National Cooperative Highway Research Program

Fiscal Year 2017 **April 2016**

Announcement of Research Projects

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

Each year, AASHTO refers a research program to the TRB consisting of high-priority problems for which solutions are urgently required by the states. The AASHTO program for FY 2017 is expected to include 16 continuations and 37 new projects.

This announcement contains preliminary descriptions of only those new projects expected to be advertised for competitive proposals. Detailed Project Statements (i.e., Requests for Proposals) for these new projects will be developed beginning in July 2016.

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

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

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IMPORTANT NOTICE

Potential proposers should understand clearly that the research program described herein is tentative. The final program will depend on the level of funding available from the Federal-aid apportionments for FY 2017. Meanwhile, to ensure that research contracts can be executed as soon as possible after the beginning of the fiscal year, the NCHRP is proceeding with the customary sequence of events through the point of agency selection for all projects. The first round of detailed project statements will be available in July and August 2016; proposals will be due in September and October 2016, and agency selections will be made in November and December 2016. This places the risk of incurring proposal costs at the election of the research agencies. Beyond the point of selecting agencies, all activity relative to the FY 2017 program will cease until the funding authorization is known. These circumstances of uncertainty are beyond NCHRP control and are covered here so that potential proposers will be aware of the risk inherent in electing to propose on tentative projects.

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♦ **Project 01-58**

Process for Evaluating the Impacts of Implements of Husbandry on Pavements

Research Field:	Design
Source:	Wisconsin
Allocation:	$400,000
NCHRP Staff:	Amir N. Hanna

The configurations and weights of farm equipment, known as implements of husbandry (IoH), have changed and increased to meet the needs of the agricultural industry. Although this equipment has been designed for use primarily in farm fields, travel from farm to field often occurs on public roadways. Understanding the impact these vehicles have on public roadways is important for state agencies. It is equally, if not more, important for local government agencies since this equipment utilizes local roadways more often and their pavement structures are not typically built to the load-carrying capacity of state highways. Impacts from conventional trucks can be evaluated using ESALs (equivalent single-axle loads). However, the obvious differences between IoH equipment and conventional trucks (i.e., size, weight, configuration, tires) are not accommodated in the ESAL evaluation for pavement impacts. Therefore, there needs to be a method (i.e., calculation, coefficients, or software) by which pavement structure engineers can evaluate these vehicles for their impacts on the life of pavement structures and their service lives.

The objective of this research is to define the key differences between IoH equipment and conventional trucks in order to develop a method for analyzing the impacts of IoH equipment on pavement structures and their service lives. Specifically, the method must be one that is readily relatable to pavement design engineers and utilizes readily available vehicle information. Pavement design engineers are familiar with the concept of ESALs. Development of ESAL factors for implements of husbandry would be very relatable and straightforward. Alternatively, simplified software could be used. Such software would have to produce results based on some basic, readily available inputs such as gross vehicle weight, axle weights and spacings, and tire type and pressure.

♦ **Project 03-126**

Operational Standards for Highway Infrastructure

Research Field:	Traffic
Source:	AASHTO Highway Subcommittee on Transportation Systems Management and Operations
Allocation:	$500,000
NCHRP Staff:	B. Ray Derr

For decades, the AASHTO *Policy on Geometric Design of Highways and Streets* (the Green Book) has been a foundational guidance document for determining the geometric features of our nation's highway system. This guidance is built upon documented research and general assumptions of how geometric elements affect system performance. The Green Book continues to provide the content that is the basis for the design standards that are adopted and deployed nationally as well as at a state and local level and drives a significant portion of highway investments.

As transportation agencies look for ways to maximize the effectiveness of this highway infrastructure, operational strategies are becoming broadly recognized as necessary and cost effective in accomplishing system performance objectives. These strategies often bring with them the ability to affect driver behavior, with direct connection to how drivers react to the conditions they encounter along their route, both in terms of real-time non-recurrent events, as well as static features such geometric elements. These strategies rely upon a different type of infrastructure and provide the ability to influence and, in some cases, redefine traditional geometric elements.

Ultimately to support decision-making processes, various analysis tools and methodologies continue to be developed and refined to better align with the needs and performance expectations of the users of the highway system, as well as to reflect new strategies available to system providers. These include work zone safety and mobility improvements resulting from 2004 FHWA Work Zone Rulemaking and advancements in the *Manual on Uniform Traffic Control Devices* to address the integration of intelligent transportation system and other future technologies. The latest efforts of the second Strategic Highway Research Program (SHRP 2) developed enhanced methodologies to assess safety, capacity, and reliability that lay the groundwork for considering cross-cutting strategies that incorporate both operational and geometric features. These tools are now in early implementation phases across the country.

These three aspects when considered together drive the initiative for a formalized transportation systems management and operations (TSMO) program that goes beyond operating efficiency to providing the best way to develop, manage, and operate transportation networks and infrastructure. In support of this comes the need for a new perspective on how we look at and consider highway infrastructure, and a new way to think about "standards" associated not only with infrastructure, but also with system management capabilities as necessary components to accomplishing performance.

The Strategic Plan of the AASHTO Highway Subcommittee on Transportation Systems Management and Operations (TSMO Subcommittee) includes eight goals, five of which could be supported by the proposed project: (1) encourage adoption of proven TSMO concepts and strategies, (2) support DOTs in implementation of system performance measurement and management to tie in with TSMO, (3) develop and evolve a workforce that is fully capable of accommodating and expanding TSMO through development of needed skill sets and training, (4) continue to make the business case for TSMO, and (5) build upon and expand the use of the capability maturity model to improve agency TSMO capability and expertise. At their June 2015 meeting, the TSMO Subcommittee expressed their overwhelming support for the proposed project and their intent to adopt the resulting product(s) through the AASHTO balloting process.

The objective of this research is to develop the first edition of "Operational Standards for Highway Infrastructure," a proposed AASHTO publication developed under the auspices of the TSMO Subcommittee.

It is expected that the Operational Standards will identify operational strategies and associated elements (e.g., traffic incident management, active traffic management, traffic signal coordination, vehicle-to-infrastructure equipment) that should be considered "standard" features of the highway system. This includes both urban and rural aspects of the highway system taking into account the operational condition of a facility and the system management capabilities necessary to meet designated performance objectives. The Operational Standards should also be useful in innovative design processes (e.g., performance-based practical design, context sensitive solutions) by coupling geometric and operational improvements to most effectively meet the project's purpose and need within a constrained budget.

NCHRP Project 20-07/Task 392, "Transportation System Management and Operations Standards for Highway Infrastructure," was approved at the AASHTO Annual Meeting in September 2015 and will develop the scope for the proposed guide. The objectives of that project are to (1) investigate the focus for, potential use and topics to be included within the context of an "Operational Standards for Highway Infrastructure" document and (2) develop a roadmap for conducting research needed in order to develop such a document. The full scope of work is available on the TRB website.

♦ Project 03-127
Cybersecurity of Traffic Signals and Related ITS Equipment

Research Field:	Traffic
Source:	AASHTO Highway Subcommittee on Traffic Engineering
Allocation:	$500,000
NCHRP Staff:	B. Ray Derr

With over 400,000 traffic signals deployed throughout the United States, traffic signal operations have a profound impact on the safety and efficiency of traffic flow for all road users on the transportation system. Recent threats in cybersecurity have made our industry more aware of potential damage that such threats can cause. Multiple researchers have found that our existing traffic signal systems, if not protected properly, can be easily hacked. For example, sometimes systems are used without any encryption for communication between a central traffic control management system and field traffic signal control units, allowing an attacker to directly change traffic signal indications. Another example involves wireless detectors that could be manipulated to feed traffic control systems with fake data and trigger incorrect options in their operations.

It is still not clear whether these vulnerabilities can create a critical fault in the system operations, or primarily cause an inconvenience that will jam traffic for a few hours. Even such an “inconvenience” will result in increased crash risk for road users as the systems will be performing with non-optimal settings. It is not easy for agencies to detect potentially malicious actions (e.g., fake updating of firmware) and prevent them. Furthermore, this task is complicated by a variety of stakeholders with diverse skill sets and goals, including manufacturers and vendors of system hardware, software and control units; transportation management center staff; traffic engineers; and IT specialists with an increasing variety of specialties (e.g., fiber optics, wireless communications, database experts, software integrators, etc.). Thus, it is necessary to research potential cybersecurity threats on traffic signal systems and related intelligent transportation system (ITS) components, and recommend actions that agencies should follow to protect those systems and properly react in the cases of emergency.

The objective of this research is to document vulnerability of our traffic signal systems and related ITS equipment and document practices to prevent cyber-attacks and remedy their potential consequences. The research should develop a set of recommendations that will be useful to agencies that own, maintain, and operate traffic signal systems. Examples of problems that such recommendations should address include:

- Lack of cybersecurity testing
- Poor or nonexistent security
- Encryption issues
- Lack of computer emergency response teams
- Unknown attack surfaces
- Patch deployment issues
- Insecure legacy systems
- Unknown resiliency of systems
- Potential ransomware threats
- Lack of cyber-attack emergency plans
- Susceptibility to denial of service
- Lack of secure communications channels with technology vendors
- Lack of response plans to address system breaches

Tasks anticipated in this project include the following:

Task 1. Review literature to categorize and describe primary cyber-attack threats and actions that agencies take to prevent such threats and mitigate consequences of potential cyber-attacks.
Task 2. Conduct a “red team” type analysis to conduct real-world penetration tests and determine possible security vulnerabilities.
Task 3. Based on the above tasks, identify a set of strategies to prevent cyber-attacks and mitigate potential problems resulting from such attacks.
Task 4. Develop a tiered set of recommendations for agencies of different sizes and system complexity to make effective use of the strategies developed in the previous step. Examples of such recommendations should include: (a) checklist-type reviews of cybersecurity, (b) proper communication with vendors to acquire all necessary security documentation, (c) procedures to fix security issues as soon as they are discovered, (d) implementation of fail safe and manual overrides on all system services, (e) access restriction for some of the public data, (f) password content and change frequency, and (g) regular penetration tests.

♦ Project 04-40
Reliability-Based Calibration of Geotechnical Resistance Factors for Micropile Design

Research Field:	Materials and Construction
Source:	Florida
Allocation:	$250,000
NCHRP Staff:	Amir N. Hanna

Micropile foundations consist of small-diameter (typically less than 12 inches) drilled and grouted non-displacement, reinforced elements. Since their inclusion as a viable deep foundation alternative in the *AASHTO LRFD Bridge Design Specifications*, they have been used successfully in various transportation projects. The salient advantages of the system are that the elements can be constructed in low-headroom, restricted-access, or vibration-sensitive sites where driven piles or drilled shaft construction could be difficult, if not impossible.

At the core of the load and resistance factor design (LRFD) methodology for bridge foundations is the direct link between the design method, and an acceptable probability of failure. *NCHRP Report 507* included a reliability-based calibration for driven piles as well as drilled shafts, which was performed using a sufficiently large database of load tests. The findings eventually made their way into the AASHTO design code.

The LRFD approach enabled designers to make a paradigm shift in geotechnical design, moving from a global safety factor that unified all uncertainty into a single number, to a more rational approach that identified uncertainty of individual components. It is important to note that such a calibration has not been done for micropiles. As per *AASHTO LRFD Bridge Design Specifications* C10.5.5.2.5, the resistance factors currently implemented in the code were calibrated to previous practice, tempered with engineering judgment (see Table 10.5.5.2.5-1).

In order to perform a reliability based calibration of resistance factors, a sufficiently large database of static load tests is required. As outlined in *AASHTO LRFD Bridge Design Specifications* 10.9.3.5, micropile design shall be verified by load test. The implication of the article is that a large number of data exists that has not been collected and organized yet. The suggested research project would consist of performing that very task, as well as carrying out data analysis and the determination of a deflection-limited capacity (nominal resistance). Once the data is collected and the nominal resistance determined, it would be possible to compute the required statistical parameters necessary for a reliability-based calibration, allowing the system to fall in line with the other deep foundation alternatives that are currently part of the AASHTO design code.

The research effort would consist of the following general tasks: (1) literature review; (2) static load test data collection from all DOTs that have used the system; (3) organization of data (soil type, stress history, installation method, load test method); (4) definition of nominal resistance; (5) statistical analysis; (6) development of resistance factors using reliability methods (e.g., FOSM, Monte Carlo, FORM) performed for various soil/rock types and design methods; and (7) submission of a final report. The results of the effort could then be evaluated by AASHTO and considered for inclusion in the LRFD design code.

♦ **Project 05-22**

Establishment of a National Specification for Use of LED Roadway Lighting

Research Field: Traffic
Source: Pennsylvania
Allocation: $400,000
NCHRP Staff: Edward T. Harrigan

The lighting industry has changed dramatically over the past decade. Roadway luminaires have moved beyond the limits of a single lamp and reflector design into the vast possibilities presented by light emitting diodes (LED), which also boast lower energy usage and improved color. The optics of legacy high pressure sodium (HPS) full-cutoff luminaires that manufacturers had to work with were restricted to the lamp and reflector design in that lamps emitted light in almost every direction which was then reflected to get to the roadway. There was only so much control possible with this configuration, which resulted in a gentle gradient at the edges of the distribution pattern and "spill" light outside of the calculation grid. AASHTO target light levels are calculated over a grid limited to the traveled roadway. Any light that landed outside of the calculation grid is not quantified in the average and uniformity results, but is still present with the distributions of HPS cobra head luminaires. With the greater ability to control the distribution and sharp cutoff at the edges with LED luminaires, light levels beyond the calculation grid may be dramatically reduced but a design may still meet the AASHTO criteria. Therefore, this should be investigated and if the results dictate, AASHTO should provide specific light-level criteria for areas immediately adjacent to the traveled roadway when using LED. Additionally, the possibility of dimming introduces some liability, and the difference in spectral power densities of LED luminaires has shown other potential impacts involving both weather conditions and nature. Currently, there are no published recommendations by AASHTO regarding dimming in response to time of day or traffic volumes. Without further research into these issues, liability increases for DOTs using this technology.

The objective of this research is to establish an application specification for LED roadway lighting addressing issues of liability for departments of transportation. This study is expected to build upon, complement, and advance the ongoing efforts of the AASHTO Roadway Lighting Committee revolving around the usage of LED lighting. This research is expected to include the following tasks: (1) Evaluate the off-axis lighting levels at both HPS- and LED-illuminated highway interchanges, including shoulders and the clear zone beyond the shoulders. Identify the average foot-candle (fc) and uniformity ratio for both systems, and identify whether there exists a difference in average fc and uniformity of the shoulder, and whether this negatively impacts the safety benefits of installing lighting. (2) Based on the results of Task 1, establish target light levels of average fc and uniformity for areas beyond the traveled lanes as to not decrease the level of safety afforded by legacy HPS systems. (3) Study the effects of white light sources in foggy conditions, where higher color temperatures and different wavelengths of light react differently than legacy HPS sources. Compare various color temperatures and spectral power densities over a range from 2200K HPS to 5700K LED. Use these results to develop guidelines for designing in areas with a high likelihood of foggy conditions. (4) Study the effects of various color temperature sources and the attraction of insects to these sources, specifically near bodies of water. Compare multiple LED cobra head luminaries to legacy HPS cobra head luminaires to determine if high color temperature LED luminaires attract insects which could negatively affect the safe travel of roadways. (5) Evaluate the liability of reducing light levels during times of traffic volumes lower than the design values. Provide recommendations in the application of dimming roadway lighting in order to limit liability to state DOTs.

♦ **Project 07-24**

Methodology for Estimating the Value of Travel-Time Reliability for Truck Freight System Users—Phase 2

Research Field:	Traffic
Source:	Washington, California
Allocation:	$300,000
NCHRP Staff:	William C. Rogers

American businesses and households depend on the reliable movement of freight. The ever-increasing demands for just-in-time supply chains, same day or time certain deliveries to e-retailing customers, and the businesses' desire to minimize inventory costs magnify the importance of a reliable transportation system, and it is necessary to consider the value of truck travel-time reliability in transportation decision-making process. However, the lack of a commonly acknowledged methodology to accurately quantify the value of truck travel-time reliability creates a barrier to measure the comprehensive benefits and costs of transportation projects.

NCHRP Project 08-99 research completes the first exploratory phase toward the objective of estimating the value of truck travel reliability to truck freight system users. It has developed descriptive models of shipper and trucker behavior in response to increasing levels of travel-time uncertainty—based on simpler surveys, interviews, and in-depth supply chain expertise—and to estimate economic costs directly from those behavioral models. Building on NCHRP 08-99, this research will center on a stated preference analysis to develop more fine-grained and statistically grounded estimates of the value of truck freight reliability.

The objective of the research is to conduct stated preference survey research, applied to a significantly larger and more stratified sample than obtained in NCHRP Project 08-99, to obtain statistically valid functional relationships between the perceived level of trip-time variability and the costs of actions taken to mitigate trip-time uncertainty, such as buffering or other strategies identified in that study. The research and empirical analysis and modeling should focus on the following key questions:

- What are the costs of employing various mitigation strategies? The Truck Freight Reliability Valuation Model produced for NCHRP Project 08-99 provides a good estimation framework and tool for those costs and how those costs vary as a function of varying levels of truck trip-time uncertainty, as measured by the trip-time distributions. The log normal specification might be reviewed, if time permits, to determine if other functional forms could provide better fits to trip time data.
- What is the "rate" of cost tradeoffs made by shippers in employing such strategies for a given truck trip-time distribution? This question relates to the functional form of the relationship between the direct cost given trip-time variability and the costs of mitigation.
- Surveys conducted in NCHRP Project 08-99 found considerable variability in on-time performance targets, from time certain, to 1 or 2 hours, to 12 or more hours. Unfortunately, because of sample size limitations, it did not identify significant differences in these on-time goals by types of

shipper, supply chain characteristics, or commodities. That information is clearly required, and should be explored in depth in the next phase of research. What factors explain these differences? Shipper characteristics/types of shipper, supply chain characteristics, or commodities are all possibilities.

- What variables explain the specific mitigation strategies employed by shippers and truck service providers, such as commodity type, trip purpose (i.e., line haul, connection to port or intermodal facilities), and how do these strategies and their costs vary at different levels of trip-time uncertainty? As noted above, additional analysis is needed to explore and explain cases where more aggressive and—in most cases—more costly mitigating strategies are employed; our surveys and interviews uncovered a range of strategies in addition to adding buffer time, such as driver teaming, real-time trip tracking, geo fencing, price surcharges for very congested service areas, and in the long run, relocation of distribution or production centers.
- How to incorporate analysis results of truck freight reliability into standard benefit-cost analysis methods currently used by state DOTs and metropolitan planning organizations? Additional work is needed to consider whether double counting issues exist, and if so, how to address them.

With these questions in mind, a stated preference analysis, entailing surveys and calibration of econometric models, is proposed.

♦ Project 07-25

Pedestrian and Bicycle Planning, Design, and Operational Issues with Alternative Intersections

Research Field:	Traffic
Source:	Federal Highway Administration
Allocation:	$400,000
NCHRP Staff:	William C. Rogers

New alternative intersection designs—including diverging diamond interchanges (DDI), displaced left-turn (DLT) or continuous flow intersections (CFI), restricted crossing U-turn (RCUT) intersections, median U-turn (MUT) intersections, quadrant roadway (QR) intersections—are being built in the United States. These designs may involve reversing traffic lanes from their traditional directions, so this may introduce confusion and create safety issues for pedestrians and bicyclists. In addition, pedestrian paths and bicycle facilities may cross through islands or take different routes than expected. These designs are likely to require additional information for drivers, cyclists, and pedestrians as well as better accommodations for pedestrians and bicyclists, including pedestrians with disabilities.

A central concern with alternative intersections is how to provide information to pedestrians, cyclists, and drivers about the direction of car traffic, pedestrian crossing, and bicycle facilities since many designs feature unfamiliar traffic flow and patterns. Visually impaired pedestrians require information about the alignment of crosswalks, signal control, crossing time, direction of traffic, and direction through islands. Various types of paths and lane markings are being used for bicyclists, with little information about advantages and disadvantages of different strategies.

The objective of this research is to identify best practices for planning and designing pedestrian and bicycle accommodations at alternative intersections. Key considerations should include wayfinding, accommodation for pedestrians with disabilities, minimizing delay for pedestrians and cyclists, increasing safety for pedestrians and cyclists, and Identifying research gaps related to safety tradeoffs. A prioritized list of research priorities for the AASHTO Technical Committee on Non-motorized Transportation should also be developed.

♦ Project 08-108

Developing National Performance Management Data Strategies to Address Data Gaps, Standards, and Quality

Research Field:	Transportation Planning
Source:	AASHTO Standing Committee on Performance Management
Allocation:	$250,000
NCHRP Staff:	Dianne S. Schwager

The availability and cost of obtaining meaningful, consistent, timely and accurate data is a limiting factor for transportation agencies seeking to strengthen their use and implementation of transportation performance management programs. Data are needed for performance indicators and to understand how performance trends are impacted by exogenous factors, outside of agency control. The results of this research are two-fold. First, the project will identify a stronger national approach to developing data collection and management strategies and standards for transportation performance management. Second, the project will develop an implementation plan and begin to implement high priority projects.

The research should also examine the rich body of knowledge related to approaches to data collection and management for other national-level data programs such as the National Household Travel Survey (NHTS), the National Performance Management Research Data Set (NPMRDS), the Highway Performance Monitoring System (HPMS), National Bridge Inventory, and Fatality Accident Reporting System (FARS).

The objective of this research is to identify common data gaps across agencies seeking to enhance performance management capabilities and to develop a set of national strategies for filling these gaps. National strategies would potentially achieve: (1) a more efficient approach to meeting common performance management data needs, and (2) a more consistent and sustainable data collection and management approach than would be possible from individual uncoordinated agency efforts.

Suggested tasks include the following. (1) Identify common gaps in data to support performance management. (2) Conduct a data summit to discuss possible national strategies for filling these gaps. (3) Develop a national data plan incorporating the most promising strategies [The research should consider the following for each strategy: business case for a national approach; use cases concerning how agencies would make use of the data; data access/distribution methods; opportunities to piggyback on existing national, regional and state data programs; opportunities to leverage commercial data sources, data collection approach (e.g., centralized collection or decentralized with consistent data specifications); Formats and quality assurance standards, data updating approach, oversight and stewardship options]. (4) Develop an implementation plan with a prioritized list of projects that includes endorsement from key national-level organizations. (5) Begin the implementation of the higher priority projects contained within the plan.

♦ **Project 08-109**
***Updating the AASHTO* Transportation Asset Management Guide—A Focus on Implementation**

Research Field:	Transportation Planning
Source:	AASHTO Planning Subcommittee on Asset Management
Allocation:	$800,000
NCHRP Staff:	Andrew C. Lemer

In January 2011, the American Association of State Highway and Transportation Officials (AASHTO) published its *Transportation Asset Management Guide—A Focus on Implementation.* This document expanded on the original AASHTO *Transportation Asset Management Guide* published in 2002. Both documents were produced with NCHRP research effort and have served to introduce and support adoption of asset management principles and practices.

The status of transportation asset management implementation in the United States has evolved since the initial guides were published. Some agencies facing funding constraints and aging infrastructure have adopted a "preservation first" mindset that focuses on "taking care of what they have" before spending money on expanding the system. Other agencies have responded primarily to federal legislation requiring the use of performance data to drive investment decisions on the National Highway System (NHS) and identification of planned investments for pavements and bridges on the NHS in an asset management plan.

In addition, completed and ongoing research under the NCHRP and other programs has produced a variety of new tools and information that agencies can use to improve their resource allocation and asset management practices. Examples include "Successful Practices in GIS-Based Asset Management" (NCHRP Project 08-87), "Transportation Asset Management Gap Analysis Tool" (NCHRP Project 08-90), and "Cross-Asset Resource Allocation and the Impact on System Performance" (NCHRP Project 08-91).

The increased use of asset management principles has been positive, but a number of organizational and technical issues have yet to be resolved by state and local transportation agencies, particularly as agency decision support needs mature beyond single facilities and asset classes to encompass program- and system-level performance. Research is needed to update and extend previous guidance on transportation asset management principles and their application by U.S. transportation agencies and to facilitate their dissemination and adoption.

The objective of this research is to provide guidance particularly for agencies that have undertaken the initial steps in implementing transportation asset management and are ready to apply more advanced techniques. This guidance may address such topics as the following examples:

- Applying asset management principles to ancillary assets
- Integrating program and system decision support with other plans
- Conducting whole life costing
- Managing risks
- Developing long-term financial plans
- Setting effective targets
- Conducting cross-asset investment planning.

Regardless of the specific scope and structure of topic coverage, the guidance should promote current leading practices in infrastructure asset management, provide direction to agencies for how best to consider the many factors that influence investment decisions (such as safety, freight, congestion, economic development, connectivity, and rural/urban alternate transportation options), and facilitate effective communication of resource needs with elected officials and other stakeholders.

♦ **Project 08-110**
Traffic Forecasting Accuracy Assessment Research

Research Field:	Transportation Planning
Source:	Ohio, Minnesota, California, Wisconsin, Florida, Virginia
Allocation:	$350,000
NCHRP Staff:	Lawrence D. Goldstein

Accurate traffic forecasts for highway design are crucial for ensuring that public dollars are spent wisely; however, unlike in other countries, there is only a small set of empirical studies that have examined non-tolled traffic forecasting accuracy in the United States. These studies are important as they provide three critically important benefits: providing insight on observed inaccuracy levels to decision makers and the public; demonstrating the value of advanced models and data techniques; and identifying methods to improve traffic forecasting practice.

Such studies are rare because of numerous challenges, including data availability, staff turnover, and absence of forecast preservation practice. These challenges are slowly being overcome in recent years as the importance of empirical accuracy reporting has grown. The need for the demonstrated value of advanced modeling and data techniques has also grown, as these techniques require significant resources. Other fields have demonstrated the effectiveness of such reviews, most notably the National Oceanic and Atmospheric Administration (NOAA) through their highly successful Hurricane Forecasting Improvement Program. In traffic forecasting, Wisconsin, Minnesota and Ohio have conducted targeted reviews of some traffic forecasts within in the past 6 years.

The objective of this study is to analyze traffic forecasting accuracy using project traffic information from various state DOTs where records are available, report the findings, develop a recommended records retention policy, and suggest ways the traffic forecasting community could improve forecasting accuracy and communicate forecasts to the users. The research team will work with several state DOTs to create a combined database of project traffic forecasts, project characteristics and assumptions, exogenous forecasts, and actual traffic volumes. It is recognized that travel models are not used exclusively for traffic forecasts, especially for smaller projects. Linear regression based on historical traffic counts is commonly used in these instances. Therefore, the research team will need to account for the method used to produce the forecast (regression model, persistence model, travel model of record, refined travel model, etc.).

Similar studies for toll roads and transit capital projects have noted the difficulty of gathering detailed project information post-construction. The research team will attempt to re-create the inputs as best as practically possible for a select number of projects. One key result of this study will be a recommended records retention policy so that similar analyses can be more easily performed in the future.

The research team will then perform a rigorous analysis to accomplish the following:

1. Develop metrics and processes for evaluating traffic forecasts
2. Evaluate traffic forecast accuracy across several dimensions:

   a. Functional classes
   b. Area types
   c. Volume groups
   d. Size of metropolitan areas
   e. Project sizes
   f. Types of projects
3. Determine under what conditions forecasting accuracy improves when travel models are used to develop the forecast.
4. Enumerate contributors to forecast inaccuracy and suggest methods to mitigate each.
5. Evaluate methods for improving communication of forecast uncertainties.
6. Provide recommendations on instituting an ongoing review of forecast accuracy, including a recommended records retention policy.

This study will fill a major gap in the United States traffic forecasting industry by providing insights on observed inaccuracy levels and identifying problems with non-tolled traffic forecast practice. Similar studies for toll roads and transit capital projects have noted the difficulty of gathering detailed project information post-construction. One key result of this study will be a recommended records retention policy so that similar analyses can be more easily performed in the future. The results of this study might also demonstrate the value of the implementation and application of modeling techniques, as opposed to regression or persistence models. Providing empirical evidence, should it exist, of the value of these techniques would significantly increase the support for investments in these areas. This study is also intended to serve as a prototype analysis that can be duplicated by all state DOTs.

♦ **Project 08-111**
Quantifying the Impact of Freight-Efficient Land Use Patterns to Support Effective Decision Making

Research Field:	Transportation Planning
Source:	Virginia
Allocation:	$500,000
NCHRP Staff:	William C. Rogers

Although recent research efforts have focused on improving the integration of freight and land use planning, as well as reducing greenhouse gas (GHG) emissions (including from freight), quantifying the impact of freight movements has not been addressed and is a critical need. The goal of this proposed research is to provide *quantitative information* on how smart growth or similar land use planning that considers efficient freight movement (through more compact regional development patterns, rail-oriented industrial development, freight villages or clusters, co-location of manufacturing and distribution hubs, etc.) can impact truck VMT and transportation energy use and emissions. The National Cooperative Freight Research Program (NCFRP) addressed this same question in *NCFRP Report 24: Smart Growth and Urban Goods Movement*, but only in one metropolitan area of the United States. The proposed research would build on *NCFRP Report 24* to look at other metropolitan areas and thereby create a more generalizable and transferable body of information. This information would allow truck and freight impacts to be included in the evaluation of land use strategies for reducing VMT, energy, and emissions.

Freight traffic is currently responsible for about one-quarter of transportation GHG emissions in the United States, with trucks responsible for nearly four-fifths of that amount. Freight travel is forecast to continue to increase in step with long-term economic growth. The U.S. Department of Energy projects a 56 percent increase in truck traffic and a 33 percent increase in rail tonnage between 2010 and 2035. These increases will greatly impact the nation’s ability to achieve objectives for environmental sustainability and livability. As metropolitan areas and communities throughout the country increasingly adopt “smart growth” land use strategies, planning for efficient freight movement must be part of the picture.

Much attention has been focused on the potential of land use strategies for reducing vehicle travel, as well as providing a range of other economic, social, and environmental benefits. A considerable amount of research has been directed into characterizing and measuring the impacts of strategies such as more compact/higher density neighborhoods, greater mixing of uses, pedestrian-friendly design, and infill development—strategies that are often collectively known as “smart growth.” However, this research has almost exclusively focused on the impacts on passenger travel and has generally ignored goods movement and other truck travel. The new research would provide needed information on the effects of various land use strategies, including freight-oriented strategies as well as general “smart growth” strategies, on goods movement, particularly truck travel, and associated environmental effects.

The objective of this research is to estimate the impacts of land use strategies, including freight-specific strategies as well as general urban form, on freight-related travel, energy use, and other environmental and community impacts.

The research would involve identifying potential freight-impacting land use strategies and characterizing how they might affect freight movement; designing and implementing one or more research approaches (empirical data collection, modeling, etc.) to measure the impacts of freight-impacting land use strategies on freight travel patterns; and summarizing findings and describing potential policy implications. The research should consider how effects might vary depending upon regional factors such as existing development patterns, projected growth, and industry mix. The research should build on the framework/typologies developed in NCHRP Project 08-96.

The research should, at a minimum, provide quantitative estimates of impacts of land use strategies on (1) truck VMT; (2) the potential for shifting modes of commodity movement, particularly truck to rail; and (3) energy and GHG emissions associated with freight movement. The research should demonstrate the viability of the tools and methods applied for *NCFRP Report 24* in other metropolitan areas with characteristics different than the Puget Sound region. The research should provide a qualitative assessment of additional factors, including: (1) impacts on regional air pollutant emissions; (2) access to jobs, particularly for low-income workers; (3) livability, including noise, safety, and air pollution impacts, especially on "environmental justice" communities; and (4) impacts on economic competitiveness and productivity. The research should describe additional research that might be conducted to assess these factors quantitatively.

♦ Project 08-112
Guidebook for Implementing Alternative Technical Concepts into All Types of Highway Project Delivery Methods

Research Field:	Transportation Planning
Source:	AASHTO Highway Subcommittee on Construction
Allocation:	$500,000
NCHRP Staff:	Edward T. Harrigan

Transportation agencies are increasingly requesting alternative technical concepts (ATCs) from the design and construction industries for incorporation in their transportation projects. In particular, some contracting agencies are awarding design-build (DB), construction manager at-risk (CMR) or construction manager/general contractor (CMGC), and certain design-bid-build (DBB) contracts incorporating ATCs. In many states, the construction and consulting industry has expressed concerns with protecting proprietary as well as sensitive business practices when proposing an ATC for DB projects in particular. Most contracting agencies want to work with their industry partners to develop transparent and fair procedures that treat all proposers fairly and provide their management with a documented ATC approval process and its incorporation into the contract award process. ATCs have huge potential for accruing sizable benefits in terms of cost savings, increased constructability, and schedule reduction. The Minnesota DOT approved an ATC on a DB bridge project that generated nearly $100 million in savings. The Utah DOT has recorded over $13.8 million is savings on its CMGC program from early contractor involvement in the design process and the Missouri DOT credited ATCs with saving over $7.0 million on a single DBB bridge project. The potential for accelerating highway construction through ATCs is so great that the FHWA included ATCs as a separate initiative in the 2012 Every Day Counts II program. Additionally, MAP 21 reduced the state match requirement for federally funded projects for states that employ ATCs on their projects. The result is a huge upswing in interest in implementing this innovative project delivery approach.

NCHRP Synthesis 455: Alternative Technical Concepts for Contract Delivery Methods found that while there are a number of different concepts for implementing ATCs, there is no substantive implementation guidance. The lack of information is especially pronounced for DBB project delivery where only one state appears to be using it with that method. A number of key procedural issues are preventing many states from taking full advantage of this proven concept. The following are a few of the major issues identified in the synthesis: Can agencies legally promise and maintain confidentiality given individual open records laws? Does allowing one contractor to bid an

ATC while another bids the project as advertised constitute an unfair comparison or eliminate the "apples to apples" premise of low bid award? Who, the state or the contractor, should bear the costs for redesign involved in approved ATCs? How are construction schedules altered by approved ATCs and how can an agency evaluate schedule impacts? What process provides a fair quantification and evaluation of savings due to ATCs? How does the use of ATCs on a given project change the National Environmental Policy Act (NEPA) and permitting processes during project development?

The challenges demand a process and/or set of procedures that allow the agency to capture the benefits accrued by permitting ATCs on a construction project without violating the public trust and commitments that may have been made during project development. Ultimately, a sound business case must be made for each ATC as well as when and where including an ATC provision in construction procurement is appropriate. This ultimately requires a methodology to identify the costs associated with implementing ATCs and a common approach to identifying a return on investment. The proposed research should address the following questions: What is the definition of an ATC? What are the requirements to validate that an ATC furnishes an equal or better product? What are the appropriate procedures for accepting, reviewing, and evaluating ATCs during procurement? What are the appropriate practices in contractually implementing ATCs (i.e., open changes to the contract for all to implement, proposer-suggested language changes, proprietary to proposers)? What are the appropriate procedures in managing confidentiality? How should agencies respond to ATCs (i.e., standard responses, no answers with incorporation into established addenda schedule, turnaround timeframes)? What level of detail is requested for submittal? What are effective practices to estimate the value of an ATC, evaluate its impact on construction schedules, produce the necessary design documents, and guarantee that permitting will be available in a timely manner? What is the practice of including schedule and price in the evaluation of ATCs? How can the agency shift liability for the performance of contractor-designed ATCs? How must the NEPA process be altered to provide the maximum latitude for ATCs without triggering a need to rework the permit (i.e., What is the minimum level of detail for commitments made during the NEPA process)? In public-private partnerships, what is the practice of considering non-technical ATCs (for example, financial or operating & maintaining-type ATCs)?

The objective of this research is to benchmark the state of the practice in using ATCs on DBB, CMGC, and DB projects and combine it with existing research on construction procurement and project delivery procedures, processes, and policies. This study will assemble a set of effective practices and develop a guidebook that can be utilized by agencies to implement based on local statutory and/or policy requirements for the application of ATC practices in construction procurement. The guidebook should include a methodology to compare ATC design alternatives on a basis of both potential cost and time savings. It should also incorporate guidance that allows DOTs to be able to justify the selection of a higher cost alternative on a basis of offsetting environmental/social benefits. Specific tasks of the research to accomplish the main objective include: (1) Benchmark the state of the practice in ATC use in construction procurement. (2) Review the legal issues involved with offering, providing, and maintaining confidentiality of ATCs during procurement and identify remedies that have been successfully implemented; prepare a white paper documenting the results of Tasks 1 and 2. (3) Select a representative set of case study projects from public transportation agencies with ATC experience that can be studied in depth to identify both best practices and lessons learned. (4) Prepare a research work plan that describes the details of the research methodology and methods for identifying best practices and developing conclusions. (5) Execute the research work plan and prepare an interim research report that articulates the data collection and analysis as well as emerging conclusions, effective practices, lessons learned, and a proposed outline for the guidebook; case study report; draft language; spec language; and legislative language. (6) Prepare the draft guidebook for implementing ATCs on construction projects delivering with DBB, CMGC, and DB (including public-private partnerships). Incorporate review comments as required and validate the guidebook's efficacy with a case study DOT. (7) Publish the final guidebook and a final research report that details the full results of the research.

♦ **Project 09-61**

Short and Long-Term Aging Methods to Accurately Reflect Binder Aging in Different Asphalt Applications

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$750,000
NCHRP Staff:	Edward T. Harrigan

Asphalt binder experiences aging during mixture production and service life of the pavement. Aging of asphalt binder directly influences the stiffness and damage resistance of asphalt mixtures. The current industry practice is to simulate short-term and long-term aging in asphalt binders using the rolling thin-film oven and pressure aging vessel, respectively. These methods and the parameters (e.g., temperature, pressure, and duration) involved in the use of these methods were developed a few decades ago and adopted as standards primarily to aid performance grading of asphalt binders. Over the last few years, there have been several changes in asphalt technology. For example, the use of warm mix asphalt (WMA) and reclaimed asphalt pavements has significantly increased. The use of additives, chemical and/or polymer modifiers to enhance binder properties, has also significantly increased; in some cases, the oxidation kinetics of such modified binders are significantly different from conventional binders. Finally, several studies have also shown that a better understanding of binder oxidation can improve our ability to predict damage in asphalt pavements. In light of the above advances, there is a need to revisit the methods that are currently used to age asphalt binders in the laboratory with the expectation that this aging reflects short-term and long-term aging of binders that occurs in the field.

The objective of this research is to develop laboratory aging methods to accurately simulate the short-term (from production to placement) and long-term (in-service) aging of asphalt binders. The research may involve investigating the relationship between different methods of laboratory aging of asphalt binders and the actual aging that occurs during mixture production, transport, and placement as well as during the service life of the pavement structure. Accomplishment of the project objective will require at least the following tasks: (1) Review the available methods for accelerated aging of asphalt binders and the feasibility of using such methods in terms of any additional capital cost, staff skill, time required, throughput, and minimum sample size. (2) Conduct laboratory and field testing to establish relationships between parameters associated with the laboratory method (e.g., aging temperature, duration, etc.) to the actual aging of asphalt binders considering factors related to the following, at a minimum: material type (e.g., polymer-modified binders, binders containing ground tire rubber, and binders recovered from emulsions); production type (e.g., binders used in the production of hot mix asphalt (HMA) or WMA with chemical agents or foaming); storage and transportation conditions during production (e.g., storage in silos for extensive durations of time or during long hauls); mixture type and in-service conditions (e.g., dense graded versus open graded mixes, and climatic conditions at the pavement location); and aggregate type that is in contact with the binder in the asphalt mixture (e.g., aggregate with typical surface mineralogies and specific surface areas). (3) Identify the best possible aging method(s) and parameter(s) that can be used to simulate different aging conditions for asphalt binders. Such a method and concomitant parameters may be based on an existing method, a variation of an existing method, or a new method. (4) Propose an implementation plan for the use of the proposed aging method and parameters so that it can be (*i*) phased into the existing framework of binder specifications and (*ii*) used to characterize the aging kinetics of asphalt binders as needed. (5) Propose a standard method for short- and long-term aging of asphalt binder in AASHTO format for submission to the AASHTO Subcommittee on Materials.

♦ **Project 09-62**

Quality Assurance and Specifications for In-Place Recycled Pavements Constructed Using Asphalt-Based Recycling Agents

Research Field:	Materials and Construction
Source:	Illinois, Virginia, Michigan, Minnesota, Florida, Washington, Colorado
Allocation:	$1,000,000
NCHRP Staff:	Edward T. Harrigan

Pavement recycling offers significant economical savings in reduced material consumption, reduced cost of construction, and reduced user delays. However, there are currently no acceptable rapid quality control/quality assurance (QC/QA) test methods to ensure that the constructed materials comply with commonly specified quality parameters and are ready for surfacing/trafficking.

Asphalt-based recycling agents (foamed asphalt or emulsified asphalt) are used in the following pavement recycling processes: cold in-place recycling (CIR), cold central-plant recycling (CCPR), and full-depth reclamation (FDR). These techniques have traditionally been accepted on the basis of moisture content and compaction in the field and strength tests in the laboratory. These tests do not readily lend themselves to assessing the as-constructed quality and ultimate performance of recycled materials, nor do they help determine the proper time that trafficking/surfacing can be applied without causing damage. Many agencies specify a mandatory curing period (ranging from 2 to 14 days) before the recycled layer can be trafficked or surfaced; however, these times are empirically based. If the actual required curing period can be identified, significant construction delays may be avoided.

There is a need to develop appropriate test(s), performed on site at the time of construction, that allow an agency to determine the quality of the recycled pavement and its readiness for trafficking/surfacing. This project will develop a new test(s) or modification of an existing test(s) to rapidly assess the in-place quality of the recycled material and compare the output of this method(s) to practices traditionally used to assess quality, develop acceptance criteria, and provide guidelines on time to trafficking/surfacing.

Several state DOTs and some local government agencies have developed construction specifications for the various forms of in-place recycling. Some of these specifications vary widely from jurisdiction to jurisdiction. Uniform specifications are needed to more easily allow in-place recycling contractors to operate in these various public agencies. Uniform specifications for all types of in-place recycling operations will be a product of this research effort.

Many existing in-place recycling specifications are method types of specifications with few QC/QA tests and acceptance criteria. Specifications need to be developed that are aligned to a quality management approach with specific quality control and quality acceptance tests and limits. Development of more end result specifications should be considered as well as warranty/guarantee types of specifications and the inclusion of in-place density requirements and ride quality. Equipment calibration procedures should be considered for inclusion in specifications.

The objective of this research is to develop (1) a rapid field-based test(s) for recycled asphalt pavement materials to guide contractors' quality while providing the transportation agency a basis for acceptance and time to trafficking/surfacing; (2) uniform guide specifications for all forms of in-place recycling; and (3) warranty/guarantee guide specifications for all types of in-place recycling.

The following tasks have been identified to complete the work for this project: (1) Conduct a literature search and survey of transportation agencies nationally and internationally to identify current test methodologies used for rapid quality assessment of recycled asphalt pavement materials and summarize the existing practice. (2) Develop new field test(s) or modify an existing test(s) for rapid field assessment of the quality of recycled asphalt pavement materials. Determine if the output from the new or modified test(s) can be related to more traditionally used tests such as unconfined compressive strength, resilient modulus, indirect tensile strength, stability testing, dynamic modulus, etc. (3) Propose and conduct a comprehensive testing program using the identified rapid field test(s), and compare to traditionally used tests, on construction projects with recycled asphalt pavement materials. The testing program must establish test method precision and bias statements as well as acceptance criteria for use with the proposed new field test(s). (4) Develop guide specifications for in-place recycling, including those applicable to projects with warranties or guarantees. (5) Develop a final report and training materials for implementation by agencies. Conduct one train-the-trainer session for the NCHRP project panel and incorporate comments into a final deliverable product. The final technical report shall include a literature review; summary of findings; equipment and test requirements; testing procedure(s), including precision and bias statements; acceptance criteria for the proposed new test(s); and proposed guide specifications.

Note: The AASHTO Standing Committee on Research directed that the project panel (1) incorporate problem statement 2017-D-11, “In-Place Recycling Quality Control/Quality Assurance and Specifications,” into the scope of this project, and (2) consider whether any elements of problem statements 2017-D-10 “In-Place Recycling Performance and Life-Cycle Cost Analysis (LCCA),” and 2017-D-09, “In-Place Recycling Project Evaluation and Alternative Selection,” can be accomplished with the available resources.

♦ Project 10-99

Guidebook for Implementing Constructability Across the Entire Project Development Process: NEPA to Final Design

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Construction
Allocation:	$500,000
NCHRP Staff:	David A. Reynaud

The FHWA Every Day Counts Program brought national visibility to implementing alternative technical concepts (ATCs) for incorporation in transportation projects and continues to encourage state DOTs to implement this alternative contracting method on projects delivered using design-build (DB), construction manager at-risk (CMR) or construction manager/general contractor (CMGC), and design-bid-build (DBB) contracts. ATCs have huge and well-documented potential for accruing sizable benefits in terms of cost savings, increased constructability, and schedule reduction. In almost every case, the approved ATC was in reality a previously unrecognized approach to alter the design and enhance its constructability by matching the design of a given feature of work with the proposing contractor’s preferred means and methods.

NCHRP Synthesis 455: Alternative Technical Concepts for Contract Delivery Methods found that the major barrier to implementing ATCs on all types of highway construction projects is the perceived difficulty of permitting a contractor to revise commitments made during the environmental permitting process to receive NEPA clearance to proceed. While projects in Minnesota and Missouri have successfully changed their environmental permits to take advantage of potentially large savings from ATCs without a substantial delay in the project schedule, the perception held both in industry and by DOT project managers that any change to approved environmental documents will trigger an unacceptable delay for resource agencies to review, narrows the scope of the ATC consideration process. Durinng a FHWA Every Day Counts ATC implementation outreach workshop with industry, both contractors and design consultants agreed that they will summarily dismiss any potential ATC that alters the project’s environmental permit regardless of the potential cost or time savings. Some DOTs that have implemented ATCs will include a statement in a project’s solicitation documents to the effect that only ATCs that can be incorporated without further external review will be accepted.

NCHRP Synthesis 455 also found that knowledge of project constructability was lacking in DOT planning, programming, and environmental staffs. Furthermore, these professionals have evolved a set of “acceptable” design solutions over the years of working with their local resource agencies. The result is that the NEPA clearance process has become more restrictive than absolutely necessary and literally constrains the DOT and its industry partners’ ability to innovate after the permit is finally approved. While changes in the permitting process are not the subject of this research needs statement, the intent of this project is to furnish a uniform set of guidelines for the application of constructability reviews during all phases of project development and delivery. The challenges demand a process and/or set of procedures that allow the agency to capture the benefits accrued by permitting ATCs on a construction project without violating the public trust and commitments that may have been made during project development. Ultimately, a sound business case must be made for each ATC as well as when and where including an ATC provision in construction procurement is appropriate. This ultimately requires a methodology to identify potential ATCs at a very early stage of project development and a common approach to conduct a tradeoff analysis during the permitting process to balance the time it takes to get final approval and the required amount of specificity articulated in permit commitments.

The research objective then becomes to focus on extending the constructability review and value analysis process, which currently takes place during final design, backward in time to begin at the appropriate point in the planning and permitting process, thus leaving the widest possible set of options for design innovation, and construction means and methods, open for implementation in the project delivery process, without the need to revisit the permitting decisions. The research will benchmark the existing research on constructability and marry it to the state of the practice in project delivery procedures, planning processes, and environmental legislation, regulations, and policies. This study will assemble a set of effective practices and develop a guidebook that can be utilized by agencies to implement, based on local statutory and/or policy requirements, the application of constructability principles across the entire project development and delivery process. The guidebook should include a methodology to compare potential design alternatives on a basis of both potential cost and time savings. It should also incorporate guidance that allows DOTs to be able to justify the selection of a higher cost alternative on a basis of offsetting environmental/social benefits.

Lastly, it is important to state that while the advent of ATCs triggered the need to relook at the environmental permitting process and ensure that it does not become unnecessarily restrictive, the proposed research is not merely restricted to projects using ATCs. Traditional low bid DBB projects encounter the same issues during the preliminary and final design phases; DOT and consultant design engineers suffer the same constraints as they attempt to develop a highly constructible design and a clear set of construction documents. Thus, the primary aim of the proposed research is to determine the minimum level of design specificity necessary to fulfill the statutory requirements to protect the environment without needlessly limiting the potential for post-permit design innovation.

♦ Project 10-100
Optimal Procedures for Validating Contractor Test Data

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$300,000
NCHRP Staff:	Amir N. Hanna

A majority of state transportation agencies utilize contractor test data in the acceptance process for construction materials. This practice is becoming even more prevalent on projects delivered using alternative delivery methods such as design-build. While this practice is allowed by the Code of Federal Regulations, CFR 637 requires that agencies validate contractor test data with independent test results. FHWA recommends a combination of hypothesis tests (specifically the *F*- and *t*-tests) to determine if the contractor and DOT test results are from the same statistical population. However, approximately 80 percent of agencies use less powerful validation methods, often comparing a single DOT test to one or more contractor tests. This can lead to payment for materials and construction based on test results that do not represent true material/construction quality. NCHRP Project 10-58(2), "Using Contractor-Performed Tests in Quality Assurance," concluded that when DOT and contractor test results for hot mix asphalt are compared, "these comparisons consistently indicate less variable and more favorable contractor test results, relative to specification limits, that give more favorable acceptance outcomes."

The *F*- and *t*-tests are both used extensively in other fields, including academic research. However, the proper application and associated mathematical risks are not well understood by many transportation quality assurance practitioners. Also, several published papers call into question the methodology recommended by FHWA regarding application of the *F*- and *t*-tests to compare data sets, specifically as relates to using the *F*-test as a preliminary test to determine whether to use the pooled variance or individual sample variance *t*-test in the analysis. In addition to recommending appropriate hypothesis tests, specification language and business rules must be developed. Often, specifications are not clear as to what specific quality characteristics the hypothesis test applies to, or what should happen in the event that the hypothesis test does not validate the contractor test data, leading to confusion, disputes, and project delays.

The objective of this research is to develop an effective method for validating contractor test data to replace the current *F*- and *t*-test procedure. Proposed tasks include: (1) Conduct a literature search on the use of statistical tests to compare independent data sets. (2) Select one or more statistical tests as potential replacements for the currently recommended *F*- and *t*-test procedure. Evaluate the tests using actual or simulated data. Determine the effectiveness of each method for evaluating independent data sets. (3) Perform a risk analysis to determine the effects of sample size and significance level. Recommend minimum samples sizes and an appropriate significance level for use in the validation process. (4) Develop recommended specification language and business rules for data validation including what action to take if contractor data is not validated; how to address the issue of "practical differences" (i.e., the difference between data sets is statistically significant, but so small as to be of no practical significance); the role of dispute resolution in the validation process. (5) Develop guidance and tools for an optimum procedure to validate contractor test data for use in the acceptance process.

♦ Project 12-112
***Update of the* AASHTO LRFD Movable Highway Bridge Design Specifications**

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

Of the nearly 600,000 bridges listed in the Federal Highway Administration's (FHWA) National Bridge Inventory, close to 1,000 bridges are movable bridges. The design and installation of structural, mechanical, and electrical components provide significant challenges for designers, contractors, and owners in any movable bridge project. The primary design guide for movable bridge design and construction is the *AASHTO LRFD Movable Highway Bridge Design Specifications*. This manual was first published in 2000 with 2002 Interim Revisions. The second edition of the manual was published in 2007, with yearly Interim Revisions from 2008 to 2014.

Based on the input from movable bridge owners, designers, and industry representatives, there is a desire to further update the current specifications to develop and implement a reliability-based design methodology and to reflect advances in electrical drives and controls, mechanical systems, and traffic/marine safety systems.

Toward this goal, NCHRP Project 20-07/Task 348, "Review of the AASHTO LRFD Movable Highway Bridge Design Specifications for Future Updates," was previously funded and a synthesis report prepared. The proposed title would no longer include the term "LRFD" (load and resistance factor design) and because, for movable machinery, power, and controls, the proposed specifications will adopt a reliability-based approach, which is consistent with how mechanical and electrical systems are designed.

The research objectives are: (1) Propose revisions to the Specifications. The revisions should be prepared recognizing the latest developments in movable bridge design and rehabilitation. Additionally, the proposed revisions should be consistent with adopted AASHTO specifications and manuals. (2) Propose recommendations for future research needs.

♦ Project 12-113
Cross-Frame Analysis and Design Improvements

Research Field:	Design
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$750,000
NCHRP Staff:	Waseem Dekelbab

Developments in bridge design and analysis in recent years have created the need for improvements to cross-frame analysis and design for steel girder bridges. In the past, the configuration of cross-frame systems were generally based upon standard designs in which member sizes and layouts were dependent upon geometry and minimum member cross section requirements. The opportunities for improvements to cross-frame analysis and design cover a variety of topics. This project will address a number of these topics in a single, comprehensive research program that should result in a dramatic improvement in reliability and economy of cross-frames for steel I-girder bridges. The topics addressed should include (1) improved definition of fatigue loading for cross-frames in curved and/or severely skewed steel girder bridges analyzed using refined analysis methods; (2) implementation of stability bracing strength and stiffness requirements in the context of AASHTO load and resistance factor bridge design; (3) additional guidance for adjustment of the effective stiffness of cross-frame members in refined analysis models to reflect the influence of end connections on cross-frame member stiffness; and (4) streamlined design procedures for tee (WT) members in truss-type cross-frames and other strut applications

The objective of this research is to provide (1) comprehensive, quantitatively based, guidance on the calculation of the design forces in cross-frames in steel girder bridges, (2) the calculation of stiffness requirements for stability, and (3) the influence of cross-frame member geometry upon the cross-frame stiffness.

♦ Project 13-06

Development of an Automated Tool to Assist in the Formulation and Maintenance of Long Range Equipment Replacement Plans

Research Field:	Maintenance
Source:	AASHTO Highway Subcommittee on Maintenance
Allocation:	$400,000
NCHRP Staff:	Amir N. Hanna

State highway agency equipment fleets are vital assets to the delivery of agency programs, projects, and services. Integrating asset management strategies, including the development of long-range replacement plans, is needed to maximize the use of available funding. State highway agency equipment fleet managers are responsible for making complex decisions related to equipment replacement that have major long-term fiscal impacts to fleet operations as well as impacts to state highway agency productivity and their ability to meet program goals. There is a great need to make the most informed decisions for efficiency and to better communicate the long-range impact from different equipment management decisions. Typically, an equipment replacement plan is a living document that identifies candidate equipment replacements using established replacement criteria usually for a 1- to 2-year period. Longer term equipment replacement projections can be prepared, but an established means for scenario-based planning is lacking. Pavement managers have such automated long-range, scenario-based tools that provide analysis of the impact of funding scenarios on pavement condition throughout the planning period. Fleet managers are in need of an analogous tool for long-range fleet replacement planning.

NCHRP Project 20-07/Task 309, "Challenges and Opportunities: A Strategic Plan for Equipment Management Research" (referred to as the Equipment Research Roadmap), calls out the need for research on long-range equipment replacement planning. The automated tool resulting from this research will allow fleet managers and decision makers to optimize replacement strategies and to better communicate the long range impact from various equipment management decisions. Without this tool, state highway agencies may underestimate and thus underfund these assets without fully understanding the impacts. Once these assets have been underfunded, a backlog of equipment replacement needs develops and can grow exponentially. Once a backlog develops, equipment costs increase significantly and state highway agency productivity decreases.

The objective of this research is to provide an automated tool to assist in the formulation and maintenance of long-range equipment replacement plans based on using highway agency fleet equipment asset historical cost, usage data, established life cycle criteria, and funding levels information. This tool should be able to project these plans using different scenarios with multiple inputs such as funding, inflation, fleet composition, fleet size, etc. This tool will be used to optimize replacement strategies and to better communicate the long-range impact from different equipment management decisions. The automated, computer-based process should have the capability to incorporate the optimized replacement cycles being developed under NCHRP Project 13-04, "Guide for Optimal Replacement Cycles of Highway Operations Equipment."

In order to achieve this objective, the following tasks are required: (1) conduct a literature review and synthesis of completed and active research in the area of long-range equipment replacement planning and scenario-based analysis including both public and private fleets with heavy equipment similar to state fleet composition; (2) conduct a synthesis of the current equipment replacement planning/practices (long range or single year) and scenario-based analysis used in highway agency equipment fleets and document best practices identified; (3) conduct a survey of state DOTs' equipment fleet managers to determine what problems, needs, and concerns they in developing long-range equipment replacement plans and scenario-based analysis; (4) using information collected in Tasks 1, 2, and 3, develop a process to incorporate the necessary factors to produce long-range equipment replacement plans and scenario-based analysis for highway agencies' total fleet and for each of the various classifications of equipment in the agencies' fleets; and (5) provide a computer-based solution that highway agencies' fleet managers can utilize to upload their data and run the various scenarios to determine their long-range replacement plans based on the process developed in Task 4. The option to upload customized replacement criteria or other needed data is required. The solution must provide a standard process using normal office hardware that can be used by all highway agency equipment fleets. The process of uploading data into the solution must be in a manner such that it can easily be performed by typical highway agency equipment fleet management staff without the assistance of information technology professionals.

A successful tool will have the following capabilities: (a) Produce equipment replacement plans that quantify long-term replacement costs including the ability to model future changes in fleet capital (including adjustments for inflation) associated with future changes in fleet size, replacement cycles, mission needs, technology (e.g., emission reduction requirements) and/or fuel-type changes and resulting cost increases, and asset ages. Time horizon length shall be configurable from 1 to 25 years. (b) Account for other than like-for-like replacement, i.e., change in fleet composition. (c) Quantify equipment replacement backlog and the rate of increase or decrease at configurable funding levels. (d) Provide a process for evaluating the effects of scenarios such as deferring or accelerating specific equipment units on the leveling of needing funds on a multi-year basis. The specific equipment units shall be configurable. (e) Conversely, the solution shall suggest equipment units in need of replacement to be deferred or accelerated in order to achieve configurable funding scenarios. Parameters related to the deferment or acceleration shall be configurable. (f) Provide a reliable basis for developing replacement rates in a sinking-fund business model to ensure that rates account for future needs including capital costs, fleet asset mix changes, or the cost of new technology. (g) Be compatible for modeling and comparing the economic and fiscal impacts of alternative capital financing approaches such as outright cash purchase, a sinking fund, debt financing, and leasing.

Note: The AASHTO Standing Committee on Research directed that this research be coordinated with the work being performed under NCHRP Project 13-04, "Guide for Optimal Replacement Cycles of Highway Operations Equipment."

♦ Project 14-39

The Effectiveness of Compost Amended Vegetated Filter Strips Using a Compost Blanket Application Method for Pollutant Removal from Highway Runoff

Research Field:	Maintenance
Source:	AASHTO Standing Committee on the Environment
Allocation:	$500,000
NCHRP Staff:	Lori L. Sundstrom

Low Impact Development (LID) techniques that are economical and appropriate for the highway environment are important tools for departments of transportation (DOTs) faced with meeting increasingly demanding water quality and hydrologic management requirements. Vegetated filter strips along highways, an accepted LID Best Management Practice (BMP), are a valuable and cost-effective alternative to hydraulically engineered BMPs. However, their use is limited by site constraints such as vegetation density, limited right-of-way, and steep side slopes. Furthermore, their effectiveness may vary greatly depending on climate, soils, and other factors. Compost amended vegetated filter strips (CAVFS) can overcome some of these limitations by promoting stormwater filtration through compost amended soils and infiltration of stormwater into the native underlying soils. CAVFS have received general use designation and approval by the Washington State Department of Ecology TAPE protocol for dissolved metals removal, including zinc and copper. CAVFS are relatively low cost and low maintenance, which makes them attractive to DOTs. Unfortunately, they can be a driving hazard since their design, consisting of an uncompacted layer of mixed compost and soil 12 inches deep, can trap the wheels of vehicles leaving the highway. This hazard limits where CAVFS can be used along highways.

A proposed modified CAVFS, consisting of a 2- to 4-inch thick blanket of coarse to medium textured yard waste compost placed on the untilled highway embankment, has the potential to match the pollutant removal and hydrologic benefits of the standard CAVFS. The thin layer of compost eliminates the risk of tire trapping associated with the deep amended soil in the standard CAVFS. Before a compost blanket CAVFS can become a standard LID BMP, it is necessary to confirm its performance and develop design guidance. This involves determining pollutant removal capability and capacity; the ability to detain and retain runoff; and the effect of climate, soils, compost composition, compost blanket thickness, and other parameters on its water quality and hydrologic effectiveness.

DOTs are facing increasing costs due to stricter stormwater management requirements intended to protect water quality and avoid adverse hydromodification of receiving waters. The large increase in the number of stormwater BMPs installed is placing an increasing burden on projects and DOTs' maintenance divisions. For example, between 2012 and 2014 the Oregon Department of Transportation more than doubled the number of its stormwater quality facilities (377 to 786). This burden magnifies the need for BMPs with demonstrated effectiveness and low construction and maintenance costs.

Developing design guidance for compost blanket CAVFS will provide DOTs with an effective and economical BMP of wide applicability, without the safety issues associated with the standard CAFVS. Results produced by testing the water quality effectiveness of compost blanket CAVFS would support the appropriate use of these BMPs to meet regulatory treatment requirements. In situations where a stormwater retrofit is needed, a compost blanket CAVFS could be very cost-effective option and its construction is very straight forward. If compost blanket CAVFS are shown to have substantial hydrologic benefits, their use could lead to a reduced size of detention basins for flow control and significantly lessen the financial strain on DOTs for stormwater management.

A literature review suggests that the research involving vegetated filter strips (VFS) looked at the standard VFS design and did not include any compost blankets on the VFS. The research generally concluded that the effectiveness of the VFS was based on the vegetation cover. In contrast to standard VFS design, compost blanket CAVFS would allow a substantial portion of highway runoff to filter into and through the compost layer. The rate of runoff is reduced, more of the runoff comes in contact with organic material that can remove dissolved metals, and the longer contact with the underlying soil promotes infiltration. The compost blanket studies looked at the benefits of applying compost to roadway embankments for erosion purposes. The studies didn't look at using compost blankets as a modification to an existing stormwater BMP (i.e., VFS) and monitoring its effectiveness over the standard VFS design.

The focus of this research is to test the compost blanket CAVFS, a design variation of the standard CAVFS BMP, to determine if it provides the same, or better, level of stormwater treatment while also providing a safer roadway embankment. The research has two main objectives:

- Objective 1: Test and establish the water quality and hydrologic management capabilities of compost blanket CAVFS, and determine the effect of various design and site factors on performance over a range of conditions typical of the highway environment. Some of these site factors include compost blanket depths, existing embankment soil types, and roadway embankment slopes. Maintenance-related factors should also be addressed.
- Objective 2: Develop guidance on the use, limitations, design, and implementation of compost blanket CAVFS for use along highways, based on the results of field and laboratory testing and literature review. The guidance is intended to be a practical manual for those who select and design stormwater management facilities. It will be broadly applicable and not limited to a narrow range of conditions or geography. The guidance will also be useful in evaluating the impact of highway runoff on the natural environment.

Achieving the project's objectives involves the following tasks:

- *Task 1: Survey and synthesis of existing literature related to the water quality and hydrologic characteristics of compost blankets, and the use and stability of compost blankets on highway or other embankments.*
  The survey should focus on the following areas: compost blanket ability to remove various types of pollutants associated with highway runoff;

leaching of pollutants from the compost used for the blanket; hydrologic capabilities of compost blankets, including detention capacity; effective lifespan of compost blankets along roadsides; stability on slopes receiving runoff; effects of climate and various underlying soil types in roadway embankments on the above characteristics; and the effect of compost blanket composition and quality on the above characteristics. The synthesis report should cover the above elements and include a gap analysis of information required to complete the project.

- *Task 2: Design and implement testing of compost blanket CAVFS.*
  Field testing should occur at two highway test locations. One test location could have a low gradient roadway embankment slope while the other location could be steeper. At each location, ensure it can accommodate three compost blanket CAVFS. One of the objectives is to test how deep the compost blanket should be. The compost blanket CAVFS should be 2 inches, 3 inches, and 4 inches in depth. There should be enough room for monitoring setup and equipment.
  Build and monitor the test sites. The compost blanket CAVFS sites would be sized per the VFS BMP design criteria with compost blankets that vary in thickness. This will help the study compare both stormwater quality and flow control benefits.
  Field and possibly laboratory testing will be conducted to address the information gaps in Task 1 and establish, and as appropriate confirm, the capabilities of compost blankets to manage highway runoff in varying roadside situations.
  Analyze data collected in Tasks 1 and 2.
- *Task 3: Develop guidance on the use and design of compost blanket CAVFS in the highway environment.*
  Include information on when and where compost blanket CAVFS are an appropriate stormwater BMP and the factors that support these conclusions.
  Develop design criteria for compost blanket CAVFS, taking into account varying roadside, climate, and traffic variables. Criteria should address compost characteristics, layer thickness, range of slopes, seeding etc.
  Discuss techniques and information required to estimate the water quality and hydrologic performance of CAVFS for project specific situations.
  Discuss what type and how often maintenance is needed for a compost blanket CAVFS.

♦ **Project 14-40**

Transforming Roadside Management Technology and Practices for the Benefit of Safety, Ecology, and Economy

Research Field:	Maintenance
Source:	Washington, New York, Florida
Allocation:	$300,000
NCHRP Staff:	David A. Reynaud

A transition to safer, more resilient and energy-efficient, and less costly methods of roadside vegetation management is currently underway throughout the country. This transformation is gaining momentum but slow to take hold in some areas. Additional research and documentation is needed to complete the shift nationwide, which will ultimately reduce maintenance requirements, benefit worker safety, and improve ecosystems.

Historically and to varying degrees nationwide, the default for a large percentage of roadside vegetation management has been based on an agronomic approach, using agricultural principles and routine mowing to maintain vegetation in a set condition. While a routinely mowed or low-growing stand of vegetation may be beneficial to traffic operations, and safety adjacent to pavement and structures (commonly referred to as the safety clear zone, or clear area), increasing evidence shows that it is better to let vegetation grow in as natural state as possible along corridors in that segment of right-of-way width beyond what is required for safety. Benefits from taking a less maintenance-intensive approach include less worker exposure to traffic hazards, improvements to local and global environments, and savings for highway maintenance budgets.

As a result, a number of states have reduced or eliminated mowing outside of the safety clear zone along wider freeway corridors. Newer methods are based on an ecological approach of selective control measures using the lowest maintenance combination possible of mowing, mechanical trimming and removal, and chemical and biological treatments. This is often part of a long-term plan to further minimize maintenance requirements over time.

However, despite the known benefits of the ecological approach, there is still pressure from the public and from some within transportation organizations to continue to use routine mowing beyond what is needed for safety.

Transportation agencies and their staff would be better able to explain and realize the benefits of an ecological approach to roadside vegetation management, if they had methodology and information that captures the overall benefit/cost advantages compared to regular mowing. Such a tool would also help transportation agencies answer public concerns and questions about why a more natural approach to roadside vegetation management is advantageous and how it can be used to improve ecological outcomes without compromising safety.

The primary objective of this research effort is to develop a framework and supporting rationale that vegetation managers and agency executives could use to compare benefits and costs between ecologic and agronomic approaches to roadside vegetation management. The application would be specific to locations where there is right-of-way area beyond the safety clear zone. The analysis would consider and account for variations in maintenance requirements of different regional ecosystem types around the country.

The framework would include a list and summary of existing research on all safety and environmental factors meriting consideration when evaluating comparative benefit/cost of agronomic vs. ecologic approaches, and recommendations on how to assign and weight values, including non-monetary values and direct labor, equipment, materials, and management/planning costs, within the context of individual agencies and regional ecosystems.

Note: The AASHTO Standing Committee on Research directed that consideration be given to incorporating aspects of problem statement 2017-F-06, “Safety Effects of Roadside Mowing Practices.”

♦ **Project 15-65**

Develop Comprehensive Objective Criteria to Reduce Serious and Fatal Lane Departure Crashes and Prepare a Major Update to the Roadside Design Guide

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$300,000
NCHRP Staff:	David A. Reynaud

The AASHTO Technical Committee on Roadside Safety (TCRS) is currently finalizing their 2015 strategic plan. The TCRS mission is to develop, implement, and maintain guidance which will reduce fatal and incapacitating-injury roadway departure crashes. Chapter 3 of the draft plan outlines a strategic approach to advance this mission. Namely, a major update of the *Roadside Design Guide* (RDG) was deemed necessary. The major update would provide a comprehensive roadside safety approach which embraces explicit design objectives for the roadside, medians, bridges, and work zones as well as provide planners, designers, and construction and maintenance personnel with tools for assessing and achieving the stated objectives.

A minor update to the RDG is currently underway. The minor update will lay the foundation for the introduction of the risk-based objective criteria which are currently being researched. This research for a major update will compile the ongoing research of risk-based objective criteria, coordinate these new criteria with other AASHTO documents and initiatives, and provide for accommodations for practical design in roadside engineering.

The development of the “objective criteria” or “selection and placement guidelines” has been the subject of numerous recommendations by the National Transportation Safety Board over the last 10 years.

The objectives of this research are to benchmark the existing risk for different roadside features, establish a goal for reduction (to be included in an updated RDG), gather the recently completed objective criteria (for the selection and placement of roadside, median, and bridge hardware), and assess recently completed/soon-to-be completed research on buses and motorcycles and available research on automated vehicles to determine appropriate encroachment adjustment factors for implementation in this update to the RDG. Then, coordinate the new criteria into a comprehensive document that communicates the RDG design objective to the user and that can be continually updated by the TCRS, based on changes to the crash testing criteria and new research.

In addition, the research should identify outdated guidelines for removal from the RDG, identify conflicts with other AASTHO documents that develop as a result of the new objective criteria, and work with AASHTO to resolve these conflicts. This research should explicitly incorporate practical design principles where supported by available research and propose a process for monitoring the effectiveness of each new guideline suggested for inclusion in the major update to the RDG.

♦ Project 15-66
Arterial Weaving on Conventional and Alternative Intersections

Research Field:	Design
Source:	Ohio
Allocation:	$750,000
NCHRP Staff:	B. Ray Derr

Arterial roadways are crucial links in the national transportation system providing both local and regional mobility and access; as such, they are critical to the vitality of our economy and quality of life. As increasing demands are placed on transportation infrastructure, and freeway congestion continues to increase, arterials have become an alternative route for many drivers, resulting in the lower performance of these roadways. In many areas, arterial safety and operational performance is negatively affected by weaving maneuvers that occur at freeway interchanges and other access points where there are large turning volumes. Intensive weaving activity is often found on the arterial segment between the interchange off-ramp terminal and an adjacent signalized intersection. It is also found on frontage road segments between the freeway off-ramp and the frontage-road/cross-street intersection. Further, many alternative intersection configurations, including median U-turns and restricted crossing U-turns, weaving maneuvers can affect their operations and safety.

The extent of arterial weaving activity is directly related to the number of vehicles that enter or exit at the ramp terminal or other access point, the distance between these entry/exit points and the driveway/access point density on the arterial. The negative effect of weaving activity on traffic speed is well-documented in the context of freeway weaving areas. Although arterial weaving reduces speeds, very little is known about the magnitude of the effect especially where alternative arterial street designs are used.

Understanding the safety and operation of alternative arterial street designs and the effect of weaving on these arterials is important for state and local agencies tasked with the responsibility of maintaining these roadways. The *Highway Capacity Manual* (HCM) provides a methodological approach for estimating the performance of weaving areas on freeway segments. This methodology, however, is not applicable on either traditional arterial street segments or on alternative arterial streets because of differences in traffic control, traffic flow characteristic, and driver behavior between freeways and arterials. The freeway section represents uninterrupted flow with merging control for entering vehicles. In contrast, the arterial segment is often regulated by upstream and downstream signals and may use no-control, yield, stop, or signal control to regulate both the entry and the exit maneuvers. Arterial weaving capacity is significantly affected by the gaps introduced by the upstream signal and the distance available for weaving (which varies with the queue length at the downstream signal).

It is likely that the current service measures for arterial analysis, average travel speed, and service measures for freeway weaving, such as speed and density, are not appropriate for alternative arterial design and arterial weaving. Therefore, this study should seek to gain insight from the traveling population and researchers to identify appropriate measures and thresholds of performance.

The objective of the research project is to develop guidelines that can be used to evaluate the safety and operations of alternative arterial designs based on consideration of access-related weaving, signalized and unsignalized access spacing, median type, upstream and downstream intersection design and traffic control, and intermediate driveway design and control. The guidelines would assist in the identification of the best combination of arterial design and intersection design (considering both conventional and alternative intersection forms) based on consideration of operational and safety issues, access management goals, construction costs, and environmental benefits. The guidelines should explicitly address automobile, truck, pedestrian, bicycle, and transit travel modes. The guidelines should be developed to assist planners and designers with the development of new construction, reconstruction, and access management decisions. The products of this research should complement (and integrate as appropriate) the recently completed research by FHWA in the area of alternative intersections and interchanges.

A key component of this research will be the development of procedures for separately evaluating the safety and operational performance of arterial street segments. These procedures should provide a means of quantifying the effect of access-related weaving movements on safety and operations. This includes the identification, from a traveler's perspective, of appropriate operational and safety performance measures, thresholds for the evaluation of level of service, and the development of a quantitative methodology for the estimation of those measures.

The safety evaluation procedure would be developed in a format suitable for inclusion in the next edition of the *Highway Safety Manual*. Similarly, the operations evaluation procedure would be developed for inclusion in the next edition of the *Highway Capacity Manual*. Draft text should be developed documenting recommended changes to the AASHTO document *A Policy on Geometric Design of Highways and Streets* (especially as it relates to Section 10.4, Access Separations and Control on the Crossroads at Interchanges).

The researchers of this project should coordinate with the researchers conducting NCHRP Project 07-23, "Access Management in the Vicinity of Interchanges." The products of this project should leverage the data and findings from NCHRP 07-23 and extend them as needed to achieve the project objective.

♦ Project 17-81
***Incorporating Road Safety Planning in the* Highway Safety Manual**

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$400,000
NCHRP Staff:	Mark S. Bush

The first edition of the AASHTO *Highway Safety Manual* (HSM) published in 2010 provides three major tools for highway agencies: (1) a roadway safety management process to identify sites with potential for safety improvement, diagnose conditions at the site, and select and prioritize countermeasures for implementation; (2) predictive methods for estimating changes in crash frequencies of alternative designs for an existing facility under past or future traffic volumes and for designs of a new facility under future (forecast) traffic conditions; and (3) a catalog of crash modification factors that can be used to estimate how effective a countermeasure or set of countermeasures will be in reducing crashes at a specific location. The HSM procedures provide robust methods for conducting spot-specific safety analyses known as micro-level analyses. These micro-level analyses can either be in reaction to evaluating alternatives to fix an identified black spot (i.e., reactive), or as part of an entirely new facility planned for an area (i.e., proactive).

Micro-level analysis procedures such as the predictive method and Crash Modification Factors presented in the HSM are significant tools that highway agencies are beginning to integrate into their safety management and design procedures and practices. Further, agency personnel are becoming more knowledgeable about and comfortable with the theory and statistical concepts in the manual through use of such tools as Safety Analyst, the Interactive Highway Safety Design Model (IHSDM), and spreadsheet tools developed by state departments of transportation. Micro-level analysis tools are suitable for analysis of specific intersections or roadway segments. They make it possible to consider the safety impacts of alternative design features such as number or type of lanes, shoulder width, or intersection control.

In contrast to micro-level analysis procedures for spot-specific or corridor situations, macro-level analysis procedures perform analyses on an area-wide basis—entire neighborhoods, cities, and/or regions. Macro-level analysis procedures can complement micro-level tools by explicitly considering area-wide impacts of planned land use and/or transportation projects, something that micro-level tools do not address. Macro-level analysis procedures would be used to incorporate safety prediction into area-wide long-range transportation system planning, programming, and policy development.

The absence of macro-level safety analysis procedures in the HSM is a gap in knowledge that has been precluding reliable quantitative safety procedures in road safety planning. The outcomes from this research could be applied immediately by state and metropolitan planning organization (MPO) planners and could be used as a consideration in community-wide safety goals and support analyses to meet MAP-21 performance requirements. The work also has the potential to be utilized as part of Strategic Highway Safety Plan or community-specific transportation safety action plans.

The primary objectives of this research are to (1) develop quantitative macro-level safety prediction models for use by transportation planners at state departments of transportation or MPOs; (2) provide guidance to state and MPO planners on application of these models and integration of the model results into agency planning procedures; (3) provide training and outreach on the methods developed; and (4) develop a quantitative safety planning chapter for the AASHTO HSM, including simple spreadsheet or web-based tools for applying the methods.

♦ **Project 17-82**

A Practical Approach to Fixed Objects Within the Clear Zone

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

Each year, roadway departure crashes in the United States result in numerous serious injuries and fatalities for road users. These crashes accounted for almost two-thirds of all fixed-object fatal crashes during this same period. The AASHTO Strategic Highway Safety Plan and the FHWA Roadway Departure Strategic Plan both highlight the importance of reducing the incidence and severity of roadside crashes. The AASHTO Technical Committee on Roadside Safety has also prioritized fixed-object crashes in its strategic plan. Current guidance directs transportation agencies to remove or avoid placing fixed objects within regions close to the traveled way. However, agencies must often consider numerous competing interests.

As state transportation agencies continue to expand the use of data-driven decision-making processes, there is a need to quantitatively evaluate the safety risks posed by fixed objects located near the traveled way as well as the benefits of implementing various safety treatments. With recent concepts, such as context sensitive solutions, complete streets, and practical design evolving into more mainstream practices, there are many factors that must be considered and balanced in the development of the roadside environment. Practitioners need a risk-based, technical approach to help mitigate fatal and serious injury crashes with fixed objects. This alternative approach would allow engineers to quantitatively and impartially balance safety with other factors as well as better communicate to decision makers and the public the safety risks posed by fixed objects placed in proximity to the roadway.

Results from this research would enable transportation agencies to use quantitative information in decision making as it pertains to fixed objects within or near the clear zone. In situations where removal or relocation proved to be infeasible, the research results would be used to communicate the safety risks posed by fixed objects as well as various safety treatments, thus allowing for improved selection guidelines based on reduced risk and an appropriate use of safety funds. This is consistent with the approach for other guidance being developed for the next version of the AASHTO *Roadside Design Guide* and the proposed draft Strategic Plan for the Technical Committee for Roadside Safety.

This research will develop objective guidance for elements related to placement of trees, utility poles, and other fixed objects, which quantifies the crash risk and will allow engineers to balance the competing factors. It is anticipated that the results of this research will be incorporated into a major revision of the *Roadside Design Guide*. State transportation agencies may utilize this research as a foundation for policy development on evaluation of roadside landscaping treatments, utility accommodations, and the placement of other fixed objects in proximity to the roadway.

♦ **Project 17-83**

Implementation and Training Materials for the* Highway Safety Manual*, Second Edition

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$500,000
NCHRP Staff:	Mark S. Bush

An update of the first edition of the AASHTO *Highway Safety Manual* (HSM) is being undertaken as NCHRP Project 17-71, "Proposed AASHTO *Highway Safety Manual*, Second Edition." The second edition of the HSM will incorporate multiple NCHRP and related research projects and other associated HSM guidance documents and publications. While the second edition of the HSM is not intended to be a complete rewrite of the first edition, the HSM will undergo significant changes in content and organization. Expanding implementation of the HSM is critical and it is through this proposed NCHRP research that AASHTO, FHWA, and ultimately the states can build upon the first edition and advance implementation of the HSM second edition.

This NCHRP project will support the implementation of the second edition of the HSM and would fill the need to build upon existing first edition HSM training material. The objective of the new training implementation materials will (1) illustrate how to apply the new content in real-world projects; (2) reinforce how to apply the previously published content in real-world projects; (3) facilitate proper and consistent application and ease of use of technical material by developing a variety of spreadsheet tools that will incorporate new material and methods, and similar terminology and approaches and that can be used to illustrate and apply the methods within projects for all facility types; (4) educate AASHTO members of the changes in the second edition of the HSM to facilitate balloting process and overall implementation; (5) inform and reinforce the value the HSM can bring to a wide range of roadway planning, design, and operations activities; and (6) support implementation through checklists, job aids, and spreadsheet tools.

♦ Project 17-84

***Pedestrian and Bicycle Safety Performance Functions for the* Highway Safety Manual**

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

While overall traffic fatalities are decreasing, walking and cycling fatalities are an increasing percentage of total fatalities. In 2012, pedestrians and bicyclists accounted for approximately 16 percent of traffic fatalities. While some states and agencies record detailed pedestrian and bicycle crash data, most motor vehicle crash data sets do not include sufficient detail for rigorous safety analysis for non-fatal crashes. The FHWA (under MAP-21) will be asking states to report on performance around pedestrian/bicycle issues, but many states don't know what data they should be collecting, or how to perform analyses with it to improve infrastructure, or how to develop other potential solutions to address crashes. The lack of quality crash and exposure (e.g., walking and biking volumes) data precludes the development of safety performance functions (SPFs) for walking and cycling as well as rigorous safety analysis to inform and use in tools such as PEDSAFE and BIKESAFE, the Interactive Highway Safety Design Model (IHSDM), and AASHTO's *Highway Safety Manual* and its online tool.

The ability to estimate crashes for walking and cycling would inform national safety improvements and countermeasure selection. From Swedish walking/bicycling data, it is generally known that many cycle crashes are off the "main" network, and solo; hence, only hospital records contain the cycling crash data, making it difficult to access for SPF development. Research is needed beyond traditional data collection to provide practitioners with reliable walking/cycling crash estimates that can be used throughout the planning and project development processes.

The objectives of this project are to (1) identify good surrogate measures that can effectively be used for the more detailed (i.e., segment/intersection volumes) exposure measures to the level of accuracy needed to achieve reliable estimates of pedestrian crashes, including a detailed case study to determine how much data is needed to make reliable conclusions; (2) perform an in-hospital pilot study to improve pedestrian/bicycle data quantity and quality, including geo-referencing, causes, and injury severity; and (3) using this improved data as it becomes available from the previous objectives, develop improved pedestrian/bicycle SPFs for the HSM.

♦ **Project 18-18**

Design and Construction of Wide-Flange Precast Concrete Deck Girders with Ultra-High Performance Concrete Connections for Prefabricated Bridge Elements and Systems/Accelerated Bridge Construction

Research Field:	Materials and Construction
Source:	Washington
Allocation:	$500,000
NCHRP Staff:	Waseem Dekelbab

In spite of the benefits of deck girder bridge systems for prefabricated bridge elements and systems (PBES)/accelerated bridge construction (ABC), their usage has been limited to relatively short span and low traffic bridges because of their long term performance of their connections, and difficulties in accommodating super-elevation transitions on bridge decks, pier skews, differential camber, shipping, and handling stability. Skewed girders cause bridge deck profile problems because the cambers in adjacent girders do not align. The diaphragms are then difficult to connect and/or quite big forces are induced if they are used to bring the girders into line.

In order to optimize the decked bulb tee design, the longitudinal joint between flanges must have sufficient stiffness such that the same live load distribution factor can be used as for I-girder bridges with cast-in-place decks. There are a myriad of potential variables for the joint including width, bar size, bar spacing, bar detailing (straight, bent, or headed), and black or epoxy bars. The variable flange thickness (thicker near the web) will help the ultra-high performance concrete (UHPC) joint, by attracting much of the total static moment due to a wheel load toward the negative moment region at the web and away from the mid-span region where the UHPC joint is located.

Research is needed to investigate design, fabrication, transportation, and construction of precast deck girder bridges. Other factors such as connections between adjacent units, longitudinal joints, live load distribution, continuity for live load, skew effects, and suitability of lightweight aggregates concrete need to be addressed by this research. The research should focus on optimizing the joint width. This project should address the constructability aspects and suggest methods of leveling the girders, how to determine the size of the leveling equipment needed, and means of holding the girders in the level position to allow the leveling equipment to be removed before the flange connections are fully cured.

The objective of this research is to implement design, fabrication, transportation, and construction algorithms and to develop suitable details for the connection for prefabricated deck girders with UHPC for PBES/ABC.

♦ **Project 19-14**

Methods for Identifying and Evaluating Transportation Investment Right-Sizing Scenarios

Research Field:	Administration
Source:	South Dakota
Allocation:	$500,000
NCHRP Staff:	Lawrence D. Goldstein

Across the United States, transportation agencies are faced with the same problem: given shortcomings and instability in transportation funding, assets and programs simply can no longer be maintained to formerly envisioned standards of performance. In June 2015, AASHTO president John Cox made a statement to Congress summarizing this new era of constraints: “For almost 60 years, the Highway Trust Fund provided stable, reliable and substantial highway and transit funding…However over the past seven years this has not been the case.” At the same time, practitioners are becoming wiser to the fact that the future will not be like the past, and—as John Halikowski, Director of the Arizona Department of Transportation (DOT), put it—”the only certainty is change.” As the transportation system ages, successive generations of users create patterns of demand, performance requirements, and transportation needs that differ from those for which infrastructure was originally planned and built. Agencies are struggling to balance the need to support new emerging demands with the need to maintain and preserve long-standing assets. DOTs need practical and implementable methods to analyze investment tradeoffs and “right-sizing” scenarios, so that they can continue to be good stewards of a functional and accessible transportation system—all while working within limited means.

This challenge has been highlighted nationally and by individual states. The NCHRP 750 Foresight Series presented a broad look at strategic issues facing transportation, addressing considerations related to potential freight movement, climate change, technology, sustainability, energy, and demographic trends. The series offers tools for addressing and managing uncertainty in the transportation planning process; several of the reports are structured around scenario analysis. Another community of practice centers on performance-based "practical design." As described by Utah DOT, practical design "focuses on maximizing improvements to the roadway system as a whole, rather than maximizing improvements to a few locations." It confronts the risk of both overdesign and of infrastructure shortcomings and emphasizes the use of clear objective to guide design selection. Iowa DOT Director Paul Trombino has presented similar thinking: "let's not let the system degrade and then we're left with whatever's left. Let's try to make a conscious choice." Embedded in these approaches is recognition that overdesign in one location effectively removes available funds from other potential projects and reduces overall system performance compared to a more holistic approach.

The emphasis on understanding the functional importance of individual assets relative to the overall system is situated within the much broader U.S. shift toward performance-based planning. MAP-21 promotes the use of performance measures within a risk-based planning framework. An important component of this new framework is to move beyond condition or state of repair measures alone and instead focus on maximizing the performance of the transportation system in serving society. That shift opens up the possibility to improve design or right-size an asset, rather than there being simply a binary decision of whether or not to maintain or replace the asset as-built. It also highlights the need for social and economic valuation approaches to assess tradeoffs within a goal-oriented planning process.

Despite innovations in practical design, scenario planning, and performance measurement, each year billions of dollars of investment needs are identified and go unmet. For projects and infrastructure elements that consistently fail to make the prioritization "cut," the long-term cost to either preserve, replace, or restore to even the most practical design and performance standards rises with each year of unmet needs until it becomes infeasible for some assets to ever perform efficiently. Furthermore, agencies are often unprepared to make decisions about the role and fate of these assets and do not have adequate tools to re-evaluate and address the underlying needs that such assets where originally constructed to meet. Quite simply, there are few practical and consistent mechanisms within the planning and resource allocation process by which an agency can evaluate funding trends, identify right-sizing opportunities, analyze tradeoffs across multiple objectives, and then select appropriate resource allocation strategies.

Therefore, there is a critical research need to enhance existing decision-making processes and organize available analytical tools into a well-understood best practice for "right-sizing" (determining and implementing the optimal, sustainable investment level), re-using, or disinvesting in existing assets and programs to support more efficient uses of limited funding. Absent such guidance, the problem of passive "disinvestment" will continue to pose both long-term performance challenges and economic inefficiencies.

The objective of this research is to develop practices for identifying and evaluating transportation investment right-sizing scenarios. Although agencies are generally equipped to assess investment strategies, less guidance is available on how to identify and assess right-sizing or disinvestment scenarios in ways that pinpoint opportunities associated with resource constraints. Outcomes of this research should enable agencies that today are equipped to answer "why are we spending on project A and what are its benefits" to just as well answer "why are we spending less on (or eliminating) project B and why is that a good decision, given the functional requirements of the entire transportation system?"

In particular, the research should:

1. Demonstrate how agencies can best recognize important patterns of investment decision-making and funding shortfalls across sequential long-range planning (e.g., LRTP) and near-term programming (e.g., STIP) processes. The ability to identify long-term trends in funding declines and unmet needs (by programs, asset classes, or geographic areas) is a necessary prerequisite to the identification of passive or intentional disinvestment situations and opportunities for right-sizing strategies.
2. Offer practical methods for "auditing" an identified recurring funding shortfall in a given program, asset class, or geographic area to ascertain (a) the appropriateness of current performance and design standards given the functional needs of

the system, (b) the adequacy of benchmarking and forecasting that may be informing the prioritization (e.g., is risk and uncertainty suitably accounted for?), and (c) the potential economic and financial long-term risk of the investment trend. The intent of such an audit process will be to understand what is driving recurring shortfalls (relative to the defined need) and whether there are opportunities for changing performance standards and investment strategies across programs, asset classes, or geographic areas.

3. Suggest a best practice (based on the application of developed approaches to real-world agency situations) in developing and implementing a right-sizing plan for areas facing reduced funding which includes (a) understanding and articulating the rationale for the funding decisions, (b) making the most efficient use of both the asset and its available funding under the right-sizing scenario, and (c) anticipating and mitigating the long-term consequences of the change in funding level for system users.

To be immediately applicable to transportation agency practitioners, the developed methods should build on currently available demand, risk, needs, and economic models to consider both the options and outcomes likely to arise from right-sizing or disinvestment situations. Typical planning scenarios today do not consider the economic risk of overinvestment versus underinvestment, or the potential impacts of a deliberate right-sizing scenario in comparison with an "unexpected shortfall" in revenue.

The final product of this research is envisioned to include a series of practical approaches based on pilot examples developed concurrently with transportation agency staff that (a) identify trends of declining investment, (b) assess factors driving such trends and their implications, and (c) offer right-sizing plans to manage the anticipated decline in ways that account for potential wider economic and societal impacts as well as tradeoffs among strategies. These approaches, and their associated methods, should be readily transferrable to DOTs, metropolitan planning organizations, regional planning organizations, and other agencies currently facing budget shortfalls and shifting demands. It should address related guidance demonstrating (a) how an agency decision-making process can be augmented to identify and confront situations of long-term reduced funding and (b) how agencies can apply currently available demand, risk, needs, and economic models to consider both the options and outcomes likely to arise from right-sizing or disinvestment situations.

In summary, the research should develop a business process with supporting analytical methods for identifying and evaluating transportation investment right-sizing scenarios. Specifically, a study is needed to (a) guide agencies in the identification of disinvestment situations and right-sizing opportunities and (b) clearly demonstrate how existing methods can be used in an integrated fashion to compare different investment and disinvestment scenarios while accounting for uncertainty and both the risk of overbuild and under-build in the long term.

♦ **Project 20-115**
Deploying Transportation Security Practices in State DOTs

Research Field:	Special Projects
Source:	AASHTO Special Committee on Transportation Security and Emergency Management
Allocation:	$0 ($750,000 from Transportation Security Administration)
NCHRP Staff:	Stephan. A. Parker

In 2012, the AASHTO Special Committee on Transportation Security and Emergency Management (SCOTSEM) adopted *NCHRP Report 525, Volume 14: Security 101: A Physical Security Primer for Transportation Agencies.* Since the publication of *this volume*, there have been 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, Volume 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 *NCHRP Report 525, Volume 14*, 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 primer is scheduled to be available in the fourth quarter of 2017.

As part of this project, the contractor will prepare a stand-alone technical memorandum titled "Implementation of Research Findings and Products." This required deliverable will (a) provide recommendations on how to best deploy the updated approaches into practice; (b) identify possible institutions that might take leadership in applying the research findings/products; (c) identify issues affecting potential implementation of the findings/products and recommend possible actions to address these issues; and (d) recommend methods of identifying and measuring the impacts associated with implementation of the findings/products.

Additionally, the contractor's final report will contain an Implementation Plan that describes, at a minimum, (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 judging the progress and consequences of implementation.

As noted in the NCHRP Project 20-59(51)A request for proposals, "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 transportation agencies due, in part, to a lack of tools, training, and tutors. This research is intended to more effectively bridge the gap between security research and DOT practice and thereby reduce the risk to the nation's travelers, economy, and infrastructure.

This proposed project 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 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 primer and related material developed in NCHRP Project 20-59(51)A.

♦ Project 20-116
Emergency Management in State Transportation Agencies

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

In 2012, the AASHTO Special Committee on Transportation Security and Emergency Management (SCOTSEM) adopted *NCHRP Report 525, Volume 16: A Guide to Emergency Response Planning at State Transportation Agencies*. This 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 past 5 years, the practice of emergency management has continued to mature, and in September 2015 a new project, NCHRP Project 20-59(51)B, "A Guide to Emergency Response Planning at State Transportation Agencies, Second Edition" was authorized to develop a recommended second edition guide. This update will incorporate an all-hazards perspective of the National Incident Management System (NIMS) and will include 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 available in the fourth quarter of 2017.

As a part of this project, the contractor will prepare a stand-alone technical memorandum titled "Implementation of Research Findings and Products." This required deliverable will (a) provide recommendations on how to best deploy the updated emergency response research findings/products into practice; (b) identify possible institutions that might take leadership in applying the research findings/products; (c) identify issues affecting potential implementation of the findings/products and recommend possible actions to address these issues; and (d) recommend methods of identifying and measuring the impacts associated with implementation of the findings/products.

Additionally, the contractor's final report will contain an Implementation Plan that describes, at a minimum, (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(51)B request for proposals, "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. This project is intended to more effectively bridge the gap between all-hazards emergency response research and DOT practice and thereby improve the DOT's response over a broad continuum of emergencies affecting the nation's travelers, economy, and infrastructure.

This proposed project 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 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 emergency management guidelines recommended in the updated *A Guide to Emergency Response Planning at State Transportation Agencies*, Second Edition and related material developed in NCHRP Project 20-59(51)B.

♦ **Project 20-117**

Deploying Transportation Resilience Practices in State DOTs

Research Field:	Special Projects
Source:	AASHTO Special Committee on Transportation Security and Emergency Management
Allocation:	$1,000,000
NCHRP Staff:	S. A. Parker

Although comparatively large public- and private-sector investments have been made to improve transportation system resiliency over the past decade, the 2013 TRB report *Critical Issues in Transportation* concluded that "[T]he performance of the transportation system is neither reliable nor resilient, yet transportation's role in economic revival and in global economic competition has never been more important." This finding was echoed by AASHTO's Standing Committee on Research (SCOR) which noted that "[a] major performance issue across all modes is the inadequacy of preparation" for natural and human-made disasters as well as for extreme weather events when it identified resiliency as the number one NCHRP emphasis area for FY2017.

SCOR also noted that the application of resiliency engineering in the transportation sector is still in its infancy. This finding is echoed by the USDOT, the National Academies of Sciences, Engineering, and Medicine, AASHTO's Special Committee on Transportation Security and Emergency Management, and others that have indicated the need for more work to be done in implementing systemic resilience-based approaches in surface transportation. TRB's Cooperative Research Programs have produced a wealth of resiliency-related studies, products, guidelines, and effective practices aimed at those responsible for system operations and performance. These projects include:

Airport Cooperative Research Program
ACRP Project 2-74: Integrating Climate Resiliency into Airport Management Systems
National Cooperative Freight Research Program
NCFRP Project 37: Making U.S. Ports Resilient as Part of Extended Intermodal Supply Chains

NCFRP Project 50: Improving Freight Transportation Resilience in Response to Supply Chain Disruptions

National Cooperative Highway Research Program

NCHRP Report 750: Strategic Issues Facing Transportation, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report

NCHRP Project 20-59(53): FloodCast: A Framework for Enhanced Flood Event Decision-Making for Transportation Resilience

NCHRP Project 20-101: Guidelines to Incorporate the Costs and Benefits of Adaptation Measures in Preparation for Extreme Weather Events and Climate Change

Transit Cooperative Research Program

TCRP Project A-41: Improving the Resiliency of Transit Systems Threatened by Natural Disasters

Each of the aforementioned research projects have included recommendations for implementation but have not had dedicated resources to carry out a systematic program of implementation support. Consequently, in spite of this large collective research effort, successful "on-the-ground" deployment has been ad hoc, inconsistent, fragmented, and slow. The fundamental problem is that new guidelines and effective practices developed by these and other programs are not being deployed by the state DOTs as quickly and uniformly as possible, leaving travelers, businesses and governments at greater risk than necessary.

This proposed project supports and aligns with Goal 4 of AASHTO's Special Committee on Transportation Security and Emergency Management (SCOTSEM) 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 this research is to develop a set of implementation support tools and services to assist transportation organizations in deploying resilience-based innovations and effective practices based on the implementation recommendations contained in completed resiliency research.

The scope of these services shall encompass those activities involving (1) organizational/institutional implementation (e.g., governance, business process/data, performance measures, work plans); (2) employee learning (grounded in modern adult learning theory and centered on facilitating learning in the workplace); and (3) stakeholder outreach and engagement. A significant component of the this project will be to organize a national summit and peer exchange on transportation resiliency to be held in 2017 and co-sponsored by TRB, AASHTO (SCOTSEM, Standing Committee on the Environment, and Resilient and Sustainable Transportation Systems), FHWA, Federal Emergency Management Agency, Department of Homeland Security, and other interested parties.

♦ **Project 20-118**

Effective Performance Management for Transportation Agencies

Research Field:	Special Projects
Source:	AASHTO Standing Committee on Performance Management
Allocation:	$500,000
NCHRP Staff:	Andrew C. Lemer

AASHTO's Standing Committee on Performance Management (SCOPM) serves as the technical and policy resource on transportation performance management issues for AASHTO members' work to enhance agency capabilities to ensure high agency and transportation-system performance. As such, the committee routinely identifies needs for research to address such matters as performance-measure definition, data collection requirements, analysis methods, target setting, and communication and reporting of performance delivery. SCOPM has recently initiated an ongoing "roadmap" process for identifying research needs and mobilizing resources to perform the needed research, disseminate research results, and facilitate adoption of these results in management practice. The process is being applied in cooperation with organizations representing the perspectives of local and metropolitan transportation agencies and operators.

The objective of the current project is to undertake selected initial research activities defined by SCOPM's roadmap process:

- **Comparative Performance Management – Non-Motorized Measures:** Non-motorized modes of transportation (i.e., walking and biking) are increasingly popular choices for personal travel. Understanding the impact these modes are having in meeting transportation agency objectives is needed.
- **Comparative Performance Management – Environmental Measures:** Understanding the impacts of transportation on the environment is a major challenge for state departments of transportation. A major focus of measuring environmental impact has been on vehicle emissions in congested locations. A broader perspective is needed.
- **Effective Performance Benchmarking Practices for the Transportation Sector:** Research is needed to outline effective benchmarking practices agencies can adopt quickly and to explain how these practices can be used to enhance management effectiveness among peer agencies.
- **Communicating the Importance of Establishing Performance Targets:** Research is needed to identify and document leading practices of state DOTs in establishing and communicating performance targets within in the context of federal legislation and regulatory requirements.

These initial topics may be addressed separately or in a consolidated research effort designed to support SCOPM's longer term goals.

♦ **Project 20-119**
Evaluating the Use of Highway Corridors by Monarch Butterflies

Research Field:	Special Projects
Source:	AASHTO Standing Committee on the Environment
Allocation:	$350,000
NCHRP Staff:	William C. Rogers

In response to the decline of critical pollinators, including butterflies, a presidential memorandum entitled, "Creating a Federal Strategy to Promote the Health of Honey Bees and other Pollinators," established the Pollinator Health Task Force. The U.S. Department of Transportation is a member of this task force and is tasked with evaluating its current guidance and identifying opportunities for establishing pollinator habitat and promoting pollinator friendly practices in transportation corridors.

The monarch butterfly is found throughout the lower 48 states, Hawaii, southern Canada, and northern South America. Because of its large bright orange and black-patterned wings and its migration path spanning much of the northwestern hemisphere, its decline has been more noticeable than most other pollinators. This butterfly has experienced a 59 percent decline, based on observations when they are concentrated in overwintering grounds. Reasons for its decline: habitat and food source loss; invasive plant species that outcompete milkweed; species both native and introduced that mimic milkweed and fool the butterfly into laying eggs where the milkweed required for the larval stage does not exist; pesticide use; and illegal logging in its very limited overwintering grounds. Milkweeds, which provide food for the larval stage, are often considered "weeds" in need of eradication in agricultural settings.

Research is needed to expand on the existing body of knowledge around roadside pollinator habitat to provide a better understanding of the relationship between long-term maintenance and roadside management activities. In particular, the information will assist in evaluating potential tradeoffs between providing monarch butterfly habitat and safety concerns relative to changes in maintenance practices to maintain the habitat.

The objectives of the research are to (1) provide objective answers as to whether planting native species, including the milkweeds preferred by the larval stage of the butterfly and nectar producing plants for the adult stage, along roadways contributes to sustainable or increased populations; (2) produce implementation guidelines on the minimal area of plantings needed to create effective habitat enhancement for the monarch butterfly, as well as location of plantings in the roadside topography, and whether planting too close to the roadway may increase butterfly mortality through strikes by vehicles or mowing plants when larvae are present in clear zones; and (3) provide information to state departments of transportation about the impacts of transportation on and benefits and drawbacks of planting milkweed and nectar providing plantings for the butterfly.

♦ Project 22-32

Development of Methods to Evaluate Side Impacts with Roadside Safety Features

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

Side impacts of vehicles into roadside hardware are a growing public safety problem. In particular, side impacts with guardrail account for 22 percent of fatalities in passenger vehicle-guardrail crashes. The occupant of a car that side impacts a guardrail has a 30 percent higher probability of being fatally injured than the occupant of a car involved in a frontal impact into a guardrail. Many roadside safety features (e.g., guardrail end treatments, crash cushions, and luminaire supports) are designed to break away under the loads which are typical of a frontal impact. However, side impacts by non-tracking vehicles may not have enough force to engage the breakaway mechanisms of these features. Because the side of a vehicle, unlike the front, has so little structure and crumple zone, side impacts can be especially severe from an injury standpoint.

To date, however, no substantive improvements have been made to the performance of roadside safety features during vehicle side impacts. *NCHRP Report 350* provided side impact test and evaluation procedures for informational purposes, but made no recommendations or requirements for side impact crash testing of roadside hardware. More recently, the appendix for side impact test and evaluation procedures was not included in the AASHTO *Manual for Assessing Safety Hardware* (MASH) crash test procedures. The few available side impact tests in the literature are now over 20 years old and were performed on a previous generation of roadside hardware with a previous generation of vehicles. Little is known about how compliant hardware performs in side impact crashes. The development of methods for evaluating these crashes would lead to improvements in roadside safety hardware and improved safety of the motoring public.

The objective of this research program will be to determine the effectiveness of current generation roadside safety hardware in side impact collisions, develop methods to evaluate and reduce the risk of serious and fatal injury in non-tracking side impacts with roadside safety devices, and establish crash test procedures based upon the developed methods. It is anticipated that this project would also identify critical hardware with respect to side impacts, determine critical impact conditions for evaluation of side impacts, and develop evaluation criteria for assessing the performance of roadside hardware in a side impact event, such as occupant risk criteria and occupant compartment deformation limits.

The project outcome will be the development of a comprehensive approach for evaluating roadside hardware under side impact conditions with the intent of incorporating this approach into the MASH crash testing procedures. The addition of side impact evaluations in MASH crash testing procedures would lead to an improvement in roadside safety hardware and, subsequently, improve safety of the motoring public. The proposed research directly supports the AASHTO TCRS mission of developing, implementing, and maintaining evaluation standards to support roadside safety innovation and decision-making.

♦ Project 22-33

Development of a Collaborative Approach for Multi-State In-Service Evaluations of Roadside Safety Hardware

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$650,000
NCHRP Staff:	Mark S. Bush

Roadside safety hardware (e.g., guardrail, bridge rail, crash cushion, etc.) is installed along the roadways to reduce the risk of serious and fatal injuries to motorists in inadvertent road departures. Impact performance criteria for roadside hardware are detailed in AASHTO MASH, based on full scale crash testing. MASH prescribes a set of specific crash tests which are limited to frontal crashes of cars, light trucks, and selected heavy vehicles. The tests are conducted under ideal site conditions, (e.g., non-sloped surfaces, idealized soils for post embedment, installation by expert installers, and carefully controlled impact conditions). MASH tests represent only a fraction of the potential types of crashes and site conditions which motorists may experience in the field. While an important means of checking impact performance, the tests are limited in what they can tell us about field performance where vehicles and occupants experience a broad range of site, impact, and field conditions.

Since *NCHRP Report 230* was published in 1981 through the current testing guidelines in MASH, in-service evaluation has been recommended as the final step in evaluating roadside hardware including end terminals. *NCHRP Report 490*, published in 2003, provided detailed procedures and guidelines for performing in-service evaluations including in-service evaluations of roadside safety hardware. Although the roadside safety community has agreed for over three decades about the importance of in-service evaluations and procedures have been available for nearly a decade, relatively few in-service performance evaluations have been completed and their role in making decisions about roadside safety is not well defined.

The need to fully understand the actual real world performance of existing and new roadside hardware safety devices has been underlined by recent concerns over guardrail end terminal performance. However, end terminals are only one example of the many types of engineered roadside systems which are crash tested and widely deployed, but for which little is known about field performance. The development of a more proactive approach, which incorporates the efforts of all affected state DOTs is urgently needed to evaluate the actual in service performance of the full range of roadside safety hardware currently in service on the nation's highway system.

The objectives of this research are to: (1) work with the states to identify the opportunities, challenges, institutional barriers, and costs associated of multi-state in-service performance evaluations (ISPE); (2) develop necessary collaborative support tools for multi-state collection and analysis of ISPE data; (3) coordinate with other existing studies and update *NCHRP Report 490* to reflect advancements in data collection and asset management protocols; (4) identify and train early adopting states in an enhanced multi-state ISPE protocol; (5) demonstrate the new protocol by working with selected states to identify a common problem of interest; (6) organize and conduct a workshop as a forum for early adopting parties in order to report results and determine possible procedures for use of the conducted ISPE and appropriate measures of effectiveness.

This research would likely result in improved recommendations and updates to the AASHTO Roadside Design Guide and would also likely provide valuable information for the FHWA and state transportation agencies in developing up-grade, retrofit and replacement policies regarding end terminals and barrier treatments. Finally, a comprehensive multi-region ISPE program would also provide the real-world foundation to potentially modify AASHTO MASH in order that crash testing results are more representative to actual crashes in the field.