paths are of utmost importance.

The Technical Committee on Geometric Design (TCGD) recently received pre-ballot review comments on the Green Book, 7th Edition, from members of the AASHTO Subcommittee on Design. Several comments were related to the turn radii and prevalence of different design vehicles which can have a major impact on intersection and interchange design.

The Green Book turning path templates provide insufficient data for software developers, such as AutoTURN, to incorporate the turning paths in CAD programs without making assumptions such as the kingpin and hitch locations. As such, the CAD programs provide similar but different turning paths than the Green Book templates. Further, with industry movement toward 3D design, ground clearances or heights of the various design vehicles are needed but not provided by the Green Book.

The objective of this research is to develop material for the 8th Edition of the Green Book that ensures the design vehicle classes represent the vehicles on our roads, including the elimination of any inconsistent and unrealistic vehicle characteristics. The research should provide guidance on the use, application, or general conservativeness of the templates. The research will provide missing design vehicle information required for 3D design applications.

**Project 07-28**
***Assessing the Impacts of Turn Lanes in Different Contexts and Modal Considerations to Increase Safety Performance***

Research Field: Traffic
Source: AASHTO Standing Committee on Highway Traffic Safety
Allocation: $650,000
NCHRP Staff: Andrew C. Lemer

Developing a better understanding of the role a turn lane has on reducing crashes is becoming increasingly important as small changes to the roadway can result in significant costs to agencies. Current design and operational philosophies are commonly focused on whether a lane is needed and how will the installation of that lane affect operations; however, limited understanding exists regarding key factors in the safety decision making process to quantifying the turn lane safety performance characteristics (such as length of storage, deceleration length area, taper treatment, offset, etc.).

For some locations, the turn-lane crash modification factors are quite significant, and at other locations and contexts, the factors are quite low. While much research exists on turn lanes, both from a safety and operational perspective, data is typically aggregated in a manner that does not allow for the fine tuning of safety considerations. The intent of this research would be to understand the impacts of turn lane design on the safety of a facility, given different modal priorities, context, and traffic mix (e.g., freight, pedestrians, and bicyclists) under different levels of traffic. Consideration of left and right turns is often a benefit to the vehicle but a disadvantage to the bicyclist and pedestrian because of increased exposure, speeds, and crossing distances.

The safety aspects of turn lane design and location should consider the implications of the "do nothing" option. As an example, left turn lanes at rural four-lane highways may only be constructed if the turning volume exceeds a minimum threshold, yet the absence of the turn lane for even one or two vehicles may result in severe rear-end, angle, or sideswipe crashes at isolated locations. Alternative turn lane design options, such as constructing a short turn lane so as to provide limited storage, can be expected to directly influence safety performance at these locations. There is a need to take a microscopic view of design and operations of turn lanes and their impacts on safety to both vehicles and other vulnerable road users to evaluate the safety performance of various designs on differing facilities, modal mixes, and contexts to better allow for categorization of new design approaches. Research is needed to develop a better understanding of the current basis for the design of turn lanes at intersections and provide updated criteria to enhance design and operational performance of future designs based on the data-driven analysis.

The objective of this research is to describe key parameters and decision criteria to enhance the safety of turn lanes and provide safety models and crash modification factors that practitioners can use to evaluate design and operational treatments for turn lane safety. Achieving this objective may entail the following tasks: (a) review of literature and current practice regarding treatment of design and operational considerations for turn lanes in multiple contexts and traffic characteristics, (b) identification of key parameters and decision criteria to be considered in turn-lane provision, (c) development of safety models for evaluating turn lane impacts on safety for all modes, (d) development of crash modification

factors for applications involving turn lanes, and (e) preparation of a guidebook or materials to supplement the Highway Safety Manual presenting the models and crash modification factors in a manner to facilitate practitioner usage.

**Project 08-118**
***Risk Assessment Techniques for Transportation Asset Management***

Research Field: Transportation Planning
Source: AASHTO Committee on Performance Based Management
Allocation: $600,000
NCHRP Staff: Lawrence D. Goldstein

Transportation agencies must contend with a wide variety of risks as they manage their physical transportation assets. In operating their transportation networks, asset owners frequently must respond to impacts of events outside their control, such as weather events, geohazards, and other threats. Planning for the future requires projecting asset performance, construction costs, and future funding, all of which can be highly uncertain. Once an agency has made its investment plans, changes in commodity prices, project timing or other factors may impact delivery of its capital program. Despite improvements in information technology and other areas, deep uncertainty remains with respect to areas such as predicting future weather events, asset condition, system demands, funding, and other critical variables. Failure to correctly account for risk can have a variety of consequences, from cost overruns on projects to inaccuracies in estimating future needs and inefficient allocation of resources. Simply following an extremely risk-averse strategy can have negative consequences, as well; an overly conservative approach to accounting for risk can result in a significant gap between investment planning/budgeting and actual costs. Asset owners thus need better techniques for assessing and managing risk in order to best manage their physical transportation assets.

A number of approaches are commonly used to manage risk, including conducting visual inspections of existing infrastructure, using design standards with conservative safety factors for new infrastructure, and applying best practices for minimizing risks of project cost and schedule overruns. Research is needed to determine how to build on existing practices to better assess the risks to transportation assets, better quantify consequences of different risks, and better prioritize investments explicitly acknowledging uncertainty in future events.

The objectives of the proposed research are to

- Provide tools that will help transportation agencies better identify, quantify and manage risk to their assets.
- Review existing and best practices in risk assessment applicable to managing transportation assets in transportation and other infrastructure-intensive industries. The review should include methods for quantifying risk consequences, such as cost, safety, reliability impacts, as well as any approaches used for addressing compound risks.
- Define improved approaches to incorporating consideration of risk in asset data collection, needs assessment, project alternatives analysis, prioritization and resource allocation, and performance reporting and tracking. The approaches should address how transportation agencies make multiobjective, cross-asset investment decisions under uncertainty to best support the national goals identified in 23 USC 150(b).
- Review techniques that would be applicable in estimating and incorporating levels of uncertainty in the decision making and asset management process. The review should

consider approaches used for managing a portfolio of financial risks, as well as other relevant techniques.

- Define measures of asset resilience that can be incorporated into performance management in support of 23 USC 150(a).
- Provide an implementation guide with practical guidance for transportation agencies to use to incorporate improved risk assessment into their existing asset management business processes, adapting strategies for managing financial risk and other approaches identified through the research.

The passage of the transportation legislation Moving Ahead for Progress in the 21st Century (MAP-21) creates an imperative for improved research. MAP-21 amended 23 USC 150(b) to include national goals for the federal-aid highway program, with a focus on better operating the existing system, such as through improving safety and infrastructure condition. Also, MAP-21 established the requirement for state DOTs to prepare risk-based asset management plans describing how they will manage their roads and bridges on the National Highway System (NHS) considering risks to the system.

This research will bridge the gap between existing transportation asset management guidance detailed in resources such as the American Association of State Highway and Transportation Officials (AASHTO) Transportation Asset Management Guide and best practices for assessing and managing risks applicable to asset management. The research will help improve the state of the practice in risk-based asset management and help ensure that the full range of relevant factors is incorporated into transportation agencies' resource allocation processes.

**Project 08-119**
***Developing Data Standards and Guidance for Transportation Planning and Traffic Operations—Phase 1***

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| Research Field: | Transportation Planning |
| Source: | AASHTO Committees on Transportation Systems Operations and Data Management and Analytics |
| Allocation: | $1,100,000 |
| NCHRP Staff: | B. Ray Derr |

Planning and operating transportation systems involve the exchange of large volumes of data. The lack of common data formats has been a limiting factor for transportation agencies and all practitioners involved in data analysis and reporting. This includes sharing data among partnering transportation agencies (transportation, planning, public safety, and emergency response agencies at the city, regional, and state levels); private-sector interests (e.g., transportation network companies, navigation providers, freight managers); travelers; and intelligent devices (e.g., traffic signals, ramp meters, connected vehicles). Well-designed data standards can be a viable solution to this problem since they improve the efficiency of data-driven processes and can support innovation.

Some standards exist for data sharing within regional mobility management, but usually in specific segments of the operation (i.e., Traffic Management Data Dictionary [TMDD], Center to Center [C2C] protocols), which do not include all data elements needed for Integrated Corridor Management (ICM), and regional mobility management. For instance, TMDD works well for data sharing between traffic management centers, but does not include some data or granularity of data needed for decision support systems and modeling systems within ICM and Smart Cities. For instance, lane data (speed, volume, occupancy) is only available in most C2C systems at the macroscopic level (all lanes combined). Transit data within C2C systems is mostly static information and does not include real-time vehicle location and passenger count information.

Lessons learned from the ICM implementations, Smart City programs, and regional mobility programs in the United States point to research gaps and ideas that can help data sharing programs. These gaps can be organized along three general areas: a) data warehousing and data sharing standards, b) use of Intelligent Transportation Systems (ITS) standards and regional ITS architectures, and c) institutional coordination. NCHRP Scan Team Report "Advances in Strategies for Implementing Integrated Corridor Management (ICM)" (NCHRP Project 20-68A, Scan 12-02) provides additional information on some of these issues.

NCHRP Project 08-36 Task 129 examined the feasibility of developing standards for transportation planning and traffic operations. The report revealed that it is difficult to predict standard adoption. There are many well-designed and technically superior standards that have failed and become marketing case studies. Based on the research, a business case and clear incentives for a critical mass of supportive stakeholders is required for market adoption. Standards are most successful if they have a clear business purpose; are clear in application, specificity, and versioning; are developed with broad outreach and buy-in; are well defined and simple; are open standards; are forward looking; and involve a national or worldwide community.

There are also many challenges associated with standard development. These include reluctant data vendors; dynamic data content; complexity of data to be standardized; standardization process takes too long to complete; standardization process does not take into account a critical mass of would be users or decision makers; there are significant disincentives or conflicts of interest; there is limited outreach to agencies that could implement; and inadequate resources to overcome the barrier of entry.

The report (available on the TRB project webpage) concluded that standards are feasible and desired. Five specific data areas or "bundles" of standards were identified to be ripe for standardization: travel time, demand, incident and work zones, network, and transit.

The objective of this research is to develop standards and/or guidance to be used and adopted by the transportation community in collecting, managing, and sharing static and real-time data for transportation planning and operations. The five standard data areas or "bundles" to be evaluated for standard development include travel time, demand, incident and work zones, network, and transit. Each bundle includes various data categories. The researcher may evaluate bundles or data categories as appropriate for moving to the next stage of standard development.

In addition to resources and efforts mentioned previously, the research should consider the FHWA's report *The Use of Data in Planning for Operations: State-of-the-Practice Review* [FHWA-HRT-15-071] and the FHWA's Geospatial Data Collaboration initiative. The guidance should facilitate memoranda of understanding or other approaches to sharing data between the public and private sectors. Emphasis should be placed upon how standards and guidance can be maintained and made easily deployable by interested agencies.

Note: This problem statement is a combination of problems 2019-A-13 and 2019-B-13. The project panel will consider whether to incorporate existing NCHRP Projects 20-102(13) and 20-102(14) on data issues associated with connected vehicles and automated vehicles.

**Project 08-120**
***Initiating the Systems Engineering Process for Rural Connected Vehicle Corridors***

Research Field: Transportation Planning
Source: South Dakota
Allocation: $350,000
NCHRP Staff: Camille Crichton-Sumners

The National Connected Vehicle Field Infrastructure Footprint Analysis is a starting point for agencies that are looking ahead to a connected and automated vehicle environment. Given the fast-paced evolution of connected vehicle technologies, agencies need a vision now for long-term planning regarding deployments. To date, most connected vehicle research has focused on applications in urban areas, but agencies need to also plan for the responsibilities and resources required for deploying, operating, and maintaining infrastructure on rural freeways. Rural freeways often include long stretches of highway with limited power and communications. Similarly, there are often long distances between cities or services for travelers and long distances of roadway infrastructure to be maintained and operated. A series of questions needs to be answered related to rural deployments of connected vehicle applications, including:

- What applications will be most relevant on rural freeway corridors?
- How should an agency prioritize when and where infrastructure should be deployed?
- How do these policies and the placement of other ITS deployments translate to the needs, prioritization, placement, and spacing for deploying equipment to support connected vehicles?
- What scale of deployments should agencies anticipate on rural freeway corridors within 5, 10, and 20 years, respectively? Specifically, what density and types of equipment should an agency expect for rural freeway corridors?
- What level of multistate coordination may be required for connected vehicle applications on rural freeway corridors, given relatively high percentages of long-distance recreational and freight travelers?
- How will connected vehicle deployments in rural areas change agency operations? What activities will be needed to support operations and maintenance, and what activities will no longer be needed? When could legacy ITS assets be decommissioned?
- Will connected vehicle deployments on rural freeways create efficiencies or increase demands on agencies and transportation management centers (TMCs), as related to data needs, data processing and archiving capabilities, communications, staffing considerations, and software requirements? How will the agencies' technical resource requirements evolve?
- How can rural data backhaul challenges be addressed?

Past studies of connected vehicle technology have focused primarily on hardware and communication protocols used for vehicle-to-vehicle and vehicle-to-infrastructure connectivity. Studies of vehicle-to-infrastructure connectivity have concentrated on urban applications, such as traffic signals. No study has examined the strategic deployment of vehicle-to-infrastructure in rural freeway environments, with long distances and relatively sparse communications infrastructure to support backhaul. The objective of this research is to help

agencies anticipate the needs of connected vehicles on rural freeway corridors, including the anticipated roles and responsibilities of agencies in deploying, operating, and maintaining equipment and the associated needs related to staffing and resources. Recognizing the value of the systems engineering process, this project will develop a model Concept of Operations and Requirements document to serve as a starting point for agencies responsible for rural highways to use as they begin to document their needs, operational concepts, scenarios, and requirements. Tasks anticipated in this project should include the following:

1. *Outreach, Research, and Synthesis of Rural Connected Vehicle (CV) Findings.* Efforts may include contacting representatives of agencies that have deployed, planned, or prepared proposals for CV deployments in rural areas to discuss their planned or actual deployments, with particular emphasis on the preliminary and/or final results of the CV Pilot deployment with existing CV groups.
2. *Rural Corridor Connected Vehicle Needs Assessment* including outreach to a number of state and/or local DOT representatives responsible for operating rural freeways, with an emphasis on multistate corridors, to gather their input and perspective on at least two key issues:
   a) To develop an understanding of the needs not currently addressed by other solutions that might be addressed by connected vehicles; and
   b) To document the potential positive and negative impacts of rural corridor connected vehicle deployments on operations and maintenance of systems and technology components (e.g., demands for staffing time and skills to perform operations, maintenance, troubleshooting).

   Task 2 should include a detailed needs assessment to help understand the need for and potential of CV applications in rural areas. It is expected that multiple representatives would be involved from each of the DOTs contacted as part of this project, representing areas such as operations, maintenance, freight, planning, traveler information, safety, information technology (IT), etc. A considerable effort is anticipated to find and engage the appropriate individuals to allow for a broad discussion about the needs and possible impacts of CV application deployment. As a result of this desire to work with multiple groups within the DOTs involved, the total number of DOTs included may be limited. The activities to accomplish the outreach and needs assessment are expected to include a variety of in-person meetings (one-on-one or workshops) with a representative set of DOT staff who can offer input on the needs assessment. The exact format of outreach is to be proposed by the researcher.
3. *Rural Corridor Connected Vehicle Concept of Operation and Requirements.* Using the needs documented in Task 2, the research team will develop a model Concept of Operations and Requirements document for a Rural Connected Vehicle Corridor. The Concept of Operations will build upon the stakeholder needs to define operational concepts (including most likely connected vehicle application deployments), scenarios, stakeholder roles, and high level functional requirements. The intent of this model document will be to serve as a resource for agencies operating rural highways to use with their local stakeholders as a resource as they start their local systems engineering process. The model document will not go into the level of detail that a local site would include, but instead will provide a basis for the more detailed discussions each agency will need to conduct. It is anticipated that the DOTs contacted in Task 2 would continue their involvement contributing to the model Concept of Operations draft versions.

4. *Final Report and Presentations.* Efforts in Task 4 shall assemble all information gathered, describe the context and intended use of the model Concept of Operations, and create and compile a Final Report and presentation materials describing the results of the project. Two presentations at national venues would be included to share results of this project.

The state and local DOTs that own and operate the transportation infrastructure are beginning to plan for a major investment of resources to prepare their infrastructure to integrate connected vehicles. While much of the emphasis has been dedicated to urban areas, connected vehicle deployments in rural areas hold tremendous potential for improvements in safety, mobility, and efficiency. Rural areas typically have less ITS infrastructure than metro areas, and deploying the backhaul communications and roadside equipment will likely take longer. Therefore, it is critical that the agencies that operate the rural infrastructure have a vision toward their likely deployment as soon as possible.

**Project 08-121**
***Operationalizing Accessibility Metrics to Support Transportation Planning and Performance Management***

Research Field: Transportation Planning
Source: Minnesota
Allocation: $500,000
NCHRP Staff: Ann M. Hartell

Recent years have seen rapid growth in the research and use of accessibility metrics in transportation planning and performance management. Accessibility metrics indicate the ease with which travelers can reach valued destinations. They combine metrics indicating the cost of travel, such as travel time or financial cost, with the potential benefits—the destinations that could be reached at a given cost. This approach allows accessibility metrics to provide a uniquely comprehensive indicator of a transportation system's ability to provide opportunities to its users. For example, an accessibility metric focused on access to jobs might indicate that residents of a particular area could reach 100,000 jobs within 15 minutes by car.

Because few federal or state guidelines exist regarding the use of accessibility metrics, this recent increase in use generally represents ad hoc efforts at state and local levels to meet local planning and performance management needs. The national transportation community would benefit from an analysis of these many different ways of operationalizing accessibility.

Accessibility metrics can be implemented in a wide variety of ways, each of which can be useful for different purposes or different subject domains. For example, an accessibility metric designed for use in public-facing communication regarding a new highway segment could use very different data and methods from one intended for use by professional planners to identify high-priority freight corridors. However, little organized guidance is available on the selection of accessibility metrics for particular use cases. An analysis and categorization of the existing and proposed approaches to measuring accessibility can help practitioners identify the most useful accessibility metrics for their purpose, without lengthy investigation and testing.

Several tools and data sources focused on accessibility exist. Tools range from large software packages to local implementations by city staff or academic researchers and exist in both open-source and commercial forms. Data sources include university-led national data processing projects, outputs from MPO planning efforts, and comparative metropolitan analyses from advocacy groups for non-motorized transportation. Both tools and data sources vary in the exact ways that they implement accessibility measurements. Regardless of the scale, scope, or subject, these tools and data sources are typically quite robust. But the fragmented landscape provides little opportunity for understanding how they relate to one another, or which one would be most appropriate to support a particular planning or performance management goal. An analysis of existing accessibility tools and data sources can help connect potential users with the most appropriate resources, while also identifying opportunities to both streamline and expand the field.

Transportation agencies are currently using accessibility metrics to support a variety of planning and performance management goals. These range from states using accessibility

metrics to inform project prioritization, to MPOs setting accessibility goals in long-range plans, to counties using them to support local travel demand management programs. An investigation of these case studies can help to identify the types of applications in which accessibility metrics can have the largest impact, compile lessons learned from these implementations, and share best practices with the wider transportation community.

The primary objective is to identify and analyze accessibility metrics in order to provide guidance for the broader transportation community. The research is anticipated to include: (1) synthesis of accessibility metric definitions in published research and technical reports from practice; (2) classification framework for accessibility metrics; (3) decision-making recommendations for the selection of accessibility metrics for different use cases; (4) survey of existing tools and data sources that can be used to produce accessibility metrics; (5) evaluation of existing tools and data by using them to implement accessibility evaluations based on real-world examples and data; (6) case studies that identify and document lessons learned and best practices in using accessibility metrics for transportation planning or performance management; and (7) priority areas for additional development of accessibility methods with a focus on reducing barriers to use by transportation professionals.

The results of the research will be provided in a guidebook for operationalizing accessibility metrics. An implementation plan will lay out an immediately actionable set of steps to facilitate the adoption of accessibility metrics in the planning and performance management activities of at least three state DOTs.

**Project 08-122**
***Metropolitan Planning Organizations: Transportation Partnerships for the 21st Century***

Research Field: Transportation Planning
Source: California
Allocation: $400,000
NCHRP Staff: Dianne S. Schwager

Metropolitan Planning Organizations (MPOs) and state DOTs together invest hundreds of billions of taxpayer dollars to produce the urban transportation systems that U.S. businesses, workers, families, and freight services rely on every day. The partnership between MPOs and DOTs dates to the 1962 Federal Aid Highway Act, which introduced the vision of so-called "3-C" (cooperative, comprehensive, and continuing) planning between local communities and states.

Much has changed since the passage of the 1962 Federal Highway Act, including the introduction of federal transit funding, the rise of active transportation modes, increased concerns surrounding coordinated growth, environmental and sustainability planning, requirements related to metropolitan freight, increased urgency surrounding basic maintenance and operations needs, and less focus on capacity enhancements. Recently, responsibility for transportation funding has increasingly devolved from federal and toward state and local levels of government. Growth in fuel-efficient and alternative fuel vehicles and the emergence of autonomous vehicles already signal significant future shifts in transportation policy and funding conventions.

Systematic review of the history, legal basis, and present functions of MPOs and regional transportation planning is needed to assess how well these organizations and processes serve contemporary needs in light of rapid changes in transportation technologies and rapidly growing metropolitan areas. The proposed project would directly inform efforts by MPOs, state DOTs, and local and state policymakers to enhance metropolitan transportation planning and the capacities of MPOs responsible for it.

This research will address ways in which the regional and state transportation institutions can respond more nimbly and effectively to rapidly changing transportation demands, conditions, and technologies in the 21st century. It will provide a menu of strategies and tools—drawn from cases and practice—for better equipping 21st century MPOs and MPO-state partnerships to plan, maintain, and improve transportation systems for U.S. metropolitan areas and the economies reliant on those systems. MPOs and DOTs collaborating in specific regions and state and federal policymakers could use these tools and strategies to enhance U.S. planning and decision-making institutions for the metropolitan challenges and changing transportation paradigms of the 21st century.

The objective of this project is to produce a comprehensive resource for federal policymakers and MPOs, state DOTs, and state, regional, and local officials who seek to make metropolitan planning and MPOs more effective in the 21st century. The research findings—and the follow-on conference presentations, webinars, and workshops that would be crafted around their completion—will address MPOs and metropolitan planning from a

variety of perspectives. They will help state, regional, and local actors understand the challenges and opportunities for MPOs and their partnerships with DOTs in light of dramatic shifts in ways transportation is consumed and delivered. The research should address:

- How do MPO structures and responsibilities differ from organization to organization and from state to state? How have these features evolved over time? What lessons can be learned from the different institutional and organizational arrangements?
- To what degree have MPOs fulfilled their designated functions as those functions have evolved over time? What obstacles have MPOs faced in the execution of their missions? Which MPOs have been most successful, in terms of generating cooperative, participatory planning, influencing regional transportation outcomes, and distributing transportation benefits equitably? What has enabled individual MPOs to succeed?
- What have been MPO experiences with and what are their abilities for handling rapid change? How can MPOs and DOTs reinforce their mutual abilities to develop effective transportation systems and solutions for the 21st century? How can MPOs and DOTs coordinate to address these new opportunities and challenges?

The proposed research would benefit state DOTs and MPOs through the publication of shared lessons learned and strategies for strengthening the future delivery of coordinated transportation investments in a rapidly changing environment. In 2020, the FAST Act will expire and there will be a Presidential election. Additionally, the 2020 decennial census will report the latest trends in metropolitan growth, and planning for the deployment of connected and autonomous vehicle technologies will be well underway in many metro areas. Given this approaching convergence, this is a critical time to assess what has worked well and what needs improvement.

**Project 08-123**
***Census Transportation Data Use and Application Field Guide***

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| Research Field: | Transportation Planning |
| Source: | AASHTO Committee on Data Management and Analytics |
| Allocation: | $375,000 (Additional $50,000 from Federal Highway Administration and $75,000 from AASHTO) |
| NCHRP Staff: | Lawrence D. Goldstein |

The Census Transportation Planning Products (CTPP) data sets and the American Community Survey (ACS) are critical data elements that support the planning and analysis of transportation plans, policies, programs, and project selection. Changes in the data products over the last 10 years and ongoing staff turnover have left a void of expertise in effectively using this data to support transportation planning. Additionally, there is no centralized resource location where one can go to learn how to use the data for real-world applications. This results in wasted time, squandered resources, and at times questionable analysis.

The field guide will fill this void and provide the following:

- Serve as the training manual on the uses and application of the ACS, CTPP and Public Use Micro Sample (PUMS) data sets.
- Provide practitioners with a thorough understanding of the data, including its strengths and weaknesses.
- Describe the data elements, table structures, and variable definitions.
- Instruct users on when and how to use the data.
- Use real-world and visual examples on how to apply the data.
- Draw in examples from different types of transportation agencies including states, MPOs, and transit.

The field guide will play a critical role in enabling junior-level planners to learn about the data and how to utilize the data to support required planning functions. The field guide will be comprehensive and cover the broad range of applications where these data are used.

The objective of this project is to develop a field guide for the transportation community on how to effectively use Census data including the ACS, CTPP, and PUMS to address transportation issues:

- Depict applications that cross sectors (public and private), are statewide and regional, depict small and large studies, and are multimodal where possible.
- Delve into the perennial issues facing the transportation community as well as those that are emerging like Environmental Justice and Title VI, providing context for resiliency planning, millennial travel patterns, and alternative commute opportunities, etc.
- Assure there are sufficient applications depicting various levels of analytical complexity that are covered and reported.

When the ACS was introduced by the Census Bureau as the replacement to the Long Form, it brought with it a change in how the data were collected and packaged for public release. This in turn brought a whole new set of data issues for the transportation analyst to understand and cope with. Margins of error, privacy protection rules and procedures,

imputation, rounding, data suppression, changes to the survey instrument and variables, and period estimates all have stretched the learning curve for the user. Staff from the states, MPOs, and transit operators all have struggled with the use and application of the ACS and data products derived from it like the CTPP and PUMS.

**Project 09-63**
***Development of a National Performance-Related Specification for Emulsified Asphalt Binder***

Research Field: Materials and Construction
Source: Rhode Island
Allocation: $500,000
NCHRP Staff: Edward T. Harrigan

The proliferation of method specifications, many of which are antiquated and outdated, has resulted in surface treatment performance deficiencies. In response to these difficulties, contractors, industry, and agencies have begun moving toward the development and implementation of performance specifications for chip seal emulsions and other emulsion-based treatments.

The key challenge in the development of performance specifications is the need to identify appropriate testing protocols and acceptance criteria that will reliably predict long-term treatment performance or the potential for failure. By developing reliable acceptance criteria, agencies will have the means to determine when a treatment has been satisfactorily constructed and to aid in assessing the appropriate level of compensation.

Emulsified asphalt technologies have been the long-overlooked stepchild of asphalt technologies in general, specifically hot mix binder that has taken most of the R&D resources over the last three decades. This effectively has held emulsion technologies stagnant with very little advancement in the technology, practices, and specifications.

As the demand for asphalt emulsions has increased due to the widespread acceptance of pavement preservation, it is recognized that a need exists to develop a nationally accepted performance-related specification for an all-encompassing emulsified asphalt similar to the SuperPave binder specifications, for use by state DOTs and local agencies. It is envisioned that the specification will utilize readily available testing equipment (i.e., Superpave-based testing equipment) and be based on environmental and traffic conditions and validated with field trials. It is anticipated that the recent findings from NCHRP Project 9-50 and FHWA/TX-12/0-6616-1 will also be incorporated.

The objective of the research is to develop and validate a national performance related specification for emulsified asphalt for use with chip seals. The study would leverage the recently completed research on emulsified asphalt performance related specifications and build on these in order to create a consensus national specification that is validated and ready for implementation by state DOTs.

Accomplishment of this objective shall require the following tasks, at a minimum: (1) collect and evaluate existing literature including published and unpublished sources and personal contacts with industry and DOT leaders; (2) utilize field and laboratory data to evaluate correlations between laboratory test results and field performance; (3) develop performance specifications; particularly performance-graded residue specifications; and (4) validate specifications via field studies performance evaluation.

**Project 10-102**
***A Guidebook for Risk-Based Construction Inspection***

Research Field: Materials and Construction
Source: AASHTO Subcommittee on Construction
Allocation: $600,000
NCHRP Staff: Waseem Dekelbab

State transportation agencies (STAs) are currently facing the critical challenge of supporting an increased demand for highway system rehabilitation and construction work with reduced funding and staff. *NCHRP Synthesis 450: Forecasting Highway Construction Staffing Requirements* found that "STAs are managing larger roadway systems with fewer in-house staff than they were 10 years ago." The high retirement rates affecting public owners during the last few years and the migration of experienced STA staff to the private sector are not only challenging these agencies' abilities to meet required staffing levels but also their capacity to retain critical knowledge. Experienced employees have developed skills to make effective decisions and address specific risks during the performance of their duties and usually those skills are lost when they retire and/or are replaced by less seasoned staff. *NCHRP Synthesis 450* found that staff constraints and the lack of needed skills are affecting virtually all STA functions, with the major impact on construction inspection (CI) capabilities. This situation has motivated STAs to seek out effective strategies to facilitate CI activities and optimize the use of limited available staff, allowing for personnel to "do more with less."

The objective of this project is to develop a risk-based construction inspection implementation guidebook for STAs. The guidebook should compile effective practices identified through a comprehensive review of the existing relevant research and a critical analysis of the state of the practice in using RBCI systems in transportation construction/maintenance projects as well as in other industries. Data should be collected through an online survey directed to STAs and four-to-six case studies strategically selected based on the maturity of their CI programs. The guidebook should include a methodology to factor the perceived risk of CI activities into the decision-making process associated with the outsourcing of CI services.

The need for this research aligns with the objectives of the Contract Administration and the Integrated Construction and Technologies Sections within the AASHTO Subcommittee on Construction. An in-depth discussion took place on the topic of risk-based construction inspections at the AASHTO Subcommittee on Construction Annual Meeting in August 2017 with the resultant development of this problem statement.

Note: The AASHTO Special Committee on Research and Innovation increased the funding of the subject problem statement from $400,000 to $600,000 to expand the research objective and develop guidelines for statistical inspection procedures for transportation projects.

**Project 10-103**
***Benchmarking Accelerated Laboratory Tests for ASR to Field Performance: Consideration of Cement and Alkali Contents and Influence of SCMs***

Research Field: Materials and Construction
Source: AASHTO Subcommittee on Materials
Allocation: $650,000
NCHRP Staff: Inam Jawed

Developing new test methods and benchmarking existing laboratory test methods for assessing alkali-aggregate reactivity and preventive measures remain a major challenge to the concrete and aggregate industry. A "perfect" test method to assess the real potential for alkali-silica reaction (ASR) would be capable of assessing actual job concrete mixtures in a relatively short period of time (1-6 months or even less) and would accurately predict the true field performance. Unfortunately, no such perfect method exists. The recently developed AASHTO R 80-17 practice (previously AASHTO PP 65) and ASTM C1778-16 Guide have significantly improved the way the concrete industry assesses aggregates for potential alkali-silica reactivity and selects appropriate mitigation means to allow the use of potentially alkali-silica reactive aggregates in new concrete construction. These documents were a result of a number of FHWA- and DOT-funded research projects on evaluating the potential for, and the prevention of, alkali-silica reaction together with a consideration of the current approach by the Canadian Standards Association. A unique feature of these projects was the use of long-term outdoor exposure sites to benchmark accelerated laboratory tests to concrete exposed to actual environmental fluctuations. The investigated concrete mixtures primarily followed mixture proportions specified in ASTM C 1293, including cement and alkali contents. This is often regarded as our most reliable test method for assessing aggregate reactivity. As a result, the current guidance documents (AASHTO PP 65 and ASTM C 1778) are based on mixtures that have high cement [708 lb/yd$^3$ (420 kg/m$^3$)] and high alkali (0.95% or 1.25% $Na_2O_{eq}$) contents. However, there is criticism that they do not properly capture concrete mixtures with lower cement contents [for example, <708 lb/yd$^3$ (<420 kg/m$^3$)] and/or lower alkali loadings. Also, recent results from long-term exposure sites indicate that the amount of supplementary cementitious materials (SCMs) needed to control ASR expansion in the concrete prism test (ASTM C1293) or that required when simply following the AASHTO R 80-17 practice or ASTM C1778 guide may not be adequate to control expansion in outdoor exposure blocks with high contents of high-alkali cements. Testing SCM mixtures in exposure blocks with more moderate (and realistic) alkali levels is needed to ascertain whether this is merely an artifact of the severe alkali loadings used in previous exposure-block studies.

The main objectives of this research are (i) to extend the current database from field-exposure blocks produced with cement contents and alkali loadings representative of highway pavements and structures for the purpose of validating and/or calibrating the prescriptive (preventive) measures in AASHTO R 80-17 and ASTM C1778 and (ii) to enable better benchmarking of the various "performance tests" or "job-mixture tests" that have been or are being developed currently.

To achieve these objectives, concrete blocks will be cast and exposed to real environmental conditions with moderate alkali loadings and lower cement contents to provide the

crucial long-term benchmarking for the development of ASR test methods for job mixtures and to validate and/or calibrate the prescriptive measures in AASHTO R 80-17 and ASTM C1778. Various modified accelerated test methods that show promise for assessing aggregate reactivity and potential mitigation options will also be investigated. The results from the exposure blocks cast in this research program will help build confidence within the concrete and aggregate industry to modify the current guidelines for assessing alkali-aggregate reactivity in field concrete in real environmental conditions.

The principal outcomes/products anticipated from this research program will include: (i) draft revisions to the prescriptive measures that are currently in AASHTO R 80-17 and ASTM C1778; (ii) recommendations for improving ASTM performance tests and a draft standard(s) for the most promising test(s); and (iii) an extensive database from field-exposure blocks in at least three different climates using a wide range of concrete materials.

At least 150 concrete mixtures will be cast to supplement the existing database from outdoor exposure sites. The variables to be considered will include: (i) a wide range of reactive aggregates with an emphasis on low to moderately reactive aggregates since much of the existing data are from highly or extremely reactive aggregates; (ii) cement contents in the range used in pavements and highway structures (300 – 400 kg/m$^3$); (iii) various cement alkali levels, especially cements with low (0.4% to 0.6% $Na_2O_{eq}$) and moderate (0.6% to 0.8% $Na_2O_{eq}$) alkali contents; (iv) a wide range of SCM types and contents with focus on moderate levels typically used in pavements (for example, 15% to 25% fly ash, 25% to 35% slag); (v) variation in environmental exposure—blocks from each mixture will be placed in at least three different climate locations to represent various temperature/humidity ranges.

In addition to concrete blocks, samples will also be cast from each mixture for laboratory testing using the currently most-promising performance tests.

The performance of the concrete exposure blocks will need to be monitored indefinitely beyond the proposed study period. Additional blocks evaluating a wide range of materials may also be produced beyond the proposed program, and all data will need to be made available on a continuing basis.

There is an urgency to address the concerns of the aggregate, cement, and concrete producers about the aggressive nature of the laboratory testing and field exposure sites with regard to high cement contents and high alkali contents. There is also a high need to broaden our laboratory and especially exposure block repository, from which modifications to the requisite standards could be made. The industry needs critical benchmarking data from exposure sites on moderate alkali contents and moderate cement contents with regard to impact on alkali-silica reactivity. There also appears to be a disconnect between our laboratory and field testing. This research program is expected to address all these issues and provide crucial missing data, removing the gaps and disconnects in our current state of evaluation of field concrete mixtures for ASR potential, enhancing the reliability of our methods for determining the susceptibility of concrete to ASR and methods to minimize or avoid this deleterious reaction, and improving the AASHTO R 80-17 and ASTM C1778 guidance documents.

**Project 10-104**
***Evaluating Use of Unconventional Fly Ash Sources in Highway Concrete***

Research Field: Materials and Construction
Source: AASHTO Committee on Materials and Pavements
Allocation: $600,000
NCHRP Staff: Inam Jawed

Supplementary cementitious materials (SCMs) are key ingredients of today's concrete and have been shown to vastly improve the durability and sustainability and mitigate alkali-silica reactivity of concrete mixtures. While the demand for fly ash (the most commonly used SCM) and other suitable pozzolans continues to increase, the supply of high quality and economically available fly ash has been dwindling or at least become unpredictable. This is partly due to shifting of fuel sources (for example, switching from coal to natural gas) at power plants and partly due to tightening environmental and air pollution regulations, which affect fly ash quality by increasing its carbon, calcium, sulfur, and ammonia contents.

Currently, less than 50% of the produced fly ash meet AASHTO M 295 (ASTM C618) requirements for use in concrete. The imbalance between the supply and demand for quality fly ash has resulted in regional and seasonal shortages, which is likely to exacerbate significantly in future. In a recent AASHTO survey, 80% of the respondents indicated issues with fly ash supply. Based on today's standards and practices, it is estimated that, by the year 2030, the supply of fly ash in the United States meeting AASHTO M 295 (ASTM C618) specifications will be approximately 14 million tons while the demand will exceed 35 million tons. Clearly, transportation agencies and the concrete industry need to identify and evaluate new and unconventional fly ash resources that will maintain the quality and performance of concrete. A vast, largely untapped resource is the fly ash stockpiled over the years in dry storage monofills. Another option is the application of fly ash beneficiation technologies that are easy to implement and do not require high capital investment.

The objective of this research is to update AASHTO M 295 (ASTM C618) standard, considering new and unconventional fly ash sources suitable for use in highway concrete. To achieve this objective, it will require completing, at a minimum, the following tasks:
*Task 1. Literature review:* The review will include previous studies on the use of recovered stockpile and lagoon fly ash, performance of non-AASHTO M 295 (ASTM C618) fly ashes in concrete, as well as various fly ash beneficiation and mineral processing technologies that are available at industrial or laboratory scale. Evaluation of the economic viability, effectiveness, and ease of implementation of each beneficiation technology will be included. Also reviewed will be standard and recently developed test methods to characterize the properties and performance of fly ash. The review will identify the most promising unconventional fly ash resources and beneficiation technologies to be experimentally evaluated in the remaining tasks of the project.
*Task 2. Acquiring recovered fly ash and high loss-on-ignition (LOI) fly ash samples:* Samples from sources of stockpiled fly ash identified in Task 1 will be obtained and evaluated to determine the degree of heterogeneity in the properties, with particular consideration to the source locations and the depths of each stockpile. In addition, several samples of marginal or high LOI fly ashes will be acquired for beneficiation and testing.

*Task 3. Characterizing and beneficiating fly ash samples:* Each obtained fly ash sample will be characterized to determine its bulk chemistry and mineralogy, unburned carbon content and physical properties. The results will be compared with AASHTO M 295 (ASTM C618) requirements to determine areas of non-conformance and to identify the necessary beneficiation. The most promising and feasible beneficiation methods identified in Task 1 will be applied to fly ash samples.

*Task 4. Evaluating the performance of raw and beneficiated fly ashes in concrete:* A well-designed experimental plan will be developed and executed to evaluate the properties of fresh and hardened concrete mixtures containing raw or beneficiated fly ash. Consideration will be given to the consistency of the entrained air content and structure and other relevant properties. The results will allow numerical evaluation and ranking of the effectiveness of various beneficiation methods. For stockpiled fly ash, this task will identify critical beneficiation processes as well as those having marginal impact on concrete performance. Guidelines for evaluating stockpiled fly ashes and recommendations for new tests or modifications of existing test methods will be presented.

*Task 5. Preparing a proposed revised/updated AASHTO M 295 standard:* Based on the findings of the evaluations performed in Task 4, a revised version of AASHTO M 295 that considers the new and unconventional fly ah sources that are appropriate for use in highway concrete will be proposed and prepared.

*Task 6. Final report:* The final report will document the entire research effort, results, findings, conclusions, and recommendations.

**Project 11-08**
***Assessing Practices for Right of Way Acquisition and Reimbursement in Utility Relocations***

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| Research Field: | Administration |
| Source: | AASHTO Committee on Right of Way, Utilities and Outdoor Advertising Control |
| Allocation: | $450,000 |
| NCHRP Staff: | Andrew C. Lemer |

When a transportation construction project involves the relocation of utility facilities, the state department of transportation (DOT) or other responsible agency must engage in a complex negotiation of state and federal statutes governing acquisition of right-of-way (ROW) or easements to accommodate the relocation and provide reimbursement to affected parties. The process can be costly and time-consuming and may delay overall project completion. While the process for ROW acquisition is controlled by the Uniform Relocation Assistance and Real Property Acquisition Policies Act (Uniform Act), state and local statutes have created significant variations among practices across the country. For example, some states legislatively cannot acquire property rights (typically easements) for utility companies, which then requires parallel ROW acquisition processes (one by the transportation agency and one by the utility company). Conversely, there are some states where the reimbursement for utility property access needs is available. Where ROW acquisition by the DOT would involve stringent policy driven negotiations, that same acquisition in the hands of the utility company may entail less effort. Reimbursement policies often depend upon the designation of a utility as a public or private entity and whether the facility requiring relocation has a property interest. When transportation agencies must employ condemnation or use eminent domain to acquire ROW, the utility companies may not have the means to gain access. Some agencies may have broad capabilities to acquire additional ROWs, others may be restricted. In all cases, replacement of ROW or acquisition of easements for utility relocation necessarily includes compensation of affected parties and negotiation of the details of that compensation.

Members of AASHTO's Committee on Right of Way, Utilities and Outdoor Advertising Control have agreed that although the legislative environment differs from state to state, there is much to be learned from an analysis of the common problems agencies must address and effective practices that have been developed for solving these problems. Research is needed to review effective practices for acquisition of replacement utility easements or ROW; allocation of authority or responsibility between the DOT, utility company, or other agencies; use of joint or shared easements; administrative policies and procedures for addressing utility relocation issues; and statutory opportunities and limitations on agency policies and procedures, for example, regarding use of condemnation or eminent domain.

The objective of this research is to identify effective policies, procedural steps, and legislative means agencies use to secure needed replacement easements or ROW for utility relocations and to develop guidance DOTs and others may use to enhance the effectiveness of their own practices. The product of this research should be a report describing the primary factors influencing policies and practice, a framework for assessing effectiveness of an agency's policies and practices, and examples of very effective policies and practices.

The report should be helpful to DOTs and utility companies that engage in utility relocations.

The research may entail review of current accommodation and reimbursement policies at the federal level and a survey of DOTs regarding their experiences, interviews with knowledgeable practitioners engaged in utility relocations, development of case studies illustrating effective experiences, identification of significant opportunities and obstacles for improving current practices, and discussions of research findings with AASHTO committees and others to refine the findings and their presentation to communicate effectively with the intended audience. The final document should include analysis of the value to DOTs and their stakeholders of effective practices for ROW acquisition and reimbursement in utility relocations.

**Project 12-116**
***Design Specifications for the Static and Seismic Design of Piles for Downdrag***

Research Field: Design
Source: AASHTO Committee on Bridges and Structures
Allocation: $500,000
NCHRP Staff: Waseem Dekelbab

The *AASHTO LRFD Bridge Design Specifications* (2012) recognize that piles in settling soil experience downdrag forces from negative skin friction and that they may also move downward with the adjacent soil. Many bridges are constructed in areas where there is compressible soil, or liquefiable soil which necessitates the consideration of downdrag forces and associated settlement. Downdrag for static conditions, as well as seismic conditions, has increasingly placed greater demands on existing and new foundations and also led to higher construction costs. In addition, experience has shown that there are significant cost advantages to the use of the neutral plane method due, in part, to differences with the approach that is currently explicitly described in the AASHTO Specifications.

The objective of the research is to develop design specifications for the Static and Seismic Design of Piles for Downdrag that will use the framework of the AASHTO specifications and incorporate the most up-to-date research on drag load. The neutral plane method will be explained in detail, and its use will be illustrated by real-world examples.

According to transportation engineers from several states, experience with the explicit AASHTO approach for downdrag has shown that it can lead to unrealistic results and the use of longer piles, surcharging, and/or ground modification. The AASHTO Specifications allow the use of the "neutral plane method," although it is only briefly referenced. The absence of detailed guidelines for the neutral plane is a reason cited for the reluctance among designers and consultants to use the neutral plane method even though the neutral plane method represents a simple, more realistic model for piles subjected to a downdrag force and its associated effects.

**Project 12-117**
***Effective Use of Duplex Coating Systems to improve Steel Bridge Structure Durability***

Research Field: Design
Source: AASHTO Committee on Bridges and Structures
Allocation: $500,000
NCHRP Staff: Waseem Dekelbab

Steel bridge coatings greatly contribute to the longevity of a bridge structure and reduce the total life-cycle cost by protecting steel bridge members from corrosion. For most steel bridges across the nation, the most popular practice is to provide a 3-coat, zinc-rich primer system. The 3-coat system generally requires regular maintenance (touchup) and may have to be completely overcoated or repainted after as little as 15 years. This approach has proved to be a maintenance challenge for bridge owners. While efforts are ongoing to improve the service life of traditional paint systems, another approach would be the use of duplex systems (hot dip galvanized or metallized with a traditional finish coat) to provide long-term protection against corrosion. The combination of a metallic coating and a traditional finish coat is often referred to as a "duplex coating." Van Eijnsbergen suggests that the synergetic life of duplex coatings is 1.5 to 2.3 times the sum of the individual lives, which may result in service lives in excess of 75 years. Unfortunately, bridge owners have had mixed experience with duplex coatings (including the galvanizing and metalizing process and/or finish coat application). Some DOTs have had great success with the approach while others have had issues with galvanizing and metalizing quality, experienced adhesion problems with the finish coating, or have had to perform maintenance painting of the duplex system sooner than anticipated. The processes are currently reliant on the experience of the galvanizers, metalizers, and coating applicators and as such may be considered more of an art than a science. The proposed project will close the gap between art and science by developing design guidelines, guide specifications, and a state of the art report.

The objective of this research is to develop practical guidelines that allow bridge engineers to position duplex coating systems among alternative corrosion control options for steel bridge structures. The researcher shall use a combination of laboratory testing and field studies to accomplish the project objectives.

This project directly addresses the 2013 SCOBS strategic vision objective to "Extend Bridge Service Life."

**Project 12-118**
***Structural Design and Analysis of Post-Tensioned Concrete Structures with Flexible Fillers***

Research Field: Design
Source: Florida
Allocation: $800,000
NCHRP Staff: Amir N. Hanna

Grouted and bonded post-tensioning tendons are the predominant post-tensioning systems used in bridges in the United States. However recent durability issues of grouted tendons have prompted state DOT's to move toward unbonded tendons using flexible fillers to facilitate future replacement of potentially corroded tendons. Structural members can be prestressed utilizing unbonded internal tendons (UIT), unbonded external tendons (UET), combined unbonded internal and external tendons (CUT), bonded tendons (BT) or combinations of bonded and unbonded tendons (CBUT). While flexible fillers have been used in Europe for decades, this new direction in post-tensioning requires reevaluation of the current *AASHTO LRFD Bridge Design Specifications* (*AASHTO LRFD*) for post-tensioned structures with UIT, CUT and CBUT. The proposed study consists of three parts: (1) analysis and experimental evaluation of shear in structures with internally unbonded tendons in the webs of structural members, (2) an analytical study to evaluate the flexural behavior of structures with UIT, CUT and CBUT, and (3) an evaluation of the resistance factors for structures with UIT, CUT and CBUT.

The applicability of the Modified Compression Field Theory (MCFT) for shear design of bridges utilizing unbonded tendons is somewhat ambiguous because the theory is formulated based on membrane elements with well-distributed, bonded reinforcement. In unbonded segmental construction, there is no continuous bonded longitudinal reinforcement at the match-cast joints to resist in-plane axial tension stress at the local level. External or internal unbonded tendons can only resist global elongation between anchorage points. Therefore this research is critical to determine the applicability of MCFT in shear and torsion design for structures with UIT, CUT and CBUT.

The current edition of *AASHTO LRFD* addresses both unbonded and bonded tendons separately and includes a section that addresses components with both bonded and unbonded tendons. The unbonded tendon approach is based on grouted external tendons resulting from research performed by MacGregor. In addressing the mixed condition (CUT or CBUT), it refers to a more rigorous detailed analysis or a conservative simplified analysis. This mixed condition however, has not been adequately evaluated and recent limited research has revealed the need to further explore this condition. While grouted external tendons are common practice, the new design philosophy could utilize internal unbonded tendons as well as combinations of unbonded and bonded tendons where the majority of the prestressing steel is unbonded.

Internal unbonded tendons introduce voided ducts in the webs and flanges of I- and Box girders. Voided ducts reduce the structural capacity of a web to resist shear. Concerns have been raised whether it is sufficient to deduct the duct diameter from the web thickness in determining the concrete contribution.

*AASHTO LRFD* currently differentiates resistance factors for bonded and unbonded state, however, it does not address a combined state. The shear and flexure design procedures should account for combining bonded and unbonded tendons in the same structural member.

The objective of this research is to update the *AASHTO LRFD Bridge Design Specifications* design procedures for bridges with unbonded tendons or a combination of bonded and unbonded tendons. The research should include the shear provisions for webs with multiple unbonded tendons (duct voids), and update the associated resistance factors. Tasks involved in this research are: (1) Perform a literature search. (2) Develop an analytical and experimental work plan that should include full scale testing of structural members with stacked unbonded tendons in the webs. (3) Conduct the experimental testing. (4) Conduct analysis based on experimentally calibrated models. (5) Develop design and analysis procedures. (6) Propose revisions to *AASHTO LRFD Bridge Design Specifications*. (8) Prepare a final report.

**Project 13-08**
***Guidelines for Decision Making for Repair vs. Replacement of Highway Maintenance Equipment***

Research Field: Maintenance
Source: AASHTO Committee on Maintenance
Allocation: $350,000
NCHRP Staff: Andrew C. Lemer

Equipment failures often force fleet managers to decide if equipment should be repaired or replaced. This may not be solely a financial decision; it is an operational decision as well. Operational impacts such as downtime, loss of function, mission criticality, etc., need to be included. Fleet managers need resources to evaluate the merits of handling both planned refurbish vs. replacement decisions and unplanned repair vs. replacement decisions for equipment that has not met the established life cycle. The repair, refurbish, or replace decision is a consideration for DOT fleets as a method to manage fleet expenditures and extend life cycle. Effective fleet management involves an evaluation of when is the correct time to repair, refurbish, or replace an asset.

Many factors are considered in making these analyses, including equipment and component condition, anticipated asset service life, costs for repair or replacement, equipment reliability, and time the equipment will be out of service for repair or arrival of the replacement. Availability of funds, whether repair or refurbishment, will be accomplished in house or outsourced; current workloads; and many other factors may affect the repair-or-replace decision.

The objective of this research is to provide fleet managers with a methodology and an electronic tool to guide decisions to repair or replace equipment. The methodology and tool should be suitable for endorsement and distribution as an AASHTO guide. The target audience for this research would be state DOT fleet managers and maintenance engineers who rely upon availability of equipment to carry out day to day operations.

**Project 14-42**
***Determining State DOT Maintenance Program Implications of Connected and Automated Vehicles***

Research Field: Maintenance
Source: AASHTO Committee on Maintenance
Allocation: $300,000
NCHRP Staff: Camille Crichton-Sumners

Connected and Automated Vehicle (CAV) research and technology are progressing at a rapid rate. Research is underway to examine how traffic control signs, markings, signals, and other permanent and temporary ancillary devices (highway assets) can be designed, enhanced, or applied for vehicle navigational guidance. However, state maintenance engineers often cite inadequate resources to maintain the existing highway system and its ancillary highway assets at an acceptable level of service. Without knowing how the technology of CAV will affect the required level of service or responsiveness for the maintenance, repair or replacement of those highway assets, the use of these assets for CAV vehicle navigation could be impaired and the adoption of CAV hindered. Research is needed to explore the financial, workforce and level of service impacts demanded to maintain these highway assets for successful CAV navigation.

The objective of this research is to examine the maintenance program implications of the use of highway assets for vehicle navigation for CAV. The research team should work in conjunction with research under way, CAV developers, and highway asset vendors to determine how the assets will be used to meet the needs of the human driver and the CAV driver. The research shall identify the current resources (e.g., financial, workforce) allocated to state DOT maintenance programs to maintain, repair, and replace highway assets and the associated levels of service (e.g., condition, response time, life cycle). It shall also identify proposed CAV navigational systems, particularly those that rely on highway assets, to determine responsiveness, redundancy, and level of services required for meeting the CAV navigational needs.

The deliverables should include an assessment of the current state of maintenance programs as well as the required future state in order to support CAV needs. Recommendations will be provided to CAV developers, highway asset vendors, and state DOT officials to design a system that can efficiently and effectively be maintained.

**Project 17-90**
***Validation of Roadside Crash Injury Metrics in Real World Crashes (Correlation of Actual Injury Outcomes to Those Predicted During Crash Testing)***

Research Field: Traffic
Source: AASHTO Technical Committee on Roadside Safety
Allocation: $400,000
NCHRP Staff: Edward T. Harrigan

The methods used to evaluate injury risk in roadside hardware crashes were developed in the 1980s and very likely outdated. The advancement of vehicle designs (i.e., vehicle crumple zones, seatbelts, frontal and side airbags, etc.) have resulted in significant changes over the last three decades. In frontal crashes, the flail-space crash injury metric is now too conservative considering that occupants are now required to wear seat belts, airbags are used as supplementary restraint systems, and vehicles have crumple zones, all specifically designed to provide controlled ride down decelerations. In contrast in side crashes, the flail space model, which does not account for intrusion, may have the opposite problem and not be sufficiently conservative.

The simplified point mass, flail-space model (FSM) was introduced in 1981 by Michie and is currently used in the United States Manual for Assessing Safety Hardware (MASH) crash test procedures to assess vehicle occupant injury risk in roadside hardware crash tests. Similar Canadian, Australian and New Zealand crash test standards also use the FSM. The European procedures use a variation of the FSM in conjunction with the Acceleration Severity Index (ASI) to gauge occupant injury risk. Both metrics are used in roadside crash tests as a substitute for an instrumented anthropometric crash test dummy (ATD). Using an ATD in MASH certification compliance testing would significantly increase the cost of crash testing to around 40 percent if not more, increasing the cost of safety hardware.

Despite long-term usage to evaluate occupant risk in full-scale crash tests of roadside safety hardware, there is little information correlating either FSM or ASI to occupant injury. In addition, FSM was developed in an era when few drivers wore seat belts, airbags were still a rarity, and crumple zones in vehicles had not yet been developed. FSM predictions are hence unrepresentative of the injury risk experienced by drivers in 2017. ASI is newer and was designed for belted occupants, but has not been validated against U.S. occupants in the current fleet. In addition, both FSM and ASI are acceleration-based measures which are better suited to head and chest impacts. They are less than ideal for predicting the risk of leg injuries, such as those injuries observed in some end terminal collisions. Also, neither metric is suited for predicting injury in crashes where the occupant compartment is compromised, including broken side windows in rigid and semi-rigid barrier impacts and A-pillar cutting that can occur in crashes with cable barrier.

This project will seek to compare the current MASH occupant risk procedure predictions with real world crash events where longitudinal and lateral decelerations have been measured and with results from instrumented ATD's placed in current barrier impacts. Alternative vehicle-based methods of determining occupant injury risk will also be evaluated. The anticipated result would be revised MASH occupant risk tolerance values and/or an improved method of determining occupant injury risk in roadside hardware crash tests.

Accomplishment of this objective shall require the following tasks, at a minimum: (1) synthesis of engineering rationale for FSM, ASI, and other Vehicle-Based Injury Criteria to include injury biomechanics basis, computational effort, and practicality; (2) determination of data sources for

validation of roadside crash injury metrics; (3) correlation of real-world injury outcomes to those predicted by the FSM, including correlation by body region, and performance of FSM in frontal vs. side crashes; (4) correlation of real-world injury outcomes to those predicted by other vehicle-based injury criteria and determination of body region as well as the performance of each in frontal vs. side crashes; (5) ranking of FSM and other vehicle-based injury criteria by correlation to real-world injuries; and (6) proposal of MASH injury criteria and limits for incorporation in an updated MASH.

**Project 17-91**
***Assessing the Impacts of Connected, Automated, and Autonomous Vehicles on the Future of Transportation Safety***

Research Field: Traffic
Source: AASHTO Standing Committee on Highway Traffic Safety
Allocation: $450,000
NCHRP Staff: William C. Rogers

Transportation agencies are charged with an increasingly complex task of balancing the needs to preserve and maintain assets while introducing new assets into an already overwhelmed transportation system. Gradually, organizations are recognizing that past practices of designing what is considered a safe traveling environment is changing as the vehicle fleet evolves to more connected, autonomous and automated driving. While it is understood that impacts are relatively minor today, the implications on the design and operational criteria of tomorrow will be substantial.

Research is needed to understand and plan for these impacts and to consider how these impacts could change the way we plan, design, and operate our facilities. Transportation agencies are constrained within the existing footprints available to reduce the increasingly burdensome impacts to the environment and right of way, as well as the economic impacts to surrounding businesses. DOTs also recognize that they are unable to maintain the state of good repair on many assets, and failure to do so adequately creates significant safety, mobility, and maintenance risks. DOTs need to understand how best to deal with these challenges to reduce burdens on deteriorating asset conditions (e.g., bridges, pavements, electrical, environmental) while maintaining safety and mobility.

In the past, design and operational criteria were developed in a manner that could be argued by some as "overdesign." This type of design occurred as a means to increase safety for the vehicle and traveler because few systems existed within vehicle fleet to account for driver errors, risky behavior, and human factors.

Since vehicles are increasingly being designed and operated to account for these factors, how we plan for, develop, and operate facilities also will need to change. With this in mind, preparing for a new design framework is critical and needs consideration. The new design framework will allow for targeting resources to those infrastructure aspects that are least impacted by the connected, autonomous, and automated driving systems. In this sense, practical design and operations should incorporate how future changes will benefit safety performance and should consider necessary design criteria modifications to maximize the potential benefits of this technology.

It is important to consider these vehicle fleet changes that can be used to prioritize investment decisions in the future. This research will evaluate potential vehicle system modifications and potential focus areas in design and operational criteria.

The objective of this research is to review and document existing and anticipated future changes to the vehicle fleet. With this information, develop an outline of how these changes will likely affect safety performance over time and what potential changes to design and operational criteria could be developed to maximize the potential benefits. The research will then be used to develop a framework and strategic approach for the safety profession

to consider in developing and implementing new design criteria and operational approaches that consider these technological advances.

Potential tasks:

- Evaluate existing literature on connected, autonomous, and automated vehicles to determine the particular crash types and contributing factors that will most likely be impacted by this new technology.
- Evaluate current highway design, traffic control, and operational criteria most often associated with the crash type and contributing factors identified in the literature review to determine potential design and operational focus areas.
- Develop a list of priority areas to be addressed that would provide the maximum benefits to transportation agencies.
- Develop methods to assess the risks and opportunities to changes in design criteria
- Develop a framework and strategic plan to incorporate vehicle fleet changes into modification of design and operational criteria including:
  - Planning activities necessary to implement the change;
  - Methods and manuals that would need to be modified to enable the change;
  - Potential timing of the fleet, design and operational changes; and
  - An outline of risk and opportunities related to the changes.

The AASHTO Standing Committee on Highway Traffic Safety (Committee on Safety) rated this its top research problem statement out of four being submitted for consideration. This research will support the SCOHTS Strategic Plan goals related to strategic highway safety planning to help reach a goal of zero traffic fatalities and to promote and support data-driven safety performance analysis and planning.

**Project 17-92**
***Developing Safety Performance Functions for Rural Two-Lane Highways that Incorporate Speed Measures***

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| Research Field: | Traffic |
| Source: | AASHTO Standing Committee on Highway Traffic Safety, Washington |
| Allocation: | $500,000 |
| NCHRP Staff: | Edward T. Harrigan |

The Highway Safety Manual (HSM) currently provides Safety Performance Functions (SPFs) for several roadway types and intersection types that highway agencies can calibrate to local conditions for use in predicting expected safety outcomes for given roadway designs and safety features. These SPFs, and others developed in-house by highway agencies, are a function of AADT, since the number of vehicles on a facility is directly related to the likelihood of crashes. However, speed is also an important predictor of roadway safety. The severity of the crash is particularly sensitive to vehicle speeds since the crash energy increases by the square of the vehicle velocity. Speed also may have an impact on the probability of crash occurrence, although this is less well-understood. Despite the importance of speed on safety, speed measures are generally not included in most SPFs.

Highway agencies have little guidance for understanding the impact of speed policies on safety outcomes. The measures used to assess safety in most crash data are usually determined subjectively after the crash and do not provide clear information about the safety effects of vehicle operating speeds for a road section or other location type by time, weather, etc. Rural two-lane roads are a priority for understanding the speed-safety relationship because more than half of all fatal crashes occur on rural roads. Nearly 40 percent of those are deemed to be speeding-related (i.e., racing, exceeding speed limits, or too fast for conditions). It is not well-understood which speed measures (such as average speed, $85^{th}$ percentile speed, speed variance, speed limit violation rate, etc.) are the best predictors of crash likelihood and severity.

The objectives of this research are to identify the most relevant speed measures for predicting safety and evaluate the potential of including speed measures in SPFs for rural two-lane facilities. The research products will help to improve the performance and accuracy of the HSM predictive methods and help agencies in deciding about appropriate speed limits.

Accomplishment of these objectives shall require the following tasks, at a minimum: (1) conduct a literature review of the existing studies on the estimated impact of various speed measures on crash likelihood and severity, such as average or $85^{th}$ percentile, speed variance, speed compliance and other identified measures, reporting the estimates, sample sizes, and the speed measures being evaluated; (2) conduct a survey of practice of highway agencies to determine what speed data they collect or have available, available roadway inventory data, and other potential data type and identify how state agencies consider the impact of speed on safety when setting speed limits and choosing safety treatments; (3) identify sources of data, data types and roadway segments for inclusion in the study, potentially including those where agencies have changed the speed limit or have observed a change in operating speed (if a before-after analysis approach is being considered); (4)

prepare a detailed work plan for the development of an SPF or SPFs for rural two-lane roads that incorporates one or more speed measures; (5) submit an interim report documenting the literature review, the survey of practice, potential data sources, and proposed work plan and meet with NCHRP within 1 month to obtain approval to execute the plan; (6) execute the work plan developed approved by NCHRP; (7) develop SPFs for rural two-lane facilities that incorporate a speed measure; (8) evaluate crash modification factors (CMFs) to determine if existing CMFs available for rural two-lane roads should be a function of one or more speed measures and propose new CMFs where appropriate; and (9) submit a final project report that documents the research and provides the speed measures, SPFs, and CMFs that would assist highway agencies in estimating the safety impacts of speed measures and prepare draft text and commentary for inclusion in a future edition of the HSM that incorporates the new SPF(s) and CMF(s).

**Project 17-93**
***Updating Safety Performance Functions for Data-Driven Safety Analysis***

Research Field: Traffic
Source: AASHTO Standing Committee on Highway Traffic Safety
Allocation: $500,000
NCHRP Staff: Camille Crichton-Sumners

Data-driven safety analysis (DDSA) methods, including those presented in the AASHTO Highway Safety Manual (HSM), are becoming increasingly popular due to their ability to reliably and quantitatively assess the safety performance of existing and proposed roadways. Predictive safety analysis methods are implemented using the following types of statistical models:

- Safety performance functions (SPFs), which predict the crash frequency for a given set of geometric and operational conditions. SPFs can be simple (i.e., AADT-only models) for planning purposes or detailed (i.e., many input variables).
- Severity distribution functions (SDFs), which predict the severity distribution of crashes.
- Crash modification factors (CMFs), which predict the effectiveness of safety treatments.

Many SPFs and CMFs used in current tools were developed over the last 30 years as research created content for the HSM. For example, AASHTOWare Safety Analyst SPFs were developed using 1993-2001 data collected from the Highway Safety Information System (HSIS). Over time, the relationships represented by the models change due to improvements in vehicle design, changes in driver behavior, new legislation, and other trends. Millions of dollars have been allocated to research that develops these statistical models, and nearly as much funding is required to update models using current model development practices.

New research is needed to determine how best to regularly update outdated models in the HSM, AASHTOWare Safety Analyst, and Interactive Highway Safety Design Model (IHSDM). There is an urgent need to examine the immense amount of resources needed to continue to develop and maintain the knowledge base to support the implementation of DDSA methods as well as to plan an efficient path forward for the future.

The primary objective of this research is to plan for updates to SPFs, SDFs, and CMFs.

The research team could consider exploring answers to some or all of the following questions, which help to describe the specific research problem:

- What potential efficiencies are available at various steps in the research process to make the development and updating of SPFs, SDFs, and CMFs less resource-intensive, considering the processes for data collection, model development, and implementation?
- How can future safety research balance the demands on resources to immediately fix critically deficient models while waiting until other models are practice-proven before revisiting them in research? Too many revisions to research are costly and could be a detriment to implementation.
- How can we (i.e., the transportation safety community) maintain and update thousands of SPFs and CMFs with limited research funding? Justifying new model development

is fairly straightforward, but it may be harder to justify regular updates in the future if it is not substantially cheaper than developing new models.

- How frequently should models be updated (i.e., how old is outdated)?
- How can we assure the various research products (e.g., spreadsheets, software tools, etc.) are updated in accordance with prediction model updates? What potential funding sources can support these needs for implementation?
- How can we assure future research continues to apply uniform SPF calibration (i.e., all models in the HSM are calibrated to California for consistent application without state-specific calibration) for new models prior to inclusion in the HSM? Is it possible to avoid this step in the future, for example by using consistent data sources?
- What new methods could make the process of developing and updating of SPFs, SDFs, CMFs, and other tools more sustainable?
- Is it reasonable to sacrifice some of the accuracy and comprehensiveness of models for efficiency and sustainability, understanding there are (and will be) resource limitations?
- Can we plan for more efficient databases, systems, or procedures that could develop, calibrate, and update SPFs automatically and comprehensively?
- Is there a need to move toward fewer models in the HSM for simplicity and sustainability, rather than producing more and more finite models?
- What framework presents the most resource-efficient, implementation-focused path forward in safety performance research?
- Should we consider a more stringent filter on the research transferred to recommended practice? In other words, which methods, tools, and models do we recommend for practice (e.g., include in the HSM) versus those otherwise available in literature (e.g., journals).
- Is there a need to prioritize research that first focuses on how to facilitate the implementation of existing DDSA methods, rather than developing new methods?
- What critical gaps and limitations remain in existing methods and models?

Furthermore, it is suggested that this effort be coordinated with NCHRP Project 17-73 and other major safety performance research projects, as applicable.

Many states have requested that the HSM and related tools undergo an update to use newer data and this research supports those requests. However, the cost to update models is currently nearly the same as developing new models, which makes updating all models in one project infeasible. This research will explore the most efficient and sustainable methods for updating existing HSM models now and in the future, all while continuing to expand the knowledge base with new research.

According to recent survey of all 50 states, Puerto Rico (PR), U.S. Virgin Islands, and FHWA Federal Lands Highway Division (FLHD) for FHWA's Every Day Counts innovation implementation initiative, 49 of 50 states plus PR and FLHD plan to deploy DDSA methods on one or more projects. Of those, 38 have already incorporated or aspire to incorporate DDSA into their policies and procedures.

Many resources present the benefits of using predictive safety analysis methods based on advanced statistics. However, the relative effectiveness of basic and advanced methods is unclear when the advanced methods and tools use data far more outdated than basic analytical tools. It is unknown how much potential safety benefit is being lost as a result of

(1) out-of-date safety performance functions being used to identify, plan, and design projects, and (2) inefficient procedures to develop and update DDSA methods and models. This proposed research will plan for more efficient use of research resources, ultimately facilitating the implementation of research and expanding the tools available to agencies.

**Project 17-94**
***Tactile Walking Surface Indicators to Aid Wayfinding for Visually Impaired Travelers in Multimodal Travel***

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| Research Field: | Traffic |
| Source: | AASHTO Committee on Traffic Engineering |
| Allocation: | $384,000 (co-funded by TCRP Project B-46 for a total budget of $600,000) |
| NCHRP Staff: | Stephan A. Parker |

Many countries make extensive use of tactile walking surface indicators (TWSIs), and may require them according to adopted standards, to aid wayfinding for travelers who are visually impaired, including those who are blind or who have low vision. TWSIs are typically comprised of attention fields (truncated domes—referred to in the United States as detectable warning surfaces [DWS]), and guiding patterns comprised of raised parallel bars. The truncated domes and guiding pattern are combined to define paths of travel in pedestrian areas, including public rights-of-way and multimodal transportation facilities.

While there has been little interest from travelers with visual impairments in the United States in having continuous tactile paths of travel, as is commonly found in developed areas in Asia, there is increasing recognition in the United States that tactile guiding patterns may be an effective solution to wayfinding problems for visually impaired travelers where there are insufficient cues in the built environment to enable effective wayfinding. Examples are rail and transit stations and hubs, intermodal terminals, plazas, irregular and confusing intersections such as roundabouts and channelized turn lanes, alternative intersections, shared streets, and parallel pedestrian/cycle paths at the same level.

Consistency in cues for wayfinding is extremely important to travelers who are visually impaired in order for them to understand the message of such cues and because they are unable to use many other cues available to travelers with unimpaired vision. TWSIs, including both attention patterns (DWS) and guidance patterns (raised bars) are loosely standardized on the basis of then existing research and practice in ISO 23599:2012, "Assistive products for blind and vision-impaired persons: Tactile walking surface indicators." The only systematic use of TWSIs in the United States is DWS, which are required at transit platform edges and curb ramps, and other locations where there is no distinction in level between pedestrian and vehicular ways. Standards ensuring consistency for the surface texture and some consistency in the installation of DWS in the US are contained in 2006 Standards for Transportation Facilities and the 2010 Americans with Disabilities Act Standards. Similar consistency is needed in the surface textures and installation of guiding patterns.

A number of U.S. jurisdictions and transit authorities have begun to explore or to install guiding patterns, in association with DWS or truncated domes, where it has been determined that there are insufficient cues for wayfinding. These include Caltrans, Los Angeles METRO, BART, New York DOT, DC DOT, Seattle, Minneapolis, Cambridge, MA, Vancouver, BC, and Alexandria, VA. While most of these installations are raised bar surfaces, there is great variation in the installation and materials, including the width and height (detectability) of the guiding pattern and where it is located.

The development of guidance on TWSIs installation practices is directly related to the committee's goal to balance safety and mobility needs for all users efficiently, equitably, and in a context sensitive matter.

The objective of this project is to produce guidance for transportation planners and engineers, based on research, for consistency in the design and installation of TWSIs in multimodal transportation in the United States. There will be two products: (1) a heavily illustrated guidebook: Tactile Walking Surface Indicators to Aid Wayfinding for Visually Impaired Travelers in Multimodal Travel, and (2) a final report including a review of U.S. and international research and practice, as well as the methods and results of human factors research conducted under this project.

Jurisdictions and passenger transport agencies are independently installing a variety of TWSIs intended to improve wayfinding for travelers who are visually impaired. Participants in workshops conducted under TOPR No. 6501-16080 found that some of the surfaces used at shared streets and shared pedestrian/cycle paths are not detectable or, as installed, provide poor cues for wayfinding. Research-based guidelines for TWSIs in the United States are urgently needed, lest differences in TWSI surface geometries and installations proliferate, thereby rendering them unreliable guides for travelers who are visually impaired.

Guidelines resulting from this research could be used by rail and transit agencies, and possibly the basis for an APTA recommended practice document related to both accessibility and mobility management by encouraging the most effective and cost-effective use of existing and emerging wayfinding resources to provide customized service to senior or disabled users of fixed-route transit services. The Federal Highway Administration, in TOPR 6501-16080, identified research needs in line with what is proposed in this research. National Association of City Transportation Officials (NACTO) is also interested in better guidance regarding the installation of guidance surfaces. The U.S. Access Board identified issues related to shared streets and shared use paths and separation of pedestrians and bicyclists in their preamble, and questions in the preamble, in the Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (proposed PROWAG), published in 2013. Proposed PROWAG has not been finalized at this time and it’s possible that recommendations from this research could be incorporated.

The proposed research is focused on determining optimal technical specifications for and installation of TWSIs in multimodal environments. All tasks should be coordinated with ongoing related research. The following major tasks are envisioned:

- Comprehensive review of TWSI research, standards, and current practice in the United States and internationally.
- Conduct human factors testing to determine the detectability and discriminability of novel surfaces for special purposes, such as to indicate intersections and changes in the direction of travel indicated by guidance surfaces, to indicate the limit of the conflict-free zone for pedestrians at shared streets, and to aid pedestrians who are visually impaired when walking on shared use paths or parallel pedestrian/cycle paths at the same level.
- Conduct human factors field tests of TWSIs with demonstrated detectability and discriminability, to validate their usefulness in ecologically valid wayfinding tasks, and to refine guidance for installation and maintenance in environments including:

    - Rail and transit stations and hubs, intermodal terminals, including approaches to the facilities, concourses, mezzanines, and boarding platforms;
    - Shared streets;
    - Plazas;
    - Parallel pedestrian/cycle paths at the same level;
    - Crossings that are hard to locate using non-visual cues, such as at mid-block crossings, roundabouts, channelized turn lanes and large-radius corners; and
    - Cold/adverse weather climates, such as snow and ice.
- Conduct focus groups participants at each field test site to refine the recommendations for selecting and presenting wayfinding information in similar sites
- Analyze results of human factors testing and focus groups
- Prepare final report and guidebook

**Project 18-19**
***Rating Concrete Permeability Based on Resistivity Measurements***

Research Field: Materials and Construction
Source: AASHTO Highway Subcommittee on Materials
Allocation: $600,000
NCHRP Staff: Amir N. Hanna

The AASHTO T 277/ASTM C 1202, Electrical Indication of Concrete Ability to Resist Chloride Ion Penetration, has been widely accepted for assessing durability of concrete. The test provides an indication of the concrete's ability to resist chloride ion penetration but it has many shortcomings: it is slow and time consuming, destructive, prone to errors caused by sample heating, and fails to adequately capture features associated with supplementary cementitious materials (SCMs). Electrical resistivity measurements (AASHTO T 358, Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration) have the potential of providing performance-based evaluation of concrete although they may not always yield accurate results. However, the data obtained from these measurements do not relate to concrete water permeability. It is suggested that a formation factor that incorporates the ratio of the resistivity ($\rho$) of the bulk concrete to the resistivity ($\rho_o$) of the pore solution or other approaches can be used to provide a better assessment of transport properties. There is need to evaluate the feasibility of using this or other approaches as a tool for rating concrete permeability based on resistivity measurements.

The objective of this research is to develop recommendations for rating concrete water permeability based on electrical resistivity measurements. Accomplishment of the project objective will require at least the following tasks:

Phase I: (1) Review literature, ongoing research findings, and current practices relevant to the characterization and measurement of concrete water permeability and its relationship to electrical resistivity. This information may be assembled from published and unpublished reports, contacts with academia, transportation agencies, industry organization, and other sources. (2) Identify and evaluate concrete mixture and test parameters that influence concrete water permeability (e.g., aggregate sources, including lightweight aggregates, cementitious materials, water to cementitious materials ratios, age of concrete, and curing regimen) and the methods currently used in the United States and other countries for measuring concrete water permeability and relating it to resistivity measurements. Discuss the merits and deficiencies of these methods, and recommend potential methods for use in laboratory evaluations, for further evaluation in Phase II. (3) Develop a research plan for an experimental investigation, to be executed in Phase II, for (a) developing and demonstrating test methods for measuring water permeability, (b) evaluating the effects of a range of the concrete mixture parameters (aggregate source, combinations of portland cement and different supplementary cementitious materials, water/cementitious materials ratios, age of concrete, etc.) identified in Task 2 on concrete water permeability and consider the range of $CaO/(Al_2O_3+SiO_2)$ ratios obtained for mixtures made with 100% portland cement to those made with commonly used SCM types and proportions, and (c) relating concrete water permeability to electrical resistivity measurements. (4) Prepare an interim report that documents the research performed in Tasks 1 through 3. Following review of the interim

report by the NCHRP, the research team will be required to make a presentation to the project panel. Work on Phase II of the project will not begin until the interim report is approved and the Phase II work plan is authorized by the NCHRP.

Phase II: (5) Execute the plan approved in Task 4. Based on the results of this work recommend (a) a test method for measuring concrete water permeability, and (b) a means for rating concrete as very low, low, moderate, and high permeability based on resistivity values. If a protocol for the recommended test method is not currently available, it should be developed and presented in AASHTO format. The recommendations for rating concrete permeability based on resistivity measurements shall be prepared in the form of a recommended practice in AASHTO format. (6) Prepare a draft final deliverable that documents the entire research effort, and submit for NCHRP review. The test protocol and recommended practice shall be prepared as stand-alone documents appropriate for incorporation into the AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing.

**Project 19-16**
***Managing the Effects of Uncertain Federal Funding***

Research Field: Administration
Source: AASHTO Committee on Funding and Finance, South Dakota
Allocation: $400,000
NCHRP Staff: Dianne S. Schwager

Uncertain federal funding adversely affects performance management, asset management, statewide and metropolitan Transportation Improvement Plans, and other planning efforts required by federal laws and rules. All of these management approaches rely on the fundamental assumption that funding is predictable during the planning analysis period. Transportation agencies are compelled to invest in increasingly costly and sophisticated management systems, but their effectiveness is ultimately limited by funding uncertainty. When funding levels are predictable, these systems can accurately forecast future asset conditions, set realistic performance targets, and devise optimal long-term capital investment plans, but uncertain federal funding undermines their effectiveness and their ability to support critical management decisions.

As the need for federal funding has increased in recent years, so has its uncertainty. Federal rescissions, obligation limits less than apportionments, and funding extensions instead of long-term appropriations bills combine to cause these effects. Federal Highway Trust Fund outlays exceeding revenue is an underlying contributor.

Some transportation agencies attempt to mitigate the effects of federal funding uncertainty by adopting conservative investment strategies, which can slow program and project delivery, leading to declining pavement and bridge conditions, reduced operational efficiency, and worsening transportation service. Many agencies are forced to adopt short-term planning horizons, while others have attempted to use probabilistic methods to incorporate uncertainty into their financial analyses. Some agencies have successfully increased the non-federal proportion of transportation funding by increasing state revenues or bonding, but all state transportation agencies remain heavily dependent on federal funding.

Agencies could benefit from understanding how federal transportation funding uncertainty affects their planning and investment processes and long-term economic growth and how their colleagues are managing this increasingly common issue to improve their analysis and decision-making.

The objectives of this research are to, at a minimum, address (1) the recent history of federal transportation funding uncertainty; (2) the nature and severity of impacts of federal funding uncertainty on the performance of state and local transportation agencies, the validity of the public involvement process, the resulting condition of assets and services, and effects on long-term economic growth; (3) the nature and effectiveness of approaches state and local transportation agencies are using to manage or mitigate federal funding uncertainty; and (4) opportunities for further application and development of successful management approaches to address funding uncertainty.

The final deliverables from this research should include (1) an executive presentation summarizing the effects of uncertain funding and successful approaches for transportation officials and policymakers to address uncertain funding; (2) a summary report and presentation that associates readily available information on transportation condition and service

levels to uncertain federal funding; and (3) a holistic discussion illustrating the total impact of uncertain federal funding on critical processes, management systems, system condition, and agency services to appropriate audiences.

Uncertain federal funding has been continuous for decades. A document describing the effects on transportation agencies and successful approaches to address and mitigate the impacts would educate and influence policymakers and administrators regarding the complexity, difficulty, and decreasing value to decision-making under these circumstances. A fundamental understanding of the negative impact of delivering transportation projects and services using a required performance management approach with uncertain federal funding is overdue.

**Project 20-124**
***Deploying Transportation Security Practices in State DOTs***

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| Research Field: | Special Projects |
| Source: | AASHTO Special Committee on Transportation Security and Emergency Management |
| Allocation: | $750,000 |
| NCHRP Staff: | Stephan A. Parker |

In 2012, the AASHTO Special Committee on Transportation Security and Emergency Management (SCOTSEM) adopted *NCHRP Report 525, Vol. 14: Security 101: A Physical Security Primer for Transportation Agencies.* Since the publication of this report, there have been both significant changes and a substantial increase in knowledge about surface transportation security. In response to this changed landscape, NCHRP Project 20-59(51)A "Update of Security 101: A Physical Security Primer for Transportation Agencies" was initiated in September 2015 to update the *NCHRP Report 525, Vol. 14* guidance and resource material. This new edition will include not only the latest state of the practice recommendations on physical security, cybersecurity, and infrastructure protection as defined in the *Security 101* primer, but will also present the transportation security function in the broader contexts of system resilience and sustainability, systems management and operations (broadly defined). The updated *Security 101* primer is scheduled to be published in 2018.

The objective of this research is to develop and implement a comprehensive deployment and change management strategy assisting states that wish to more effectively evaluate and implement the revised security guidelines recommended in the updated *Security 101* primer and related material developed in NCHRP Project 20-59(51)A.

The following draft set of tasks illustrates the scope and scale of the proposed work:

*Task 1.* Meet with the project panel to discuss and finalize the working plan.

*Task 2.* Review the updated *Security 101* primer, the 20-59(51)A Implementation Plan, and the technical implementation memorandum.

*Task 3.* Review the current physical and cybersecurity practices of transportation agencies in meeting their responsibilities and assess the gaps existing between commonly deployed practice and the recommendations contained in the revised *Security 101* guidelines.

*Task 4.* Develop a security guidelines deployment strategy and a revised work plan for Phase II. Based on the material contained in the updated *Security 101* primer, the project's Implementation Plan and the Technical Implementation Memorandum, develop security implementation, workforce development and change management plans incorporating both didactic and experiential tools, techniques and workplace learning approaches. The plan should include recommendations of appropriate learning and change management techniques spanning a 12-month deployment schedule.

*Task 5.* Develop training and educational courses and supplementary materials. Based on the strategy, techniques, and approaches selected in Task 1, develop and test the lesson plans, training courses and other materials for use in the deployment strategy.

*Task 6.* Coordinate stakeholder outreach and engagement; implement the deployment strategy. Based on the strategy approved by the NCHRP Panel, conduct, at a minimum, the following events:

- At least one national workshop/training class of at least six hours.
- At least four regional events—one per AASHTO/SCOTSEM Region of at least two hours.
- At least two events to be held at an individual DOT.
- At least one nationally publicized webinar.
- At least two conference presentations, one at the TRB Annual Meeting and one at the TSSR Annual Meeting.

Contractors are encouraged to be creative in the selection of their proposed venues and events, identifying a diverse audience from field personnel to CEOs. Co-locating and joint scheduling with existing meetings, conferences, and other training events is encouraged.

*Task 7.* Final deliverables should include the following: (1) the updated *Security 101* implementation and change management strategy and all supporting lesson plans, scripts, training exercises, and all other didactic and experiential material developed in support of the strategy; (2) a final report summarizing the background research; (3) an updated interim meeting PowerPoint presentation suitable, upon revision, for posting on the project website; and (4) a stand-alone 1-page executive summary in a suitable format of text and graphics aimed at senior decision makers.

**Project 20-125**
***Strategies for Incorporating Resilience into Transportation Networks***

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| Research Field: | Special Projects |
| Source: | AASHTO Special Committee on Transportation Security and Emergency Management |
| Allocation: | $600,000 |
| NCHRP Staff: | Lawrence D. Goldstein |

Over the past 25 years, the global goods movement system has suffered from many large-scale disruptions such as the 2011 Japanese tsunami that crippled worldwide auto manufacturing or the 2010 Iceland volcanic eruptions that affected millions of travelers and thousands of time-sensitive shipments. Unfortunately, these incidents appear to be increasing in both severity and frequency, as illustrated by the 2017 hurricane season. Over this same period, longer and more complex supply chain management techniques such as just-in-time/just enough production, inventory, and distribution systems have created demands for more reliable and resilient delivery systems that, in turn, depend on a reliable and resilient multi-modal freight transportation infrastructure. Disruptions to this system, especially to critical components, can cause significant economic damage to companies, local communities, and increasingly to national and global interests. Moreover, increased interconnectedness and interdependencies between companies have introduced new risks and result in greater economic damages. For example, a recent Accenture study estimated that significant supply chain disruptions reduced the share price of affected companies by as much as seven percent. Not surprisingly, companies worldwide see better protection, reliability, and resilience of their supply chains as a major priority.

*NCHRP Report 732: Methodologies to Estimate the Economic Impacts of Disruptions to the Goods Movement System* described the impacts of bottlenecks and interruptions to the flow of goods through the nation's freight system, the dynamics of that flow in response to disruptions, and the full economic impact on public and private freight interests. Although the project explored the feasibility of developing a high-level and more detailed level methodology for assessing the economic impacts of disruptions to freight networks, the researchers indicated that it would be very useful to further develop their approach by including the economic impacts due to varying degrees of resiliency (i.e., the amount of time and effort necessary to recover or restore supply chains from a significant disruption), particularly of the publicly funded transportation infrastructure.

Transportation network resiliency is one of the most important aspects of determining the ultimate economic impact of a disruption. The degree to which a network (i.e., infrastructure) can bounce back from a significant disruption (generally defined as >96 hours) is directly related to the level of economic impact. If a rail line that is disrupted can be restored or traffic diverted in a short period of time, the economic impact is likely to be not as great as a disrupted line that causes weeks of delay. The concept of resiliency, and how it relates to economic impact and the strategies for incorporating resiliency in networks, is an important topic in the broader investigation of economic impacts of network disruptions.

The fundamental problem is this: public sector infrastructure managers are often unaware of the supply chain requirements of their users and the impact their resilient-related

decisions have on multiple supply chains while supply chain managers have little opportunity to influence public infrastructure reliability and resilience investment decisions. The economic implications of this disconnect are profound. Transport services are protected, restored, or enhanced using “worst first” approaches, often without regard for supply chain impacts.

Related to the previous issue, research would be useful in identifying the costs and benefits of different investment strategies to enhance the reliability, resiliency and cost efficiency of multi-modal freight networks. What strategies make the most sense given the different magnitudes of economic costs to likely disruptions? What are the benefits of implementing such strategies? What are the costs associated with this implementation?

The objective of this project is to develop and apply a conceptual model and guidelines for linking supply chain economic (i.e., cost efficiency) impacts (i.e., risk, benefit) with transportation infrastructure investment decisions affecting network resilience. This unified resilience model should encompass port, project, corridor, regional and statewide scales.

**Project 22-37**
***Development of a Barrier Design to Accommodate Vehicles, Pedestrians, and Cyclists***

Research Field: Design
Source: AASHTO Technical Committee on Roadside Safety
Allocation: $500,000
NCHRP Staff: Ann M. Hartell

There is an urgent need to foster the development, operation, and maintenance of an integrated national transportation system that gives consideration to the presence and safety of non-motorized users. As the number of non-motorized users continues to grow within the United States, crashes between motorists and non-motorized users continue to grow as well. Based on National Highway Traffic Safety Administration (NHTSA) data from 2015, 5,376 pedestrians and 818 bicyclists were killed in crashes with motor vehicles. These two modes accounted for 17.7 percent of the nation's 35,092 total fatalities in 2015. Unfortunately, a large percentage of our nation's roadways are not designed to safely accommodate non-motorized users. Thus, non-motorized users such as pedestrians and bicyclists are expected to jointly use facilities that have inadequate lateral offsets between the travel lanes and the non-motorized transportation facilities such as sidewalks and multi-use paths. On many of these facilities, right-of-way, fiscal, and/or geographical constraints prohibit transportation agencies from increasing this offset distance, which leaves agencies with the option of doing nothing or trying to fit some type of positive protection device in between the travel lanes and the non-motorized transportation facility. Currently, no positive barrier systems have been designed specifically for the purpose of providing positive protection between non-motorized transportation facilities and motorized facilities.

There is a critical need to develop a new multi-functional barrier system complying with the specific requirements needed for the accommodation of vehicles, pedestrians, and cyclists: affordable from a constructability and installation standpoint; appealing from an aesthetic perspective; takes into consideration adequate and proper sight distance; and designed to safely contain and redirect direct hits away from non-motorized users. The ultimate objective of this proposed research is to develop a barrier system that considers the safety of motorists, pedestrians, and bicycles while satisfying the Proposed Right-of-Way Accessibility Guidelines (PROWAG) and the American Association of State Highway Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) Test Level 3 requirements.

This project would seek to investigate the geometric and design requirements needed to develop and appropriately evaluate a multi-functional barrier system that safely accommodates motorists, pedestrians, and cyclists on roadways that serve multiple modes of transportation. The following tasks are anticipated: (1) literature review of documented national and international research regarding the investigation and adoption of bicycle and pedestrian rail heights; (2) survey of state DOT personnel and international transportation agencies to determine current practices, as well as related needs and concerns regarding combination railing systems; (3) determine available relevant crash data sources to complement needed information; (4) develop a guardrail system design to accommodate motorists, pedestrians, and cyclists; (5) construct full-scale crash test, and evaluate the proposed system to MASH Test Level 3 requirements; (6) develop criteria for placement and

use of an appropriate combination traffic-pedestrian-bicycle railing height; and (7) identify appropriate system terminal option(s) for design and evaluation in a future study.

Note: The AASHTO Special Committee on Research and Innovation directed that the project should analyze tradeoffs in safety between different modes.

**Project 22-38**
***Development of MASH TL-3 Deflection Reduction Guidance for 31-inch Guardrail***

Research Field: Design
Source: AASHTO Technical Committee for Roadside Safety
Allocation: $500,000
NCHRP Staff: Mark S. Bush

With the design and installation of guardrail systems, there routinely exist needs to provide a stiffening mechanism to reduce the lateral deflection distance behind these systems, for example when concrete bridge piers are located near roadway shoulders. Various means of providing reduced deflections have been made with past systems that have included nesting of guardrail and the reduction of guardrail post spacing. With the recent adoption of the American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH), there is currently little to no guidance on the use of MASH compliant guardrail installations that reduce these types of deflections within Midwest Guardrail Systems (MGS) and their necessary transitions. Thus, a need exists to provide guidance for the use of MASH compliant guardrail installations that provide a safe transition to a stiffening mechanism which will reduce the deflection distances behind guardrail while maintaining the integrity and safety performance of the MGS. This research will continue the development of guidance for the design and installation of reduced deflection guardrail systems that are MASH compliant.

The objective of this research is to develop guidance for the use of MASH TL-3 compliant guardrail installations that provide a safe transition to a stiffening mechanism that will reduce the deflection distances behind guardrail while maintaining the integrity and safety performance of the MGS.

The proposed scope of project are to: (1) determine potential stiffening mechanisms to reduce barrier deflection to desired levels; (2) perform an analysis of those mechanisms to determine their performance and safety; (3) perform full-scale testing of the proposed reduced deflection designs; (4) determine the need for providing a transition to the mechanism within the guardrail system; (5) provide a design of the transition; and (6) evaluate the transition through MASH TL-3 full-scale crash testing.

**Project 22-39**
***Guardrail Performance at Various Offsets from Curb for MASH TL-3 Applications***

Research Field: Design
Source: AASHTO Technical Committee on Roadside Safety
Allocation: $600,000
NCHRP Staff: Mark S. Bush

Curbs are used to control drainage, separate pedestrian facilities, limit right-of-way, provide access control, and limit erosion. However, the need for curbs often competes with guardrail installation. For example, a steep slope needs curb to control drainage and erosion, and this steep slope also may need shielding. If a pedestrian facility is near curb, the guardrail will have to be further offset from the face of curb. Typical solutions for curb placed near a guardrail, such as using a sloped curb or reducing curb height, can be difficult to use. Dropping the curb height or sloping a curb may cause ADA problems (sight impaired pedestrian may unexpectedly enter a roadway). Shorter curbs may not have the hydraulic capacity needed. There has been some crash tests with a curb placed near guardrail. Many of these tests have failed due to guardrail rupture, barrier override, or vehicle instability. Traditionally crash testing has focused on the performance of pickup trucks striking guardrail with a nearby curb. Some recent crash testing has indicated that more research is needed on small vehicles hitting a guardrail near a curb. Crash testing guardrail installed near a curb with pickup trucks has shown the difficulties in using just computer modeling to set beam guard placement recommendations.

The objective of this research will be to develop guidelines for the use of the 31-in. MGS adjacent to curbs under MASH TL-3 impact conditions. The research will consider the effect of curb geometry, barrier offset from the curb, and barrier height relative to the roadway on the performance of the guardrail. Guidance will be developed for placement of 31-in. guardrail adjacent to curbs based on these parameters. It is anticipated that a combination of previous research, computer simulation modeling, and full-scale crash testing will be required to develop and verify the guidance.

**Project 22-40**
***Update to AASHTO M180 and Associated Material Specifications***

Research Field: Design
Source: Wisconsin
Allocation: $300,000
NCHRP Staff: Edward T. Harrigan

Many states use AASHTO and ASTM specifications for their guardrail components. A number of changes to the state of practice and material standards have generated a need to update AASHTO M180 as well as some associated materials specifications.

A lack of a consistent standard can increase fabrication costs for hardware suppliers and ultimately transportation agencies. A manufacturer can spend a significant amount of resources matching one state's standards only to start completely over to match another state's standards. Consistency will also help to increase competition, allowing for the possibility for lower hardware costs for transportation agencies.

In recent years, there has been an increased focus on roadside hardware. Making sure that transportation agencies are using the correct materials in a barrier system has become more important.

The objective of this research is to review existing material requirements for guardrail. Accomplishment of this objective shall require the following tasks, at a minimum: (1) review existing state specifications, standard drawings, crash test reports, and material standards (e.g. AASHTO, ASTM, etc.) and (2) identify gaps in material standards, inconsistencies in material standards, and updates to material standards.

**Project 25-57**
***Innovative Mitigation Strategies for Highway Noise***

Research Field: Transportation Planning
Source: AASHTO Noise Work Group
Allocation: $250,000
NCHRP Staff: Ann M. Hartell

The objective of this project is to identify innovative methods to avoid transportation noise impacts or to reduce impacts where traditional noise mitigation methods are not feasible and reasonable. These methods could help reduce the overall cost of a project, when compared to what it would cost if traditional noise mitigation was used, and provide relief to communities where traditional methods are not applied. In addition, these methods may increase the effectiveness of traditional mitigation methodologies when used in conjunction.

Highway noise impacts require agencies to implement expensive noise abatement measures when feasible and reasonable to protect nearby communities. Highway noise mitigation typically uses noise barriers as the most common abatement measure. Due to the high cost of noise walls (an average of $2 million a mile for a single direction) and acoustic feasibility or constructability issues, barriers may not be built, leaving portions of communities unmitigated.

This project will identify nontraditional methods to reduce highway noise. There are methods currently being applied, as well as promising theoretical methods, focused on changing project design aspects or determining better material selection to reduce highway noise. In some cases, these methods would result in avoiding noise impacts and eliminating the need to build noise walls. In other cases, these methods would help to reduce noise levels where traditional methods are not feasible or reasonable or desired by adjacent residents.

The objective of this research is to gather information on the use of methods including, but not be limited to: (1) solid safety barriers in place of guard rails; (2) sound-absorbing ground surface adjacent to the highway; (3) vegetated swales/retention basins; (4) quieter pavements for highways and highway shoulders; (5) quieter bridge decks and joints; (6) quieter rumble strips; (7) retrofitted absorptive or vegetative sound wall treatments; (8) retrofitted lightweight noise wall overhangs; (9) bike path and bike path separation zones; (10) on-board sound intensity measurements to identify loud sections for targeted rehabilitation for highways; and (11) small height berms (3’-6’). Also of interest are methods that resulted in worsening noise effects.

**Project 25-58**
***Post-World War II Commercial Properties and Transportation Project Development: Historic Context and National Guidance on Evaluation of National Register of Historic Places Eligibility***

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| Research Field: | Transportation Planning |
| Source: | AASHTO Committee on Environment and Sustainability |
| Allocation: | $300,000 |
| NCHRP Staff: | Ann M. Hartell |

The rapid expansion of commercial development in the United States from the end of World War II through the 1970s created vast numbers of commercial properties along state and federal transportation routes in urban, suburban, and rural areas. An overwhelming number of these properties are already 50 years of age or older, with more reaching that age every year. Thus the rate of exposure of transportation improvements to such properties will continue to rise drastically. This presents an enormous challenge for state DOTs and other agencies to evaluate for National Register of Historic Places (NRHP) eligibility as required by Section 106 of the National Historic Preservation Act which mandates agencies to consider the effects of their projects on historic properties. Section 4(f) requires all possible planning to minimize harm to historic properties. Post-World War II commercial properties, including gas stations, shopping centers, drug stores, office buildings, restaurants and other businesses, that are more than 50 years of age may be considered historic properties if they possess architectural or historic significance and are considered eligible for the NRHP.

This problem statement complements NCHRP Project 08-77, published as *NCHRP Report 723: A Model for Identifying and Evaluating the Historic Significance of Post-World War II Housing*, which successfully addressed the need for a national historic context and National Register eligibility guidelines for post-war houses and residential subdivisions. *NCHRP Report 723* has proven to be extremely beneficial to state DOTs; and is one of the most downloaded reports among the Transportation Research Board's online publications.

Similar to residential construction, post-war commercial properties were closely intertwined with transportation improvements, including the expansion of state highways after World War II and the construction of the Interstate Highway System beginning in 1956. Commercial properties frequently stand in close proximity to highways because they took advantage of undeveloped land close to new interstates and housing developments to attract customers. Like housing, commercial properties were built in staggering numbers after 1945, but very little information exists on how to consistently evaluate the potential significance of these properties.

First, this research is intended to provide to the state DOTs a proper historic context, supplying a better understanding of the historic and architectural significance of the plethora of commercial properties. Second, the research will give guidance on how to evaluate the integrity and NRHP criteria. Third, this research will provide state DOTs, FHWA, State Historic Preservation Officers (SHPOs), and Tribal Historic Preservation Officers (THPOs) guidance on how to avoid disputes that drive up project costs and delay project delivery. Aside from the greatly needed guidance on this property type, this research could form the basis of a regulatory "Program Comment" from the Advisory Council on Historic

Preservation (ACHP) to exempt certain common property types and designs from Section 106 consideration.

The research objective is to develop resources to complement *NCHRP Report 723* on post-World War II housing by providing an historic context that synthesizes national post-World War II commercial sector development, identification of elements, design styles and construction materials and techniques.

**Project 25-59**
***Regional Guidebooks of Current Practices for Roadside Pollinator Conservation and Endangered Species Act Compliance***

Research Field: Transportation Planning
Source: AASHTO Committee on Environment and Sustainability
Allocation: $500,000
NCHRP Staff: William C. Rogers

Pollinating insect populations are declining. As a result, there is increased interest in protecting pollinators along roadways. Several insect pollinators have been petitioned for listing, or listed, under state laws and the federal Endangered Species Act (ESA). Many of the species listed to date have had limited spatial distributions, but species with more widespread ranges are now being considered. State DOTs face uncertainty in practices to best design and maintain roadsides to accomplish the legislative mandate of providing safe transportation while conserving species and, in cases of listed species, complying with state laws and the ESA. This project will compile information on current and previous conservation and compliance strategies and practices across the United States to inform state DOTs as they determine how best to conserve, maintain, and improve roadside pollinator habitat.

Over 30 species of butterflies, skippers, and moths are listed as threatened or endangered, as well as a fly, beetle, three bats and several birds (US Fish and Wildlife Service [USFWS]). While most of these species are listed because they have limited remaining habitat areas, some of that habitat is on roadsides, and state DOTs have already worked out approaches to maintenance and conservation in those areas. The techniques developed and lessons learned by those DOTs can be transferred to other DOTs and local transportation agencies to help as additional pollinating insects may become candidates for listing under the ESA, especially species that were historically more widely distributed. For example, the once widely occurring rusty-patched bumble bee was recently added to the list and the western bumble bee and Monarch butterfly are under consideration for listing, both of which are found across multiple states.

The objective of this project is to build on the existing syntheses of best management practices (BMP) for pollinator habitat in general by adding information on strategies for complying with regulatory requirements for currently listed, and preparing for future possible listing of additional, insect pollinators. The main synthesis of information will focus on best practices shared by transportation agencies, upcoming research, and approaches to conservation of pollinating insects listed under the ESA. This information could be used to contribute to a template Candidate Conservation Agreement with Assurances, for development of BMPs for credits under Section 4 of the USFWS Director's Order 218, "Policy Regarding Voluntary Prelisting Conservation Actions" or for development of a Habitat Conservation Plan for candidate or future-listed pollinators on roadsides. The following tasks are proposed:

*Task 1: Conduct survey and collect information for synthesis.*

- The synthesis would include collecting information from a survey of transportation agencies and non-government organizations (NGOs) involved with Section 7 consul-

tations (gathering Biological Assessments, Biological Opinions, and related maintenance and monitoring plans) and Habitat Conservation Plans for pollinating insects under the ESA as well as information on ongoing research from transportation agencies and NGOs. One aspect of particular interest would be whether implementing pollinator-friendly maintenance strategies has resulted in cost savings.

*Task 2: Regional peer exchanges*

- Hold a peer exchange in each of the four AASHTO regions with DOT maintenance, design, and biology staff to discuss success and the challenges of approaches to pollinator habitat design and maintenance (policy, partnering, design strategy/guidelines, maintenance strategy/guidelines/training, and safety issues). Include USFWS, FHWA and other partners such as the Volpe Center for the purpose of developing a programmatic approach at the peer exchanges.

*Task 3: Synthesize existing information and new information from Tasks 1 and 2*

- Approaches to creating/restoring habitat for listed pollinators – within or outside the right of way (ROW), which parts of ROW, etc.
- Practices, such as changes in mowing schedules or techniques, that allow natural revegetation of pollinator habitat in locations where such habitat can be maintained without compromising transportation asset safety or operational concerns.
- Maintenance practices to avoid in the ROW.
- Communicating such practices to the public and within transportation agencies about mowing and spraying practices, effective signage and fencing.
- Strategies for long-term management of, and habitat conservation within, the ROW.
- Create a rating system for different approaches; rank by effectiveness.
- Create BMP listing and descriptions needed for a programmatic agreement template.
- Write draft and final reports.

*Task 4: Regional Guidebooks and Programmatic Template*

- Develop a regional *Guidebook of Current Practices for Roadside Pollinator Conservation and Endangered Species Act Compliance* with sections targeted for environmental, design, construction, and maintenance staff for each of the four AASHTO regions.
- Include a summary/matrix of regulatory tools DOTs can use to develop and maintain pollinator habitat and be in compliance with the ESA.
- Develop a template *Programmatic Voluntary Prelisting Agreement for Roadside Pollinator Conservation and Endangered Species Act Compliance*

State DOTs are being encouraged by—and proactively partnering with—many stakeholders to create pollinator habitat on their rights of way. This can be a significant change in the way of managing their roadsides for many states and will require new systems for selecting areas for habitat creation, designing and constructing it, planning maintenance and training staff to avoid damage to habitat once it is created—whether by new plantings or changes in vegetation practices that allow vegetation to naturally return to roadsides, as happens when mowing limits, frequencies, or herbicide applications are changed. In the future, as more widely distributed insects are undergoing general population declines and may be considered for listing under the ESA, mistakes in roadside maintenance practices may have a greater potential for violations. As a result, many states are wary of creating or enhancing pollinator habitat without knowing of successful practices for managing it. However, if pollinator habitat continues to be lost and not replaced, the trajectory toward

listing of more pollinators will continue. For this reason, it behooves state DOTs to share knowledge and successful practices learned from situations with already listed species and existing pollinator habitat areas. This project will result in information sharing through both peer exchanges and through the development of a guidebook with different sections aimed at designers, construction personnel, biologists, and maintenance staff to increase the success of creating habitat for pollinators, whether they are listed under the ESA or not.

**Project 25-60**
***Watershed Approach to Mitigating Hydrologic Impacts of Highway Projects***

Research Field: Transportation Planning
Source: AASHTO Committee on Environment and Sustainability
Allocation: $500,000
NCHRP Staff: Ann M. Hartell

Departments of transportation are under pressure to address the adverse impacts of larger stormwater volume discharges from increasing impervious surface area (aka hydromodification). Development and more impervious surfaces in a watershed results in a change to the storm hydrograph, increasing runoff volumes, heightening peak flows, and shortening the duration of the runoff event. This change increases flooding, triggers stream channel change, accelerates stream bank and bed erosion, increases sediment loads and turbidity, harms aquatic habitat, and reduces low flow discharges. While the U.S. Environmental Protection Agency (EPA) has not promulgated federal rules to regulate stormwater volume directly as a pollutant, Endangered Species Act (ESA) compliance conditions, some state-issued NPDES MS4 permits, and some state regulations do have hydromodification requirements. For example, in Washington state projects must reestablish pre-development hydrology, and in Oregon conditions of ESA Biological Opinions for highway projects require maintaining pre-project hydrology for channel forming flows.

The traditional technique for addressing hydrologic impacts of highway projects is to construct detention and retention basins. While the basins are effective at reducing peak flows and flood issues, they are less well suited to maintaining or reestablishing relatively "natural" hydrology for streams, and may in fact lead to local degradation. They also require considerable right-of-way adjacent to highways, add to the maintenance burden, and can become attractive nuisances. Full infiltration of stormwater discharges on-site is frequently not feasible due to physical constraints. Other approaches, such as using compost amended vegetated filter strips for volume reduction, are promising, but still require right-of-way that may not be available.

Various elements of the landscape, primarily wetlands, forests and floodplains, reduce, delay and desynchronize peak flows from precipitation, and are important elements in establishing the natural hydrology of a watershed. While individually these elements have on occasion been used to mitigate for project impacts, there has not been a broader examination of, or methodology for, an integrated approach to mitigating for highway or development impacts on surface water hydrology at the watershed scale.

This project will investigate the capability of landscape modifications elsewhere within a watershed to off-set the hydrologic effects of the increase in impervious surface and changes in drainage associated with highway improvement projects. Examples include floodplain reconnection, use of strategically placed and designed created or restored wetlands, and reforestation. The goal of the research is to identify effective actions, develop techniques for quantifying the benefits of the actions and assessing their ability to compensate for project and system impacts, and develop guidance for evaluating and selecting the appropriate approach for the affected watersheds. It will be useful for project mitigation, advance mitigation and watershed enhancement efforts. This research will be a companion

to *NCHRP Research Report 840: A Watershed Approach to Mitigating Stormwater Impacts*.

The proposed project is intended to identify elements of the landscape in a watershed that can be enhanced or created to offset adverse hydromodification, assess the feasibility and effectiveness of creating or enhancing those elements, and develop a methodology for mitigating highway project and system impacts. The research is anticipated to provide a practical methodology and guidance for: (1) identifying opportunities in a watershed to enhance or create landscape features that moderate runoff or storm flows and can be used to offset hydrologic impacts of highway facilities; (2) designing created or enhanced landscape features for hydromodification mitigation; (3) quantifying hydrologic changes from creating or enhancing landscape features; (4) analyzing the effectiveness of modification of specific landscape features, singly or in concert, to offset highway hydrologic impacts.

Work on the project to include identifying and evaluating hydrologic models and techniques for their suitability for the project's goals. Testing of the methodology can demonstrate the practicality and accuracy of the results. Depending on the approach taken by the researcher, software or a model to support decision making and quantification of the hydrologic impacts of mitigation alternatives may be developed. The final product should be aimed at DOT hydraulic engineers, environmental staff, and planners, but would also be useful for city and counties responsible for watershed improvements.

**Project 08-124**
***Quantifying the Impacts of Corridor Management***

Research Field: Traffic
Source: Virginia
Allocation: $450,000
NCHRP Staff: Lawrence D. Goldstein

The integration of transportation planning and land use is critical to ensuring sustainable corridor functionality and surrounding growth. Corridor management is an important transportation planning activity that integrates transportation and land development and coordinates state DOT and local decision-making. More specifically, corridor management—in its full form—coordinates the planning, design, and operational characteristics of a highway or thoroughfare with the local street network and the layout, access, and interconnectivity of adjacent land development. Corridor management yields results that demonstrate the impact of utilizing a coordinated, comprehensive approach throughout the transportation planning and land development processes. However, it can be difficult to assess and *quantify* the impacts of corridor management in a manner that persuades state and local officials that they should invest time and money into developing corridor management plans and processes in lieu of utilizing their current independent approaches.

Many states have designated corridors of significance, but long-term planning for the management of these corridors is lacking. The absence of such planning might relate to the fact that there are no tools focused on this topic. This research project proposes to fill this critical gap by quantifying the impacts associated with corridor management. This quantification would support improved, proactive planning and altering of inefficient practices.

FHWA's Integrated Corridor Management program is strictly directed toward *operations and performance* on corridors using technology and ITS. This research proposal is focused on corridor management as a proactive transportation/land use *planning* activity.

The objective of this research is to evaluate and, where possible, quantify the impacts of corridor management. As is evident from the literature review, there is often little or no follow up from the step of implementing corridor management to the point of quantifiably measuring the impact that such techniques have on the businesses, travelers, land values, and the long-term sustainability of a corridor. This project will assemble and develop comparative data—both quantitative and qualitative—for corridor management components and attributes such as access density, median usage, signal spacing, crash rates, development connectivity, value of improvements, business stability, land values, and aesthetics. Obtaining these types of data will require data collection specific to selected corridors. Some of the data may already be available or collected by government agencies; other parts of data will require detailed research of historic records and conditions and interviews with local planners and engineers.

**Project 20-44(09)**
***Capturing the Value of NCHRP Research***

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| Research Field: | Special Projects |
| Source: | AASHTO Special Committee on Research and Innovation |
| Allocation: | $1,000,000 |
| NCHRP Staff: | Sid Mohan |

In any given year, NCHRP produces dozens of research products intended to be practice-ready and can be suitably modified and/or implemented within state DOTs. While the research produced by NCHRP has contributed towards transportation practices and policy impacts at local, state, and national levels, the value of those impacts has not been systematically monitored or captured over the years.

Several efforts have been undertaken to capture the use of NCHRP research products and the resultant value they present to their users, particularly through the "Impacts on Practice" and "Paths to Practice" briefs published by NCHRP. These efforts, however, do not follow any formal guidelines to assess the value of the research results. Considerable thinking has also gone into measuring the impacts of transportation practices themselves, usually from the perspective of planning for a project. The resultant efforts provide adequate guidance to transportation professionals and other interested stakeholders to calculate, within a degree of certainty, what the impacts of their transportation project would be. However, such transportation projects are seldom the result of a single piece of research, and previous efforts on calculating impacts do not help in ascertaining how a particular research product (or a set of research products) contributes towards achieving the impacts of the project.

Assessing the value of NCHRP research may not be straightforward. There can be a significant time lag between when the research product is developed, when it is put into practice, and when the impacts of that practice is realized. The nature of the research products are also wide-ranging. Some research products are geared towards improving existing practices, while others are useful for informing policy decisions. There can also be challenges in accurately measuring the impacts themselves, in terms what measures would be most appropriate, relatively easy to collect and monitor, and replicable. Finally, attributing impacts to a research product, when the research product is used as part of a portfolio of other existing products and practices needs to be considered. Assessing the value of NCHRP research therefore requires approaches sensitive to the context of the research and the perspective of the stakeholders trying to understand its benefits.

The objective of the proposed research is to develop guidance that will allow NCHRP to capture the value of its research, both ex-post and ex-ante. The guidance should also help NCHRP to demonstrate the effectiveness of its research products in changing practices and/or standards, in leading to additional research, and in informing policy decisions. The guidance will complement previous NCHRP research on communicating the value of transportation research *(NCHRP Report 610: Communicating the Value of Transportation Research Guidebook*) and on determining performance measures and reporting mechanisms for research programs (*NCHRP Web-Only Document 127: Performance Measurement Tool Box and Reporting System for Research Programs and Projects*).

To meet the objective, potential tasks may include (1) literature review and key informant surveys on existing practices on capturing the value of transportation research; (2) classification of research products produced by NCHRP by subject matter, end-use type, pathways to use etc., and development of measures to assess their respective values; (3) development of measurement protocols and process for the aforementioned measures; (4) piloting measurement protocols and processes for selected research products; and (5) development of final guidance document to capture the value of NCHRP research.

**Project 20-50(22)**
***LTPP Data Analysis: Accounting for Temporal Variations in Pavement Performance Monitoring Measurements***

Research Field: Special Projects
Source: Federal Highway Administration
Allocation: $450,000
NCHRP Staff: Amir N. Hanna

The LTPP Seasonal Monitoring Program (SMP) was based on further discovery of the influence of temporal changes in pavement structural characteristics. The primary measure of change in pavement structural characteristics was deflection data from falling weight deflectometers (FWDs). In an attempt to explain the observed temporal changes in FWD measurements, LTPP SMP sites were instrumented to measure local weather and subsurface moisture and temperature states. To date, the full potential of LTPP FWD and corresponding pavement-state data has not been fully examined. In addition to monthly FWD measurements on LTPP SMP test sections, LTPP collected seasonal data on longitudinal pavement profile on the SMP test section. In July 2013, LTPP implemented a program to measure diurnal changes in longitudinal profile on jointed PCC test sections in response to recommendations from industry. The results of some published and unpublished findings internal to the LTPP program show that on some LTPP jointed portland cement concrete (PCC) test sections, temporal variations for a few hours during a single day can have significant impacts on the International Roughness Index (IRI) computations from longitudinal pavement profile measurements, which can be translated to how highway agencies perform smoothness measurements for construction quality control and determine construction-related pay factors. There is a need to consider time-based pavement performance measurements to refine current standards and guidelines on how to properly account for temporal variations in measured pavement properties.

The objective of this research is to refine current guidelines on FWD and longitudinal profile field measurements to properly account for daily and seasonal variations in pavement condition and response. At a minimum, the guidelines on FWD measurements should consider (1) frost-thaw issues in deep-freeze and multiple freeze-thaw climate zones; (2) frozen, partially frozen, and unfrozen subsurface pavement layers; (3) time and method to measure load transfer efficiency; (4) effects of warping and curling on basin testing of jointed PCC pavements; and (5) the influence of pavement base and sub-base layer types (material and thickness, bonding conditions) and other features (e.g., shoulders and joint types) on the temporal changes of both flexible and rigid pavements.

**Project 20-116**
***Emergency Management in State Transportation Agencies***

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| Research Field: | Special Projects |
| Source: | AASHTO Special Committee on Transportation Security and Emergency Management |
| Allocation: | $750,000 |
| NCHRP Staff: | Stephan A. Parker |

In 2012, the AASHTO Special Committee on Transportation Security and Emergency Management (SCOTSEM) adopted *NCHRP Report 525, Vol. 16: A Guide to Emergency Response Planning at State Transportation Agencies*. The *Guide* reflected accepted practices (circa 2010) in emergency response planning and incorporated advances made over the previous decade in Traffic Incident Management (TIM), Emergency Transportation Operations (ETO), and supporting programs. In the intervening years, the practice of emergency management has continued to mature and in September 2015 a new project—NCHRP 20-59(51)B, "A Guide to Emergency Management at State Transportation Agencies, Second Edition"—was authorized to develop a recommended Second Edition Guide. This update incorporates an all-hazards perspective of the National Incident Management System (NIMS) and includes the latest state of the practice and guidance in emergency management from USDOT, FHWA, AASHTO, FEMA, TSA, DHS, and TRB useful in a state DOT context. The Second Edition is scheduled to be published in 2018.

As a part of NCHRP Project 20-59(51B), the contractor prepared a stand-alone technical memorandum titled "Implementation of Research Findings and Products." The technical memorandum (a) provides recommendations on how to best deploy the updated Emergency Response research findings/products into practice; (b) identifies possible institutions that might take leadership in applying the research findings/products; (c) identifies issues affecting potential implementation of the findings/products and recommend possible actions to address these issues; and (d) recommends methods of identifying and measuring the impacts associated with implementation of the findings/products.

Additionally, the Contractor's Final Report contains an Implementation Plan that describes (a) the "product" expected from the research; (b) the audience or "market" for this product; (c) a realistic assessment of impediments to successful implementation; (d) the institutions and individuals that might take leadership in applying the research product; (e) the activities necessary for successful implementation; and (f) the criteria for evaluating the progress and consequences of implementation.

As noted in the NCHRP Project 20-59(51B) RFP, "Implementation of these recommendations is not part of the [update] research project and, if warranted, details of these actions will be developed and implemented in future efforts." All too often, research products are not fully deployed in state DOTs due, in part, to a lack of tools, training, and tutors. NCHRP Project 20-116 is intended to more effectively bridge the gap between all-hazards Emergency Response research and DOT practice and thereby improve the DOTs's response over a broad continuum of emergencies affecting the nation's travelers, economy, and infrastructure.

NCHRP Project 20-116 supports and aligns with Goal 4 of SCOTSEM's 2014-2018 Strategic Plan, "Advance the state-of-the-practice and awareness of transportation infrastructure protection and emergency management through training, technical assistance, and technology transfer activities."

The Final Report Summary for NCHRP Project 20-59(29) *All-Hazards Security and Emergency Management Implementation Plan*, (November 2010) was used to identify potential deployment strategies and funding estimates.

The objective of NCHRP Project 20-116 is to develop and implement a comprehensive deployment and change management strategy, assisting states that wish to more effectively evaluate and implement the revised Emergency Management guidelines recommended in *A Guide to Emergency Management at State Transportation Agencies, Second Edition* and related material developed in NCHRP Project 20-59(51)B.