National Cooperative Highway Research Program

Fiscal Year 2023 May 2022

Announcement of Research Projects

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

Each year, AASHTO refers a research program to the TRB consisting of high-priority problems for which solutions are required by the states. The NCHRP program for FY 2023 is expected to include 12 continuations and 59 new projects.

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

Before nominating yourself to serve as a panel member, please review our Conflict of Interest policy: https://www.trb.org/NCHRP/COI-CRP.aspx. Please be advised that if you are selected to serve on a panel and we receive a proposal for that project that presents a conflict of interest for you, we will reject the proposal. This also applies to liaisons.

Detailed Requests for Proposals (RFPs) for these new projects will be developed beginning in September 2022. Please note that NCHRP requests for proposals (RFPs) are available only on the TRBwebsite. Those who have an interest in receiving RFPs can register on the website http://trb.org/nchrp. Upon registration, you will receive an e-mail notification of every RFP posting and an e-mail notification of new anticipated projects in future years.

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

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IMPORTANT NOTICE

Potential proposers should understand clearly that the research program described herein is tentative. The final program will depend on the level of funding available from the Federal-aid apportionments for FY 2023. Meanwhile, to ensure that research contracts can be executed as soon as possible after the beginning of the fiscal year, the NCHRP is proceeding with the customary sequence of events through the point of research agency selection for all projects. The first round of detailed Requests for Proposals will be available starting in September 2022; proposals will be due beginning in October 2022, and research agency selections will be made beginning in December 2022. 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 2023 program will cease until the funding authorization is known. These circumstances of uncertainty are beyond NCHRP control and are covered here so that potential proposers will be aware of the risk inherent in electing to propose on tentative projects.

National Cooperative Highway Research Program
NCHRP FY 2023

Project Number	Problem Number	Title	Allocation	Project Manager	Synopsis Page No.
01-62	C-06	Impact of Flooding and Inundation on the Resiliency of Pavements	$650,000	Barcena	5
03-145	G-12	National Traffic Sensor System Evaluation Program	$600,000	Deng	5
03-146	G-13	Transportation Operations Manual Best Practices Guide	$350,000	Deng	6
03-147	G-18	LED Applications on Traffic Control Devices	$500,000	McKenney	7
03-148	G-26	Capabilities, Requirements, Planning, and Preparing to Virtually Operate Traffic Management Systems (TMS).	$600,000	Deng	8
03-149	G-32	Signal Timing Manual: Development of the Third Edition	$750,000	Deng	9
05-26	G-01	Development of an Updated Warranting System for Roadway Lighting	$350,000	McKenney	11
05-27	G-20	Best Practices for Roundabout and Alternative Intersection/Interchange Lighting	$500,000	Retting	12
07-33	G-14	Evaluate the Benefits of Increasing Clear Zone at Higher Speed/Traffic Volume/Crash Locations	$450,000	Crichton-Sumners	13
07-34	G-28	Toward Artificial Intelligence-Enabled Decision Support Systems for TSMO Applications	$450,000	Deng	13
08-163	B-03	Defining Appropriate Design and Accommodation Thresholds for Active Transportation in a Context-Driven Approach	$550,000	Weeks	15
08-164	B-04	Institutional Integration of Active Transportation	$600,000	Crichton-Sumners	16
08-165	B-05	Integrating Active Transportation Data into Transportation Decision-Making	$550,000	Weeks	17
08-166	B-06	Racial and Economic Disparities in Pedestrian and Bicyclist Safety	$750,000	Weeks	18
08-167	B-08	A Guide for Creating Effective Visualizations	$375,000	McKenney	18
08-168	B-09	Analysis and Assessment of the National Performance Management Data	$550,000	Barcena	19
08-169	B-10	Equity, Diversity, and Inclusion, and Other Indicators to Improve Transportation Asset Management Impact and Outcomes	$500,000	Weeks	20
08-170	B-12	Frameworks, Guidance, and Tools to Support Post-Implementation Evaluation of Transportation Projects	$600,000	Weeks	21
08-171	B-13	Institutionalizing Safe Systems and Safety Culture in the Transportation Planning Process	$400,000	Schwager	21

Project Number	Problem Number	Title	Allocation	Project Manager	Synopsis Page No.
08-172	B-14	Benefit Analysis of Private Health Sector Investments in Public/Human Transportation	$400,000	Crichton-Sumners	22
08-173	B-35	Impacts of E-Commerce on Travel and Land Use Patterns	$400,000	Weeks	23
10-115	D-02	Guide on Progressive Design-Build for Transportation Projects: Project Planning through Project Implementation	$300,000	McKenney	24
10-116	D-04	Variability in Pavement Materials and Construction	$500,000	Hanna	25
10-117	D-06	GFRP Barrier Testing Evaluation and Repair Strategies	$850,000	Hanna	26
10-118	D-07	Guidance for Efficient Timelines and Incentives/Disincentives for Accelerated Bridge Construction Projects	$275,000	Abu-Hawash	27
10-119	D-08	Guidelines for Implementing Utility Investigations in Alignment with Project Delivery	$400,000	Jared	28
10-120	D-09	Guidance for Including Right-Of-Way and Utilities in Value Engineering Studies	$400,000	McKenney	29
10-121	D-13	Performance-based Specification for the Application of Ground Modification Methods for Bridges, Retaining Structures, and Associated Geotechnical Features	$450,000	Abu-Hawash	30
10-122	D-17	Update of the AASHTO Practical Guide to Cost Estimating (PGCE)	$250,000	McKenney	31
10-123	D-18	Quality Assurance and Sustainability	$350,000	Hanna	31
10-124	D-23	Development of Field Test to Determine Actual Percent Embedment of Chip Seal Aggregate	$400,000	Barcena	33
10-125	D-26	Update to the AASHTO LRFD Bridge Construction Specifications	$800,000	Abu-Hawash	34
12-125	C-07	Earthquake-Induced Bridge Displacements	$450,000	Abu-Hawash	35
14-36(01)		AASHTO Guide to Bridge Preservation Actions Implementation Workshops	$355,000	Abu-Hawash	36
15-82	C-11	Effects of Operating Speed and Posted Speed Limit in Conjunction with Roadway Geometric Design on Safety Performance for High-Speed Rural Highways and Freeways	$950,000	Deng	36
17-111	G-02	Speed Management Solutions and Strategies to Improve Pedestrian and Bicyclist Safety on Arterial Roadways	$550,000	Deng	38
17-112	G-03	Enhancing Highway Safety Manual Guidance on Pedestrian and Bicyclist Countermeasures (CMF/SPF Development)	$600,000	Retting	39

Project Number	Problem Number	Title	Allocation	Project Manager	Synopsis Page No.
17-113	G-04	Incorporating Safe System Approach into the NCHRP 500 Series	$700,000	Retting	40
17-114	G-05	Integrated Strategies for Managing High Travel Speeds	$500,000	Deng	41
17-115	G-08	Pedestrian Crosswalk Spacing and Placement Guidance to Improve Safety	$500,000	Deng	42
17-116	G-09	Practical Approaches to Quantifying Safe System Concepts	$450,000	Jared	44
17-117	G-10	Safety Performance Functions for Horizontal Curves	$350,000	Deng	45
17-118	G-11	Understanding the Impacts of Operational Changes on Safety Performance	$450,000	Retting	46
17-119	G-15	Conflict-Based Crash Prediction Method for Intersections	$550,000	Deng	48
17-120	G-19	Improved Method to Link Crash, Emergency Medical Service, and Trauma Registry Data to Expand Safety Data Analyses and Safety Program Development	$400,000	Retting	48
17-121	G-24	Using Advanced Technologies to Reduce Commercial Motor Vehicle Crashes in Work Zones	$500,000	Crichton-Sumners	50
17-122	G-27	Evaluation of Trespassing Detection and Warning Systems in the Vicinity of Highway-Rail Grade Crossings	$450,000	Hanna	50
19-22	A-03	Future Equity Impacts of Existing Fuel Taxes	$450,000	Crichton-Sumners	52
19-23	A-04	New Mobility and the User Fee Concept	$450,000	Schwager	53
22-57	C-03	Development of MASH Full-Scale Test Matrices for Additional Roadside Safety Devices	$500,000	Jared	53
22-58	C-04	National Guidance for Defining Acceptable Roadside Hardware Field Performance through In-Service Performance Evaluations (ISPEs)	$400,000	Barcena	54
23-29	A-02	Enterprise Data Warehouse Implementation Guide	$350,000	Barcena	54
23-30	A-05	Knowledge Strategies to Support the Research Lifecycle and Application of Research Results	$400,000	Jared	55
23-31	A-06	Lessons Learned from Two Decades of Knowledge Management	$250,000	Jared	56
23-32	A-08	Development of the AASHTO Transportation Asset Risk & Resilience Manual: Phase 1	$4,000,000	Abu-Hawash	57
23-33	A-11	Guidance in Planning for Managed Retreat as an Extreme Weather and Climate Adaptation Strategy	$500,000	Crichton-Sumners	59
25-66	B-15	Update the National REMEL Database Used in FHWA Traffic Noise Model	$1,000,000	Deng	60

Project Number	Problem Number	Title	Allocation	Project Manager	Synopsis Page No.
25-67	B-19	Cultural Resources Mitigation: What Works and What Doesn't?	$500,000	Weeks	61
25-68	B-23	Successful Practices in Tracking and Implementing Environmental Commitments	$350,000	Weeks	62

Project 01-62
Impact of Flooding and Inundation on the Resiliency of Pavements

Research Field: Design
Source: AASHTO Committee on Pavements
Allocation: $650,000
NCHRP Staff: Roberto Barcena

The resiliency of pavements after inundation by flooding will gain greater significance in the foreseeable future. For many years, transportation agencies have dealt with the aftermath of flooding from major storm events, but the threat of sea-level rise from global climate change now looms more ominously. During the 20th century, the sea level rose 15-20 centimeters (roughly 1.5 to 2.0 mm/year), with the rate accelerating towards the end of the century. Climatological projections predict an even faster sea-level rise in the 21st century.

The objective of this research is to determine the impact that submergence and inundation related to flooding and sea-level rise have on the long-term performance of pavement systems and provide guidance on improving pavement resiliency.

Research results will support the development of design guidelines, standard practices, training sessions, and other activities that can be given to practicing engineers for limiting flood damage to new and existing pavements.

Project 03-145
National Traffic Sensor System Evaluation Program

Research Field: Traffic
Source: AASHTO Committee on Transportation System and Operations
Allocation: $600,000
NCHRP Staff: Zuxuan Deng

Traffic sensors are essential components of all highway traffic monitoring and traffic management systems. Traffic monitoring depends upon reliable vehicle detection and accurate measurement of traffic volume, speed, classification, and weight. Active traffic management systems and other intelligent transportation systems applications require these parameters and more, for varied uses like wrong-way driving detection, near-miss crash analysis, commercial vehicle screening, predictive analysis, and others.

Sensor systems based on new and emerging technologies—such as optics, electronics, communications, and artificial intelligence—are rapidly supplanting traditional traffic sensor systems, but their accuracy and performance typically lack objective and independent evaluation. State and local agencies must often rely on informal, inconclusive evaluations and pilot deployments to assess sensor systems' suitability for highway applications. The burden to test every sensor type and revision that comes to market creates massive duplication of effort and wastes time, effort, and funding.

Although millions of traffic sensors are in use, manufacturers and distributers can rarely provide independent third-party test results demonstrating their real-world performance. Sensor errors can seriously affect safety and mobility, particularly in critical traffic contexts. For example, the lack of quantified error rates and types introduces significant risk into use cases involving high traffic volumes and speeds. In addition, the lack of information regarding system performance and reliability in different operational domains can lead to misapplication of sensor systems, unacceptable performance, or short service life.

An authoritative method is needed to characterize the performance and identify the operational domains of current and emerging traffic sensor systems. The research should develop test procedures that could be applied within the AASHTO's National Transportation Product Evaluation Program or a similar program.

This research should examine current practice and needs, and then define a comprehensive evaluation methodology applicable to traffic management and traffic monitoring sensor systems in each mode being detected (e.g., vehicle, pedestrian, and bicycle). The test protocols should incorporate factors such as weather conditions, lighting and background, and traffic and roadway characteristics to characterize sensors' operational domains. The methodology will allow testing laboratories to evaluate sensor systems and show whether the methods and protocols are replicable, transferable, and ultimately useful to transportation agencies. The research should also examine the feasibility of establishing a national testing program through existing or newly created institutions and evaluate potential business models in consideration of the needs and receptivity of transportation agencies and industry.

Project 03-146
Transportation Operations Manual Best Practices Guide

Research Field: Traffic
Source: AASHTO Committee on Transportation System and Operations
Allocation: $350,000
NCHRP Staff: Zuxuan Deng

The *Transportation Operations Manual* (Manual) being developed under NCHRP Project 03-126, "Transportation Operations Manual" is nearing completion and should be published in 2022. To support the implementation of the Manual, this project would identify best practices for each of the Manual topics by organizing and identifying best practices found in existing case studies gathered by the National Operations Center of Excellence (NOCoE), from the AASHTO Committee on Transportation System Operations (CTSO) best practices webinar series, and other industry resources.

The project will identify gaps between the existing body of knowledge already gathered by the NOCoE and the Manual's chapters and fill those gaps through gathering additional case studies and best practices. The resulting product would be a digital best practices guide that would support the Manual chapters with practical real-world examples and best practices. The framework for the best practices guide should enable updates through the NOCoE's ongoing work in gathering case studies and best practices.

The objective of this research is to have a best practices guide that would support the Manual chapters with practical real-world examples and best practices. Potential tasks could include: (1) identifying and categorizing best practices found in the NOCoE Case Study Library; (2) identifying and categorizing best practices found in additional resources, including the CTSO Best Practices Webinar Series, resources in the NOCoE Knowledge Center, existing NCHRP research, and FHWA peer exchange and state-of-the-practice materials; (3) identifying gaps between the existing body of knowledge already gathered by the NOCoE and the Manual chapters and filling those gaps through gathering of additional case studies and best practices; and (4) establishing a framework for the best practices guide, including how best practices are categorized to support the implementation of the guide as well as how users will most effectively access the information.

Project 03-147
LED Applications on Traffic Control Devices

Research Field: Traffic
Source: Delaware Department of Transportation
Allocation: $500,000
NCHRP Staff: Christopher McKenney

The use of LED's has expanded into the traffic control area with units used to enhance attention/conspicuity of signs, create dynamic sign legends, and provide basic traffic control. The *Manual on Uniform Traffic Control Devices* (MUTCD) administered by the Federal Highway Administration (FHWA) contains limited LED provisions to guide LED applications. This has led to uncertainty on the part of transportation agencies for the appropriate application of LED's in traffic control applications. The National Committee on Uniform Traffic Control Devices has submitted LED recommendations to FHWA that maintain basic traffic control concepts, recognize the adaptability of LED technology, and provide guidance for LED use. In the course of developing those recommendations, a number of issues were identified where research was not available to support the recommendations. There continues to be growing use of LED signs without clear understanding of possible safety advantages and impacts to automated vehicles, road users, and adjacent residents. Therefore, research is needed to provide industry clarification on the LED applications and guide roadway agencies on basic traffic control concepts that ensure life cycle of significant investments and safety to road users.

The objective of this research is to evaluate various LED sign applications and provide research data that supports the best LED application on regulatory and warning signs for the road user. To accomplish the research objective, a research plan for each issue in priority order should be developed and approved, which could include:

- What is the optimal refresh rate for LEDs in traffic control applications, and how can this be shared across street lighting and vehicle lighting use?
- Would different specified flash rates for beacons based upon groups of signs, such as stop, warning, or pedestrian, to identify the sign application be beneficial for the road user?
- When should the various flash rates be applied to produce the best outcomes for safety? Should these flash rates be unique to single traffic control devices or applications to have maximum effect? Given the range of enhanced conspicuity, which flashing rates align with various traffic control devices?
- What LED pitch or spacing should be used to display sign legend and provide maximum sign legibility consistent with MUTCD legends, text, and symbols? Can standard CMS (define) font forms matching the standard highway fonts be created to improve uniformity?
- What spacing of LED's in the border are needed to identify the sign shape for the various regulatory and warning signs and provide enhance conspicuity?
- What are the recommended LED size for regulatory and warning sign applications that provide the best sign conspicuity while preserving sign legibility? Does the size of LED,

dimming, or the intensity of display impact glare and road user/automated vehicle recognition of traffic control device function?

- Does the use of LED's in sign legends permit smaller sign sizes for the some roadway applications?

Potential tasks include (1) conduct a literature search; (2) investigate current state of the practice; (3) create research approaches that provide data-driven resolution to each of the issues/questions; (4) conduct research studies that provide data and support to determine optimal LED specifications; and (5) develop recommendations based on the research to address the issues identified and identify potential solutions that may include physical, electronic, or operational changes to traffic control devices, vehicle image capture and image processing systems, or both, that meet the needs of human drivers and automated driving systems.

Project 03-148
Capabilities, Requirements, Planning, and Preparing to Virtually Operate Traffic Management Systems (TMSs)

Research Field:	Traffic
Source:	AASHTO Committee on Transportation System and Operations; Georgia Department of Transportation
Allocation:	$600,000
NCHRP Staff:	Zuxuan Deng

The ability to virtually manage and operate traffic management systems (TMSs) is no longer a luxury. It needs to be a capability of the system and a core capacity of an agency's operations program. It has become a necessity for agencies to work toward developing and sustaining the capabilities and having the resources necessary to remotely manage and operate their own or another agency's TMS. Agencies continue to explore which organizational policies, procedures, capacity, resources, and capabilities may be needed when the agencies determine it is in their interest to virtually manage and operate their TMSs to support day-to-day traffic management for planned (e.g., concerts, festivals) and unplanned (e.g., during the COVID-19 pandemic or a weather emergency) special events. Agencies are looking to develop and adopt policies, operational procedures, review and identify human resource requirements, and identify the resources and changes needed to allow TMSs to be managed and operated virtually and ensure TMSs and their operations centers can be managed and operated remotely. Agencies are also looking for resources to explore what planning, development, and training may be needed to successfully position or prepare TMSs with the capabilities and resources needed to allow an agency to transition the operation of a TMS, involving highly technical traffic management centers, to a virtual operating environment with minimal service disruptions.

This research should address issues and analyses appropriate for agencies to consider when assessing the current capabilities, needs, requirements, and possible improvements that may be needed to enable current or the next generation of an agency's TMS to be managed and operated virtually or remotely. This research should identify the policies, procedures, processes, staffing (e.g., human resource issues), tools (e.g., laptops), capabilities (e.g., internet access, electronic access to data, secure access to operating systems), and practices for agencies to consider when planning, developing, preparing, testing, transitioning, and evaluating the ability of existing or the next generation of an agencies TMSs to have the ability to virtually manage and operate TMSs.

Considerations for virtual operations may include necessary security measures to be developed and in place; verify needed resources are available and functioning; and the development, testing, implementation, and verification of specific system capabilities (e.g., remote access to electronic files and user interface for system), policies, procedures, operational protocols, testing, and training resources are available.

The objective of this research is to develop two technical resources:.

1. The first technical report will compile and review available resources, offer insights, and synthesize current practices for agencies to consider in the planning, design, and development of projects to improve their TMSs to enable virtual operations. It should also assess and identify key issues to consider (capabilities, needs, requirements, technologies, and other issues) to integrate the virtual or remote operation of a TMS into the planning or design of a new or improved legacy system. This information will support agencies in assessing the current capabilities of legacy TMSs, identifying possible improvements needed to enable or meet agencies needs for operating virtually, assessing the capabilities and requirements when planning or designing the next generation of their TMS.
2. The second technical report will explore issues agencies may consider to ensure they have the authority, policies, procedures, capability (e.g., human resource issues, position descriptions, security clearances), capacity (e.g., IT, security, access to agencies operating system and files), and resources (e.g., access to resources normally available and used in the operations center, laptops for remote access, internet access, software) to ensure remote operation of their TMS. This research will also explore the range of initiatives, planning, projects, testing (e.g., acceptance testing, scenario training), and training agencies may conduct in support of establishing, using, and demonstrating ability to virtually managing and operate their agencies, or another agencies TMS.

This research could be executed in phases, and potential tasks may include preparation of a literature review, development of an annotated outline for the technical report, development of the final deliverables, and preparation of outreach materials.

Project 03-149
Signal Timing Manual: Development of the Third Edition

Research Field: Traffic
Source: Utah Department of Transportation
Allocation: $750,000
NCHRP Staff: Zuxuan Deng

The *Signal Timing Manual* (STM) has been the most widely accepted reference across the signal timing field. Since the release of its second edition in 2015 (STMv2), there have been significant advances in signal timing research and practices. Several NCHRP and FHWA initiatives have been implemented, and major industry references such as *Highway Capacity Manual*, 6th edition (2016), *Highway Capacity Manual*, 7th edition (2022), NEMA-TS2 Standard Version 3.07 (2016), and NTCIP 1202 v03A (2019), have been updated incorporating new computational methods and operational practices. New technological trends have emerged, such as applying new computational approaches to the signal timing process, developing signal timing plans using novel datasets, and instrumenting new signal timing paradigm for connected and autonomous vehicles (CAV). The signal timing community has highlighted important topics to be addressed in a new version of the STM, including the signal timing of unconventional intersection geometries; advanced bicycle, pedestrian, and transit signal timing; cybersecurity risks tied to the signal timing procedures; and innovative signal timing design using standards-based controller features.

While the current STM edition has materially assisted traffic signal professionals, it was developed in the previous decade and is lacking coverage of the most up-to-date developments in the signal timing field. There is an urgent need to develop a new edition (STMv3) that incorporates outcomes of the latest NCHRP and FHWA initiatives that have advanced to successful implementation, and the latest updates of major industry references (e.g., NEMA-TS2, NTCIP 1202, HCM6 and HCM7); provides timely coverage of new technological trends applicable to the signal timing process; and addresses common interests of the community with added or updated topics.

The purpose of this research is to update the current STM, which will be a decade old by the time the STMv3 is published. The new edition will synthesize up-to-date best practices and research outcomes that have been successfully implemented after STMv2, provide proper coverage of technological trends applicable to the signal timing process, and complement existing STM structure with updated and new chapters addressing common interests of the signal timing community.

Potential topics to be covered include:

1. New technological trends relevant and applicable to the signal timing process, such as the usage of novel datasets for developing signal timing plans, new computational methods, and new signal timing paradigms for CAVs.
2. Cybersecurity in the signal timing process, and related policy implications.
3. Updated guidance and support systems to effectively manage, operate, and maintain traffic signals.
4. Updated guidelines on flashing yellow arrows and signal phasing. Multimodal signal timing and performance measures, including advanced treatments for bicycle, pedestrian, and transit signal timing. Best signal timing practice for divergent diamond interchanges, single-point urban interchanges, and unconventional arterial intersection designs. Performance measures about right-turn-on-red operations.
5. Enhancement of the current STM structure, providing proper details, references, guidelines, or illustrative examples. Candidate subjects include Dallas phasing, third-car detection for permissive/protected left turns, application of peer-to-peer communications and logic processors, innovative usage of overlaps, advanced detection logics, algorithmic details for typical transit signal priority, preemption, and transition logics.

Potential tasks may include: (1) conduct an up-to-date state-of-the-art review, and review purpose, objectives, target users, and target usage for the STM and identify major gaps in current STM edition; (2) identify subjects, updates, and additions; and (3) prepare training materials based on the new STM edition.

Project 05-26
Development of an Updated Warranting System for Roadway Lighting

Research Field: Traffic
Source: AASHTO Technical Committee on Roadway Lighting and Delaware Department of Transportation
Allocation: $350,000
NCHRP Staff: Christopher McKenney

Many state and local departments of transportation (DOTs) and safety practitioners use warranting to define the need for lighting. Currently there are two main warranting systems for roadway lighting: one is in the AASHTO *Roadway Lighting Design Guide* that defines lighting warrants for freeways and highways, and the other in The Transportation Association of Canada (TAC) *Guide for the Design of Roadway Lighting* that defines warranting for streets, highways, freeways, and intersections. The majority of the warranting in TAC is based on a weighted point score system developed in the 1970s and derived from an early 1970s NCHRP research and the late 1970s FHWA *Federal Highways Lighting Handbook*. The AASHTO warranting system was developed in the early 1980s and has not changed significantly since then. Although the AASHTO and TAC publications are relatively current, the warranting system contained within them has not been updated in at least 30 years.

The existing warrants for lighting were developed before the recent development of active safety systems in vehicles, solid-state lighting, and the implementation of the use of crash modification factors (CMFs) in roadway safety analysis. With the advancement of applications of LED lighting system for new or replacement of existing lighting fixtures, there is a significant requirement to create new data associated with the need for new lighting. In addition, warrants do not address safety-based alternatives to roadway lighting, which include retroreflective pavement marking and roadside delineators. There is also growing pressure to reduce potential environmental impacts of roadway lighting. Jurisdictions often must balance the safety benefits of roadway lighting while aiming to reduce potential environmental impacts, such as energy use and impacts to wildlife.

Roadway lighting also can be expensive to install and operate. Over-lit and unwarranted lighting luminaires can result in excessive glare, lighting trespass in the adjoining neighborhood, and sky glow. Additionally, current warranting systems do not address the cost-benefit of roadway lighting as a safety measure compared to other safety alternatives, resulting in inconsistency as to where and when roadway lighting is applied. Therefore, research is needed to develop appropriate CMFs for state-of-the-art lighting system as most state and local DOTs are relying on CMF to justify the safety benefits of installing roadway lighting.

The objective of this research is to develop an updated warranting system that (1) provides linkages to CMFs, and (2) assess roadway lighting compared to other roadway safety treatments and consider the safety impacts on modern vehicle technology and new lighting technologies. The goal would be to develop a system that is easy to use and creates consistency with respect to how roadway lighting is applied as a safety countermeasure. In addition, other safety measure frameworks to access the benefit of roadway lighting to other road safety measures also would be discussed.

Project 05-27
Best Practices for Roundabout and Alternative Intersection/Interchange Lighting

Research Field: Traffic
Source: AASHTO Technical Committee on Roadway Lighting and Delaware Department of Transportation
Allocation: $500,000
NCHRP Staff: Richard Retting

Alternative (or innovative) intersections and interchanges are junctions of two or more roads that do not use traditional intersection or interchange layouts. Most alternative intersections/interchanges installed in the United States have roadway lighting, in part because lighting is supported by FHWA's Alternative Intersection and Interchange Report and *NCHRP Report 672: Roundabouts: An Information Guide*. However, lighting adds significantly to the upfront construction cost and ongoing maintenance costs, which can be a barrier to successful implementation. Lighting can also be a barrier to implementing projects where local communities are concerned about light pollution or trespass. Some agencies have a formal or informal policy that alternative intersections/interchanges must be lit, but do not necessarily light traditional signalized intersections (a policy that may be backwards given that traditional signalized intersections typically have a greater number of conflict points for pedestrians and vehicles than alternative intersections/interchanges).

The objective of this research is to provide answers to the following questions:

1. What safety benefits can lighting provide for motorists and pedestrians at various alternative intersection/interchange types?
2. Can criteria be established that prioritizes what characteristics of alternative intersections/interchanges most strongly warrant lighting? Example criteria might include number of lanes (e.g., multilane vs. single-lane roundabouts), presence of pedestrian or bicycle facilities, etc.
3. What are best practices for lighting design of alternative intersections/interchanges?
4. For some junction types, lighting has been recommended to reduce risk of wrong-way entry, for example going clockwise in a roundabout or entering wrong-way on a diverging diamond interchange. Does lighting provide measurable benefit in reducing risk of such maneuvers? Note that for alternative interchanges, wrong-way entry risk may be lower than it is at traditional diamond interchanges.

Potential research activities include (1) literature review; (2) survey of current state practices, and practices in other countries where roundabouts are more common than in the United States; (3) review crash data for existing alternative intersections/interchanges with and without lighting; (4) driver simulation analyses of various alternative intersection/interchange types with and without lighting, and with different lighting strategies; and (5) develop conceptual layouts showing recommended pole/luminaire placement for common alternative intersection/interchange types. The primary final product would be suggested revisions to the AASHTO Roadway Lighting Design Guide.

Project 07-33
Evaluate the Benefits of Increasing Clear Zone at Higher Speed/Traffic Volume/Crash Locations

Research Field: Traffic
Source: AASHTO Committee on Design, Technical Committee on Roadside Safety
Allocation: $450,000
NCHRP Staff: Camille Crichton-Sumners

The current edition of the AASHTO *Roadside Design Guide* (RDG) provides guidance to transportation agencies to develop standards and policies for determining the widths of clear zones along roadways based on design speed, traffic volume, roadside slope, and curvature. By providing clear zones, transportation agencies can increase the likelihood that a roadway departure results in a safe recovery and mitigate the severity of crashes that do occur. The development and use of the clear zone concept has dramatically reduced the number of crashes, injuries, and fatalities on urban and rural highways. The RDG provides only a general approximation of the needed clear zone distance. Clear zone recommendations can be extrapolated for design speeds greater than the maximum ranges shown in the 4th edition of the RDG, corresponding to 65 to 70 mph (100 to 110 km/h) and for average daily traffic (ADT) greater than 6,000 vehicles/day or more. However, it is unclear if extrapolated values are optimized for posted speed limits (PSLs) greater than 70 mph (110 km/h) or for roads with ADTs significantly higher than 6,000 vehicle/day.

Two of the key factors in assessing risk are design speed and traffic volumes. In some locations in the United States, PSLs have been increased to 80 mph (129 km/h) or more, and there are many segments of highway in which the ADT is greater than 50,000 vehicles/day. Limited data has been collected to evaluate the effectiveness of clear zone recommendations not consistent with the existing ranges shown in the RDG. The width of the clear zone should be based on actual risks. Therefore, there is a need to analyze crash data to determine if revisions to the RDG clear zones are warranted to accommodate increased design speeds, locations with higher crash frequencies, and increased traffic volumes. The guidance developed through this research directly correlates with TCRS' (define) Strategic Plan and the number one goal in the TCRS mission statement is, "develop, implement, and maintain guidance which will reduce fatal and incapacitating-injury roadway departure crashes." Results of this research will help guide future editions of MASH, the RDG, and other AASHTO documents.

The research objective is to recommend guidelines for clear zone values corresponding to conditions with design speeds, traffic volumes, and crash frequencies in excess of thresholds recommended in the RDG.

Project 07-34
Toward Artificial Intelligence-Enabled Decision Support Systems for TSMO Applications

Research Field: Traffic
Source: Louisiana Department of Transportation
Allocation: $450,000
NCHRP Staff: Zuxuan Deng

As contemporary transportation systems get more complicated, it becomes much more challenging for decision makers to consider a large number of intertwined factors to optimize the systemwide processes, including planning, operation, asset management, and maintenance. For example, when an accident occurs, operational strategies need to be put forward to provide timely and effective multimodal services, such as vehicle routing, ramp metering, variable speed limits, emergency vehicle preemption, hard shoulder running, and adaptive traffic signal control to improve traffic incident management performance. Over the years, decision support systems (DSSs), which are primarily computer-based information systems used to sort, rank, or choose alternatives, have been developed to help infrastructure owners and operators (IOOs) and policy makers to gear transportation systems towards favorable directions. However, conventional DSSs are usually built on a set of expert rules that might not be able to provide customized and optimal solutions. On the other hand, artificial intelligence (AI), especially advanced machine learning (ML) technique, has been revolutionizing every facet of daily life, including transportation. It takes advantage of the availability of a massive amount of real-time data to model system behaviors, predict traffic states, and evaluate overall performance, which is well aligned with the key functions of DSSs. Therefore, there is a need to explore AI potential for transportation DSSs.

As an effective tool to support offline planning and online operation, transportation DSSs have received much attention from practitioners, researchers, and policy makers in the past few decades. They are widely used for land use planning, networked traffic assignment, logistics and supply chains, congestion or bottleneck mitigation, traffic incident management, and fleet/asset repair and maintenance. However, most of these DSS tools are rule-based or model-based without taking full advantage of available data from various sources. Recent advances in artificial intelligence, such as deep neural networks, have unlocked a myriad of opportunities to improve transportation systems, such as the development of connected and automated vehicles. Relatively few studies and deployments have been focused on the exploration of AI or machine learning to the development of data-driven DSSs for traffic system management and operations.

The objective of this research is to leverage the state-of-the-art development in artificial intelligence and machine learning, and explore their potential to improve DSSs mainly for transportation system management and operations (TSMO). The research should address (at a minimum) the following questions:

1. General: (a) What is the state of the art about decision support systems for TSMO? (b) What are the gaps of existing DSSs for TSMO? (c) What is the state of the practice for the application of artificial intelligence and machine learning in DSSs for TSMO?
2. Data: (a) What would be the minimum requirement about data (such as data sources, contents, spatial/temporal resolutions, and data quality) to enable AI application for TSMO? (b) Are there any innovative ways to collect data (while keeping privacy) necessary to support or improve AI-enabled DSSs for TSMO applications?
3. Methodology: (a) What are the suitable machine learning-based methodologies and tools for data pre-processing (e.g., cleaning, fusing) in DSSs for TSMO applications? (b) What are the appropriate AI tools that TSMO should use to solve specific functionalities?
4. Digital infrastructure: (a) What kind of sensors are suitable for different functionalities to collect data for AI-enabled TSMO applications? (b) What kind of communication means are required to support reliable information transmission for AI-enabled DSSs for TSMO applications? (c) What kind of computational power is needed to support timely decision-making in AI-enabled DSSs for TSMO applications?

Potential research tasks include:
1. Identify success stories and lessons learned from AI-enabled TSMO applications.
2. Conduct a survey on the basic requirements for a DSS in terms of spatial context, operator engagement, decision latency, proactive capabilities, cross-facility and cross-mode coordination.
3. Analyze the TSMO's basic functionalities (e.g. demand prediction, travel time prediction, development of action plans and schemes, human-machine interaction, etc.) and identify the role of AI in facilitating these functionalities based on the latest state-of-the-art and state-of-practice.
4. Design a roadmap toward AI-enabled DSSs technology development and adoption in terms of data requirements, algorithmic aspects, validation and testing, computation needs, performance evaluation, infrastructure readiness levels, and workforce training requirements.
5. Demonstrate the developed roadmap through the selection of two use cases to evaluate readiness, identify infrastructure, technical, and workforce gaps, and develop strategies for closing these gaps.

Project 08-163
Defining Appropriate Design and Accommodation Thresholds for Active Transportation in a Context-Driven Approach

Research Field:	Transportation Planning
Source:	AASHTO Committee on Active Transportation
Allocation:	$550,000
NCHRP Staff:	Jennifer Weeks

A common approach to transportation engineering and design is to set minimum accommodations or guidelines for different modal uses, such as a minimum width for a sidewalk or bike lane or a minimum number of bike parking spaces. The concept also is used at the planning level. For example, some Complete Streets policies specify minimum accommodations for pedestrians and bicycles. However, minimum accommodations are frequently used as the default or preferred width, despite the potential impact of local conditions to support goals such as growth in use of walking, bicycling, and rolling, particularly among all types of users and in areas where greater walking, bicycling, and rolling activity is possible. Research is needed on the design flexibility and the different levels of accommodation recommended for different contexts and roadway types.

The objective of this research is to identify appropriate ranges of accommodation for different modes within a specific road and usage context. Specifically, this research should address (1) how the use of "minimum" accommodations actually service the needs for active transportation, and (2) what alternative approaches and design flexibilities may be appropriate for serving different levels of accommodation for different contexts and roadway types to better serve all road users, with a focus on the design and engineering of roadways and intersections. The research should include an empirical analysis of current designs used by state departments of transportation (DOTs), including the extent to which recommended "minimum" right-of-way guidelines are used or exceeded by state DOTs and the reasons for the decisions that are made. The analysis should similarly address conditions that would warrant restricted accommodation, such as situations with constrained right-of-way.

Possible alternative approaches (or contexts) for a multimodal design application may include:

- Focus on desired performance, such as achieving specific mode share goals;
- Focus on the relative level of service and comfort for different modes within different designs (e.g., what percentage of the population would feel comfortable using the facility walking, bicycling, or rolling) and how that would change with different designs; and
- Focus on a safe-systems approach that includes expectations for safety outcomes. This would explicitly acknowledge that some users are at higher risk.

Project 08-164
Institutional Integration of Active Transportation

Research Field: Transportation Planning
Source: Committee on Active Transportation
Allocation: $600,000
NCHRP Staff: Camille Crichton-Sumners

There are several informative national guidance documents to aid practitioners working in active transportation. Despite this, walking, bicycling, and rolling needs are often not considered or considered only as an afterthought in transportation projects. There is some limited research to explain why active transportation infrastructure, practices and processes are (or are not) institutionally adopted. That research identified factors such as political leadership, local advocacy, taking advantage of timely opportunities and experiments, and increased learning and training, including exposure to places with high levels of bicycling and walking (Dill et al., 2017; Wilson and Mitra, 2020; McLeod et al., 2020).

There are applicable theories from other disciplines that help explain the processes of institutional policy learning and transfer, as well as learning transfer—theories that examine how knowledge gets transferred and implemented between and within agencies (Glaser et al., 2019; Marsden and Reardon, 2017; Marsden and Stead, 2011). Theories of organizational culture and change among public agencies are also relevant (Fernandez and Rainey, 2006).

This research will look at state department of transportation institutional structures, policies, programs, processes and practices from top leadership through various disciplines and program phases, including planning, environment, design, construction, operations, maintenance, safety, communications/public outreach, and contracting (hereafter referred to as "agency institutional structure and policies") and how active transportation can be effectively institutionally integrated. This research should (1) identify and assess the challenges to embedding active transportation throughout agency institutional structure and policies, (2) identify existing strategies to overcome those challenges, and (3) recommend additional strategies to overcome those challenges. The research will focus on internal challenges that can be influenced and changed directly by state departments of transportation.

Project 08-165
Integrating Active Transportation Data into Transportation Decision-Making

Research Field: Transportation Planning
Source: AASHTO Committee on Active Transportation
Allocation: $550,000
NCHRP Staff: Jennifer Weeks

Active transportation data can inform transportation decision-making at various agency levels. However, tools and resources are needed on how to identify what type of data is most useful for guiding such decision-making, how to package and present such data to convey its meaning and limitations, and how to integrate data from different sources and develop data flow systems to get information where it needs to go. As data sources and systems have become more abundant, they have also demanded more specialized skills to interpret and apply them.

The objective of this research is to provide tools and resources for data usage: how to select data and data sources, and how to interpret, apply, and integrate active transportation data into transportation decision-making. The research will help state departments of transportation and other transportation agencies with assessing, interpreting, and applying active transportation data to transportation decision-making in various program phases, including planning, finance, environment, design, traffic engineering, construction, operations, maintenance, and safety. The research will document best practices and develop a set of tools and step-by-step instructions to leverage active transportation data to improve decision-making.

Tasks to accomplish this objective may include: (1) conduct a literature review on active transportation data-informed decision-making in planning, finance, environment, design, traffic engineering, construction, operations, maintenance, and safety; (2) develop initial application matrices outlining which data can be used for which agency decisions in planning, finance, environment, design, traffic engineering, construction, operations, maintenance, and safety; (3) conduct an industry scan aimed at better understanding the state of practice with respect to how active transportation data are being applied to improve agency decision-making in planning, finance, environment, design, traffic engineering, construction, operations, maintenance, and safety; and what data, processes, skills, training and resources are needed for successful data application; and (4) conduct a survey of external active transportation practitioners regarding what data they have, how they use/apply data, and what skills they need to apply such data. From these data, a set of tools or resources may be developed for transportation planners on how to collect, use, and integrate active transportation data into transportation decision-making.

Active transportation data-informed policy and decision-making could help transportation agencies deliver priority, safer walking and bicycling networks; improve active transportation modeling; identify safety hazards and hotspots; focus spending and prioritize resources; and improve agency decision-making processes. Better active transportation data could also help inform emissions reductions strategies. The results of the research will be used by agencies to assess where and how to better integrate active transportation data into their decision-making, and how to better support agency staff to make use of data.

Project 08-166
Racial and Economic Disparities in Pedestrian and Bicyclist Safety

Research Field: Transportation Planning
Source: AASHTO Committee on Active Transportation
Allocation: $750,000
NCHRP Staff: Jennifer Weeks

Disproportionate levels of pedestrian crashes, injuries, and fatalities are experienced by Native Americans, people of color, and people with low incomes. Although there is limited data on bicycle injury and fatality disparities, initial research suggests there may be disparities in safety outcomes and in access to safe and comfortable bicycling facilities. There is a need for further data and analysis on exposure to unsafe conditions, such as high-speed and high-volume arterials, and access to safe facilities, including the differences in access based on income versus race.

Disparate exposure does not end at traffic safety. Several other issues are also at play including but not limited to an analysis of air quality and public health, driver behavior regarding yielding to pedestrians from these communities, and decisions made regarding whether and when to bike or walk in specific environments. Finally, there is a need to better understand the role of underreporting of pedestrians and bicycle exposure and crashes, particularly for certain groups, and how that might affect the understanding of pedestrian and bicycling safety disparities.

The objective of this research is to clarify the strengths, limitations, gaps, and biases of existing data and data sources for understanding active transportation safety equity implications, propose improvements to data collection practices, and improve the application of available data and modeling. This research should seek to disentangle disparities by race and income, since disparities may be different between distinct demographic groups. The research should also assess urban, suburban and rural areas separately, to separate the effects of urban context with race or income effects. The research should also examine walking and bicycling separately, recognizing the commonalities and differences between the modes.

Activities to be undertaken could include (1) documenting available data, current data applications, and proposing updates to data collection and application processes to be utilized in assessing pedestrian and bicycle safety disparities; and (2) developing an understanding of the extent and causes of active transportation safety disparities. Better data and a better understanding of how to analyze active transportation safety disparities is a key step in acting to address causes and promote investment in targeted safety programs and infrastructure, and inform policies to improve bicycle and pedestrian data and safety in disadvantaged areas.

Project 08-167
A Guide for Creating Effective Visualizations

Research Field: Transportation Planning
Source: AASHTO Committees on Data Management and Analysis; Planning; Performance Based Management
Allocation: $375,000
NCHRP Staff: Christopher McKenney

Data visualization can be "effective" in several ways: providing information, informing policy and decision-making, and influencing behavior. There is little guidance on how to systematically evaluate a visualization's effectiveness by any of these measures. This problem affects transportation professionals and the traveling public, including movers of freight.

Even with clear data visualizations providing insight, sophisticated "nuggets of truth" from vast amounts of information and solutions to vexing problems, there may be viewers who do not comprehend or respond to that type of presentation. Developing a means to evaluate the effectiveness of visualizations deployed internally and externally would significantly enhance the value of visualizations.

This research addresses this problem by: evaluating the effectiveness of noteworthy practices currently being pioneered by state departments of transportation (DOTs) that were documented, but not assessed, in previous NCHRP research projects; addressing new tools that have been produced; and ultimately developing an easy-to-use guide to creating effective visualizations.

The object of this research is to develop an easy-to-use guide for evaluating the effectiveness of transportation visualizations that state DOTs can use to improve communication and decision-making. With this guide, state DOTs will have the tools to hone their message, manage the data overload that occurs in visualizations, and impact travel behavior with effective visual data increasing safety, security and mobility.

Effective data visualization has the power to dramatically improve the safety and efficiency of the transportation system by effectively presenting data and other information that facilitates a feedback loop that enables and promotes continuous improvement. Previous research demonstrates that state DOTs have invested considerable time and expertise in developing visualizations to communicate performance measures effectively.

This guide would build on prior work by developing clear guidance on how to create effective visualizations and how to evaluate their effectiveness. It will enable states to focus and capitalize upon the investment, time, and expertise they are currently deploying. It will provide a roadmap to the states that are in the early development of their visualization efforts, and will provide an opportunity for well-established programs to expand their efforts by evaluating the effectiveness of their visualizations.

Project 08-168
Analysis and Assessment of the National Performance Management Data

Research Field: Transportation Planning
Source: AASHTO Committee on Performance Based Management
Allocation: $550,000
NCHRP Staff: Roberto Barcena

The 2012 Moving Ahead for Progress in the 20th Century Act and the 2015 Fixing America's Surface Transportation Act laid the groundwork for a comprehensive national-level performance management framework. The first four-year reporting period began January 1, 2018 and ended on December 31, 2021, and will result in the first complete set of consistent national-level performance management data. With the collection of this data comes a unique opportunity: conduct the first analysis and assessment of this data set and combine with other datasets to tell a more complete and consistent state department of transportation (DOT) performance management story.

An initial assessment of these data sets has been conducted. In 2020, FHWA sent out letters to each state DOT indicating whether they had made significant progress towards their target achievement for the five safety performance measures. FHWA sent out subsequent letters in 2021about making significant progress with respect to the asset measures and system performance measures. AASHTO obtained copies of these data and conducted its own preliminary analysis of the data to better understand how close the actual numbers were to the targets; what the impact is on those states that did not make significant progress; how many states' targets showed improvement; what kind of targets states established; what is the correlation between target setting technique and making significant progress; and if there are other techniques that could be used to determine making significant progress. The results of this preliminary analysis revealed a lot of good information.

The objective of this research is to prepare an authoritative analysis and assessment of the national performance management data and, based upon the analysis and assessment, to provide recommendations on future state DOT capacity-building activities and possible new performance measures.

Project 08-169
Equity, Diversity, and Inclusion, and Other Indicators to Improve Transportation Asset Management Impact and Outcomes

Research Field:	Transportation Planning
Source:	AASHTO Committee on Performance Based Management
Allocation:	$500,000
NCHRP Staff:	Jennifer Weeks

Investments in roadways historically have been focused on safety, mobility, and system preservation considerations. As the understanding of the impacts of roadway decisions mature, other factors such as socioeconomic impact, sustainability, accountability, transparency, integrity, and innovation are increasing in importance by state departments of transportation (DOTs). Recently, strategic initiatives related to diversity, equity, and inclusion (DEI) are growing in importance and need to be considered in transportation investment planning. Advancing the understanding of DEI and other related indicators can help DOTs improve the impact of transportation asset management (TAM) investment decisions, especially to underserved communities.

The product or products of this research should provide transportation agencies with the information and resources needed to use DEI and other related indicators to balance competing, strategic objectives related to asset performance, safety, mobility, and DEI.

Tasks may include: (1) compile DEI and other related indicators for use in TAM decision-making; (2) identify institutional barriers and challenges in asset management and planning to support underserved communities; (3) develop a framework for applying DEI and other related indicators in TAM decision-making processes, including methods to forecast impact, means to develop and analyze alternatives with an equity lens, including investment tradeoff decisions; and community engagement supportive of DEI in transportation asset management; and (4) develop additional quantitative and qualitative performance measures for asset management and planning that consider DEI and other factors in transportation investment decisions.

Project 08-170
Frameworks, Guidance, and Tools to Support Post-Implementation Evaluation of Transportation Projects

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $600,000
NCHRP Staff: Jennifer Weeks

State departments of transportation (DOTs) and metropolitan planning organizations (MPOs) have implemented robust performance-based planning and programming processes in their agencies in response to the federal requirements articulated in the 2012 Moving Ahead for Progress in the 21st Century Act, the 2015 Fixing America's Surface Transportation Act, and other state and federal laws. According to the FHWA *Performance-Based Planning and Programming Guidebook*, there are three core elements of the performance-based planning and programming (PBPP) framework: strategic direction (establishing performance goals); analysis to identify the best means of achieving that direction; and programming the resources.

These elements are well documented in existing transportation planning and programming processes. This research will facilitate understanding a fourth element that focuses on implementation and evaluation of investments against the original strategic purposes. This element, which includes monitoring, evaluation, and reporting, is something that the transportation industry has struggled with. Since the PBPP process includes an aspect of a feedback loop that attempts to assess whether projects built actually delivered the performance predicted, the implementation and evaluation is a critical component that is not done on a regular basis.

The objective of this research is to provide a guide that provides needed frameworks and tools for transportation planners and analysts to better evaluate individual transportation projects and programs of projects. Evaluating post-implementation benefits provides a feedback loop to help ensure that information on the effectiveness of projects and programs informs future project selection and implementation. In addition, findings from post-implementation studies can help to identify the characteristics of a corridor or situation under which certain projects and program are most effective. Finally, results can be useful for communicating with the public and decision-makers about the benefits of strategies such as demand management and operational improvements, where projects and programs are often not as readily visible to the public.

These research results will be of primary interest to state DOT and MPOS, as well as offices responsible for performance and asset management, public engagement, and research. The guide and toolkit should be developed to be easily implemented by these offices, such as easy to use self-assessments, checklists, and methods and examples of effective practices.

Project 08-171
Institutionalizing Safe Systems and Safety Culture in the Transportation Planning Process

Research Field: Transportation Planning
Source: AASHTO Committee on Planning
Allocation: $400,000
NCHRP Staff: Dianne Schwager

Conventional transportation planning and policies, and engineering and design standards operate under the assumption that people can safely use the roadway system that is in place. However, over the last 10 years, severe crash numbers have not seen any significant rates of improvement and in 2020, a year when people drove less and walked and biked more, traffic fatalities increased by about 8 percent.

The 2015 *NCHRP Report 811: Institutionalizing Safety in Transportation Planning Processes: Techniques, Tactics, and Strategies* produced a transportation safety planning (TSP) process framework to help planners at state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) integrate safety into the different aspects of the transportation planning process (public engagement, stakeholder coordination, goal and objective setting, data analysis, performance management, project prioritization, and monitoring and evaluation). The goal was to give planners practical guidance on how to address transportation safety in the context of their current responsibilities.

Because planners are required to take a holistic view of the entire system and foster partnerships with the public, elected officials, and other transportation and safety stakeholders, they sit in one of the best positions and have ample opportunities to consider a Safe System approach during the transportation planning process and influence safety culture. This research will help planning and safety professionals more fully understand the relationships between transportation planning, safe systems, and safety culture with insights that can be used to target fatality reduction programs and projects.

The objective of this research is to investigate the opportunities and challenges for MPO and DOT planners and safety partners to integrate safety culture and safe system elements into the planning process. The products of this research should include final materials for use by transportation planning agencies to integrate safety culture and the Safe System approach into planning decisions.

Project 08-172
Benefit Analysis of Private Health Sector Investments in Public/Human Transportation

Research Field: Transportation Planning
Source: AASHTO Committee on Public Transportation
Allocation: $400,000
NCHRP Staff: Camille Crichton-Sumners

State departments of transportation (DOTs) are responsible to the transit-dependent public for maximizing investments of state and federal dollars in public transportation, but available funds often leave projects partially or wholly unfunded. Available public funding is not sufficient to meet all transportation needs, particularly in those areas where public transit does not currently exist. Planning efforts that focus on maximizing transportation availability and accessibility may not be furthered due to lack of implementation resources. Mobility managers, who are frequently housed within state DOTs, are responsible for coordinating transportation resources for individuals with unique access needs and are sometimes challenged to find any transportation options for the individuals they aim to serve. While the Coordinating Council on Access and Mobility (CCAM) is addressing non-emergency medical transportation (NEMT) from a federal policy and funding perspective, additional, unencumbered private resources for this transportation need could create meaningful change in support of CCAM’s work. If private and nonprofit funding from the health care industry, including hospitals, is available to subsidize transportation, opportunities exist to increase the availability of NEMT while also providing an even greater monetary benefit to the health care industry. In some cases, health care providers and hospital systems are able to provide transportation funding or develop their own services to transport their clients. The aim of this research is to provide information that will inform decisions to incentivize private health investment in NEMT by demonstrating its returned value, and for future research to examine the effects of such an investment.

The objective of this research is to design and conduct a benefits analysis that state DOTs, public transit and NEMT providers, and transportation stakeholders could utilize to demonstrate to hospitals and other health care providers how they might make small, supportive private investments in NEMT. This research should explore the effects of healthcare investments in communities with existing public transit, human services transportation, and other NEMT. The research could include cost-benefit analyses of healthcare investment in transportation, including analyses conducted in a rural, small-urban, and urbanized area in states with varying geography, demographics, and economies. It should also provide a tool for measuring the direct and indirect benefits (monetary and public health) of transportation subsidies by healthcare providers, and a recommended process for presenting the findings to the healthcare industry to incentivize investment.

Project 08-173
Impacts of E-Commerce on Travel and Land Use Patterns

Research Field:	Transportation Planning
Source:	Texas Department of Transportation
Allocation:	$400,000
NCHRP Staff:	Jennifer Weeks

E-commerce (electronic commerce) generally refers to the buying and selling of goods and services over an electronic network, primarily the internet. These transactions occur as business-to-business (B2B), business-to-consumer (B2C), consumer-to-consumer or consumer-to-business. The rapid growth of e-commerce trends seems to have transformational impacts on land use and transportation in settings ranging from small cities to large cities. Some of the potential impacts to transportation include environmental and safety risks, travel behavior pattern changes, congestion growth, changes in land use patterns, and evolving freight demand. Other externalities might be truck-parking shortages, competition for curb space, impacts to brick and mortal retail, and policy considerations like local tax revenue streams.

State departments of transportation (DOTs), metropolitan planning organizations (MPOs), and local governments increasingly are confronted with the need to manage the effects of e-commerce on urban and regional economic activity, land use, and transportation demand; and how to manage public investments in transportation facilities and services to maintain economic vitality and high quality of life.

The objective of this research is to comprehensively document the effects of current e-commerce trends on transportation and land use, and provide methodologies for state DOTs and other agencies to take to address them. This research is expected to answer how to incorporate e-commerce travel trends into transportation and urban freight planning, design, and operations.

To this effect, research comprising a literature review, survey of stakeholders, and evaluation framework should be undertaken to advance the development of methodologies to plan for e-commerce growth.

Project 10-115
Guide on Progressive Design-Build for Transportation Projects: Project Planning through Project Implementation

Research Field:	Materials and Construction
Source:	AASHTO Committee on Construction and Maryland Department of Transportation
Allocation:	$300,000
NCHRP Staff:	Christopher McKenney

Transportation agencies started using design-build (DB) over 25 years ago, now considered a standard "tool in the toolbox." The most commonly used methodology for DB contractor selection involves a best value process, with significant weight accorded to price, resulting in a fixed price contract for design development and construction. Progressive Design-Build (PDB) is an advancement of fixed price DB that allows early contractor involvement, including elements similar to construction manager/general contractor (CM/GC). It transfers design and construction responsibilities to a design-build team starting with a preliminary planning and design phase through construction completion, with negotiation of the price for final design and construction at the end of preliminary design phase, similar to the process used for CM/GC pricing. The qualifications and experience of the DB team are significant factors in contractor selection, and while legislation often dictates consideration of price in the selection, in some cases public owners use a pure qualifications-based selection process.

PDB contracts include procedures for development of the design, schedule/phasing plan, and a price for final design and construction, which typically is in the form of a guaranteed maximum price construction (GMP). Development of the GMP is a key component of PDB as it allows owners to hire a designer-builder without a price commitment for final design and construction until after reasonable design details are defined. To ensure agencies are able to make the price reasonableness determination required for federally funded projects, the public owner often uses an independent cost estimator to develop a full price of construction based upon an agreed upon scope of work and schedule. The negotiated price typically includes allowances and contingencies for potential unknowns and risks that are agreed upon by the owner and the contractor. Several state departments of transportation (DOTs) have started to use PDB, based on models that have been used successfully in water/wastewater, airport, municipal street/roadway projects, flood control, and transit sectors. Moreover, in contrast to traditional design-bid-build (DBB) and CM/GC, and like fixed price DB, PDB transfers design liability to the contractor.

The benefits of using PDB include: (1) greater agency control of design decisions, scope, cost, and schedule; (2) flexibility of delivery; (3) risk mitigation and contingencies; (4) innovative project-specific solutions and better scoping of owner needs and expected outcomes; (5) accelerated schedule and phasing opportunities; (6) increased diversity in contracting opportunities and workforce development; (7) increased life-cycle value for money; and (8) and greater designer and contractor collaboration.

This research will provide updated information about successful practices, case law, and statutes relating to PDB project delivery to assist agencies in evaluating when PDB should be considered for a project, and how to develop the framework for successful use of PDB.

Project 10-116
Variability in Pavement Materials and Construction

Research Field: Materials and Construction
Source: AASHTO Committee on Materials and Pavements
Allocation: $500,000
NCHRP Staff: Amir N. Hanna

Variability is inherent in all pavement materials and construction processes. Understanding the magnitude of variability is important to pavement construction industry stakeholders. State departments of transportation (DOTs) need to quantify the typical variability of pavement materials and construction processes to establish rational specification limits. Material producers and contractors need to identify and measure sources of variability to manage quality.

While quality has traditionally been defined as "fitness for use" or "degree of excellence," a modern definition of quality states, "quality is inversely proportional to variability." Relating pavement material properties to variability has traditionally relied on quality characteristics such as binder content, aggregate gradation, mix volumetrics, in-place density and smoothness for asphalt pavement, and compressive strength, air content, thickness, permeability, and smoothness for concrete pavement. *NCHRP Synthesis of Highway Practice 232*: *Variability in Highway Pavement Construction* (1996) published typical variabilities for many of these quality characteristics. However, in the past 25 years, improvements in mix design practices, test equipment and methods, material processing and construction practices, increased use of recycled materials, and changes in state DOTs' specifications (including improved quality measures such as percent-within-limits and alternative project delivery methods (which typically include advanced quality management program components)) are likely to have impacted variability. In addition, new performance tests such as performance-graded binder tests, asphalt mixture cracking and rutting tests, concrete tests such as the Super Air Meter, and surface resistivity are being introduced, most of which have not been evaluated for typical variability values.

As state DOTs move from pavement acceptance based on traditional quality characteristics to performance tests (some of which rely on test methods that cannot be performed as frequently as traditional tests due to testing complexity), it is critical that the variability of pavement materials and construction processes be better understood so that pavements consistently meet the long-term expectations of state DOTs. Also, introduction of nondestructive test methods and technologies, with greater coverage than traditional methods, have the potential to provide a great deal of useful data regarding pavement construction that can be leveraged to improve quality, if their variability is documented. It is also important to know if quality assurance (QA) specifications instituted by many state DOTs since 1996 have resulted in decreased variability, and therefore have resulted in improved pavement quality.

The objective of this research is to prepare a report quantifying the typical variability of pavement construction materials and processes and provide guidance for state DOTs to evaluate the variability of newly implemented performance tests. Tasks could include the following.

Literature review to identify the major fundamental sources of variability for mixture production, transportation, and placement for concrete and asphalt pavements, and to compile a prioritized list of data and metadata that could be useful for the analysis, with consideration of what is possible to obtain from agencies, producers, and contractors.

1. Conduct a survey to identify state DOTs that have pavement quality characteristic test data stored in digital format that spans a decade or more to evaluate in the range of variability over time.
2. Collect test data and metadata from agencies, producers, and contractors on various pavement quality characteristics using the list compiled in Task 1.
3. Identify the main components of variability that comprise overall material variability, and conduct statistical analysis to determine typical variability for various quality characteristics and the relative impacts of key materials and/or construction processes that impact the variability of these quality characteristics.
4. Quantify the changes in the variability of quality characteristics that has occurred since publication of *NCHRP Synthesis of Highway Practice 232*.
5. Develop guidelines for state DOTs to quantify variability of new test methods for pavement materials and processes, including mixture performance tests and nondestructive tests of various construction quality characteristics.

Project 10-117
GFRP Barrier Testing Evaluation and Repair Strategies

Research Field: Materials and Construction
Source: AASHTO Committee of Bridges and Structures
Allocation: $850,000
NCHRP Staff: Amir N. Hanna

Deterioration of bridge decks and safety barriers in salt exposure conditions using traditional steel reinforced concrete, or even using epoxy coated steel, has demonstrated the inability of steel reinforcement to satisfy today's desired 100-year service life due to the susceptibility of traditional steel reinforcement to galvanic corrosion. While the AASHTO Load and Resistance Factor Design Specifications do not specify a specific service life for bridges, more recent guides provide a path for selecting a target service life including life cycle cost analysis approaches. Other international standards such as the British Standards set a specific required 120-year service design life.

One solution to address the long-term service life target of 100 years that many state departments of transportation (DOTs) desire in their bridge deck systems is to use noncorrosive reinforcing materials such as glass fiber reinforced polymer (GFRP) in lieu of traditional steel or steel-coated systems. Since the late 1990s and early 2000s, GFRP materials have been demonstrated in bridge elements, including bridge decks in both hybrid reinforced deck applications or more recently fully steel free GFRP reinforced decks. However, a few challenges in the 2000s and 2010s have slowed the widespread implementation of steel free GFRP usage into bridge deck systems. These are generally perceived as (1) AASHTO design standards developed for using these materials, (2) remaining concerns on the materials long-term durability, and (3) development of barrier systems along with physical crash testing and repair strategies for damaged barrier systems. In recent years, efforts have been made to address challenges one and two. Late in 2018, AASHTO produced the second edition of the *GFRP Design Guide Specification* (AASHTO, 2018). In addition, several states including Florida, Ohio, and Missouri, have initiated efforts to develop and standardize GFRP reinforced barriers. The first major effort to thoroughly investigate a significant number of GFRP reinforced concrete (RC) bridge decks after 15-20 years of service exposure has been completed, showing no signs of degradation in the reinforcing materials. In this investigation, 11 bridges situated mostly in aggressive northern climates were inspected, sampled, and studied in depth, including microstructure analysis.

It appears that the remaining issue to a fully validated steel free deck system, including the bridge barrier, is to (1) develop repair strategies on the barrier configurations developed/under development by the aforementioned DOTs, (2) conduct full scale crash testing on undamaged GFRP RC barriers and repaired GFRP impact damaged barriers, and (3) benchmark the test results in objective 2 to currently available crash test data for traditional reinforced barriers.

The objective of this project will be to build on existing research on GFRP RC barriers in crash testing and tested design repair strategies for impact damaged GFRP RC barriers to restore full crash test capacity to damaged GFRP RC barriers. The desire of the repair strategies is to examine anchorage and internal continuity detailing such as innovative couplers and splicing details. Major tasks could include the following.

1. A state DOT survey and literature review to collect all information on current DOT GFRP RC barrier systems along with any laboratory and field-testing undertaken to date.
2. A literature review to identify promising coupler and continuity devices that have demonstrated experimental results to develop full tensile capacity in discontinuous GFRP bars. These are to be considered in the repair strategies.
3. To design and evaluate GFRP RC barriers developed with repair strategies under finite element method (FEM) modelling and laboratory static and cyclic evaluation.
4. To compare existing data on baseline RC control barriers (w/steel and GFRP) to the same barriers that have incorporated the repair strategy in the prior task.
5. Undertake full scale crash testing and FEM modelling on undamaged GFRP RC barriers as well as damaged GFRP RC barriers that have undergone the repair strategy. MASH TL-4 impact conditions for initial testing and repair should consider static/dynamic component testing for investigations/verifications as required. Results from these field tests would be benchmarked to existing crash tested steel RC barriers of the same size and cross section.

Project 10-118
Guidance for Efficient Timelines and Incentives/Disincentives for Accelerated Bridge Construction Projects

Research Field: Materials and Construction
Source: AASHTO Committee on Bridges and Structures
Allocation: $275,000
NCHRP Staff: Ahmad Abu-Hawash

State departments of transportation (DOTs) operate to minimize the impact of construction activities on the traveling public and commerce. Given the operational needs of DOTs, project timelines have become more compressed and prescriptive. Contractual provisions and methods such as incentives/disincentives (I/D), payment for acceleration, liquidated damages (LQD), and cost-plus time (A+B) procurement have been used for conventional construction projects to promote meeting project schedule targets. In addition, accelerated bridge construction (ABC) methods can greatly compress the closure time required during bridge construction. Generally, ABC minimizes the overall construction window (from months to weeks), or minimizes the out-of-service time of the facility (from weeks to hours). Compressed project schedules may reduce impacts and improve safety for the traveling public; however, the project staff and contractor may be subject to safety risks because of the accelerated work schedule and nature of ABC technology. Generally, ABC techniques alleviate significant user costs; however, these technologies may have significant project costs that are difficult to accommodate within limited owner construction budgets. For example, the use of self-propelled modular transports (SPMT) could significantly increase the construction cost of a project.

This research will answer the following underlying questions that owners must address when using both ABC techniques and contractual provisions to achieve project goals: (1) what type of contractual timeframes are appropriate when using ABC; (2) what are the risks that contractors face in implementing specific ABC approaches; (3) what are appropriate ranges of incentives and disincentives; and (4) what types of risks are introduced to project staff, contractors, and the public as a result of accelerated timelines, and how are those risks addressed?

The objective of this study is to develop guidelines that state DOTs and other bridge owners may use in making project-specific ABC implementation decisions related to contract provisions.

This work will help state DOTs and owners manage project schedules and set appropriate contractual provisions related to time and incentives for projects utilizing ABC techniques. Significant costs can be saved upon implementation, e.g., reduced cost as measured by comparison of actual incentives paid. These results will also incentivize the construction industry to introduce ABC details into projects to mitigate schedule requirements and maximize competitiveness.

Project 10-119
Guidelines for Implementing Utility Investigations in Alignment with Project Delivery

Research Field:	Materials and Construction
Source:	AASHTO Committee on Right of Way, Utilities and Outdoor Advertising Control
Allocation:	$400,000
NCHRP Staff:	David Jared

While permitting the installation of utility infrastructure in roadway right-of-way (ROW) has systemic benefits, the practice has contributed to utility-related issues being one of the leading causes of delays for transportation projects (FHWA, 2018). These delays are often attributed to unknown or inaccurate utility locations. Utility investigations, inclusive of subsurface utility engineering (SUE), are procedures state departments of transportation (DOTs) can implement to locate utilities and assist their project development teams with avoiding these issues. However, few guidelines exist for aligning the timelines for implementing utility investigation procedures with those of the project delivery process. Also, there are (a) many factors that influence the optimal approach of utility investigations for a specific project; and (b) variations in utility investigation needs based on the timing of design elements within the project delivery process.

Inappropriate utility investigations contribute to the $50 billion drain on the U.S. economy cause by the lack of (?) utility and highway coordination. This is also a major factor in utility impacts as one of the top three causes of delays for projects. The proper investigation of utility locations would help project teams eliminate substantial risk from DOT projects.

The primary objective of this research is to develop guidelines for DOTs to strategically align utility investigations to project development phases. The guidelines to be developed will address: application criteria; depiction approaches; prequalification of service providers; deliverable expectations; quality assurance practices; alignment of utility investigation to design phases; alignment of design element timelines to utility investigation; and approaches to staffing and roles, and other programmatic decisions.

Project 10-120
Guidance for Including Right-Of-Way and Utilities in Value Engineering Studies

Research Field:	Materials and Construction
Source:	AASHTO Committee on Right of Way, Utilities & Outdoor Advertising Control: Subcommittee on Utilities
Allocation:	$400,000
NCHRP Staff:	Christopher McKenney

According to 23 CFR 627, a Value Engineering (VE) analysis is the systematic process of reviewing and assessing a project to identify the needed project functions, optimize the value and quality of the project; and reduce the time to develop and deliver the project. It also indicates that state transportation agencies (STAs) must conduct VE studies for projects on the National Highway System (NHS) receiving federal assistance with an estimated total cost of $50 million or more; and bridge projects on the NHS receiving federal assistance with an estimated total cost of $40 million or more. It is not necessary to conduct VE studies for design/build projects, but the federal regulations provide guidance for construction manager/general contractor (CM/GC) projects. STA policies and requirements typically mirror those at the federal level. VE studies have been effectively incorporated into the STA project development process.

The VE body of knowledge is largely silent on the topic of right-of-way and utilities. At the state and national level (both federal regulations and FHWA guidance documents), there are only casual references to right-of-way or utilities in VE studies. STA manuals typically include guidance on how to conduct VE studies, but any reference to right-of-way or utilities is brief and without any practical guidance. This lack of documented knowledge increases the risk that VE study teams will lack the kind or level of right-of-way and utility information they need to do their job properly and may be missing unique opportunities to add value to a project.

Utility and right-of-way issues are repeatedly documented as causes for project delay and increased costs. It is imperative to the tenants defined in VE to consider these aspects of project development and delivery. They are critical factors in project costs, potentially offsetting the VE benefits garnered through the VE process. Therefore, research is needed to develop guidelines for the inclusion of right-of-way and utilities in VE studies.

The objective of this research is to develop guidelines for the inclusion of right-of-way and utilities in VE studies. To achieve this objective, at a minimum, tasks should include: (1) conducting a survey of STAs to examine VE studies practices of right-of-way and utilities; (2)

reviewing sample VE study reports and conduct interviews with the corresponding STA officials and VE study teams; and (3) testing the guidelines on pilot VE studies.

The research could have a number of benefits including (1) earlier and more effective identification of right-of-way issues that might have been overlooked by a project team reduces project risk in terms of cost and schedule; (2) earlier and more effective identification of utility issues that might have been overlooked by a project team reduces project risk in terms of cost and schedule; (3) construction delay claims will be reduced with fewer right-of-way and utility issues; and (4) lower right-of-way acquisition and utility relocation costs are expected.

Project 10-121
Performance-based Specification for the Application of Ground Modification Methods for Bridges, Retaining Structures, and Associated Geotechnical Features

Research Field: Materials and Construction
Source: Alabama Department of Transportation
Allocation: $450,000
NCHRP Staff: Ahmad Abu-Hawash

Over the last half century, public transportation agencies have greatly increased the use of ground modification methods due to a need to use marginal sites for new construction purposes and to mitigate the risk of failure or poor performance of constructed facilities. More recently, ground modification has been selected to meet challenges associated with accelerating construction in difficult geotechnical circumstances.

Ground modification methods have been used to provide proactive and reactive geotechnical solutions for a range of issues including mitigating soft or loose ground, or potential geohazards; increasing the speed of construction; and improving efficiencies in design of highway features. Ground modification methods are commonly used in all areas of transportation including structure foundations, pavement subgrades and bases, cut slopes, embankments, and earth retaining structures, and are used to provide practical solutions that mitigate geotechnical risks, remediate poor feature performance, and improve long-term durability of transportation assets.

During this time, the Federal Highway Administration (FHWA) and several state departments of transportation (DOTs) have conducted research and have developed guidance documents and other resources to remove the mystique surrounding these solutions, which have typically been developed by contractors in search of innovative approaches to complex geotechnical issues. Research efforts have successfully summarized design methods and quality assurance (QA) procedures developed for commonly used ground modification methods and have demonstrated the design methods based in accepted geotechnical practice. Design and construction methods, equipment needs, technical feasibility, and acceptance criteria have been widely implemented through products, such as the FHWA Demonstration Project 116, and subsequent reference manual updates that have now become Geotechnical Engineering Circular (GEC) 13 – Ground Modification Methods. Training courses provided through the FHWA's National Highway Institute (NHI) have assisted state DOTs in developing and implementing design manuals to govern the use of ground modification methods regionally and, most recently, the development and deployment of GeoTechTools as a solution-based web tool continues to assist with increased safe, reliable, and cost-effective use.

The objective of this research is to develop an AASHTO guideline specification to assist public transportation agencies. There is a wide applicability of solutions for structure and earthworks, and large number of methods commercially available for ground modification. For continued promotion and cost-effective use, a guideline specification for the use of ground modification methods would provide agencies with a minimum and consistent standard for the selection, design, construction, and acceptance for commonly used techniques in transportation applications. Guideline specifications have the potential to dramatically increase the efficiency and cost-effectiveness of ground modification solutions by assisting designers with specification language that could help avoid common issues, such as incorrect application of methods, a lack of understanding of mechanisms for improvement, and reliable metrics for acceptance and payment of constructed solutions. A significant problem faced by state DOTs is the lack of a standard for selecting from many methods available and proper application for the problem or issue being addressed.

Project 10-122
Update of the AASHTO Practical Guide to Cost Estimating (PGCE)

Research Field: Materials and Construction
Source: Louisiana Department of Transportation
Allocation: $250,000
NCHRP Staff: Christopher McKenney

The PGCE provides state departments of transportation (DOTs) as well as other transportation agencies with practical guidance on how to develop realistic estimates of project costs. The original PGCE was published in 2013 and since then, newer means and methods of estimating have been identified and need to be considered. The guide also needs to be updated to address estimating as it applies to the newer alternative delivery methods. In addition, various software references, tools, website links, charts, and tables need to be updated to maintain the PGCE's relevance to current cost estimators. The PGCE is also the foundation for training, such as that provided by the AASHTO Technical Committee on Cost Estimating (TCCE) and Risk-based Estimating Training sponsored by the Federal Highway Administration (FHWA). Research is needed to help transportation agencies successfully manage and deliver their programs by providing them with the necessary guidance to develop consistent and reliable cost estimates.

The objective of this research is to produce a new edition of the PGCE. Potential tasks may include (1) identifying current state-of-practices of state agencies, relevant research in cost estimating, and regulatory or other compliance information relevant to industry practice; (2) identifying new material and training that can be incorporated such as terminology, charts, references, methods, etc.; and (3) consideration or commentary regarding estimating project costs when projects are delivered using alternative project delivery methods.

Project 10-123
Quality Assurance and Sustainability

Research Field: Materials and Construction
Source: Maine and Minnesota Departments of Transportation
Allocation: $350,000

NCHRP Staff: Amir N. Hanna

Transportation agencies across the nation are implementing a variety of measures to meet their environmental, economic, and social sustainability goals. Historically, quality management activities have contributed to the sustainability of transportation projects through quality assurance (QA) programs and quality control (QC) plans, which help improve performance, reduce the quantity of unacceptable product constructed and the associated environmental impacts of rework, increased materials use, and community impacts, among other benefits.

In recent years, green public procurement (GPP) initiatives have become increasingly of interest to agencies hoping to reduce the environmental impact of their infrastructure. GPP initiatives rely on construction materials environmental product declarations (EPDs) to communicate the environmental impacts of a material and to compare choices. Some agencies that have started to use some sustainability-related quality metrics (such as global warming potential, emissions, or gallons of water conserved). However, these metrics are not uniform and need to be expanded. Quality metrics could be established for EPD programs to support sustainable procurement for many materials. Although effectively supporting environmental improvements, there has been concern that PCRs and EPD programs, as currently developed and used by manufacturers, provide a range of comparability and harmonization across sectors. As a result, the information communicated by EPDs may not meet agency needs for comparing impacts and performance. The level of detail and extent of third-party verification also varies by EPD program. Agencies are interested in using EPDs to support GPP, but guidance to support their use to meet agency sustainability objectives is limited.

FHWA has been supporting work to improve both comparability and harmonization of EPDs. However, agencies still lack guidance on ways to implement strategies to support comparability and harmonization. In addition, there is also the issue of verification of EPD properties (such as when an EPD for a mixture indicates it incorporates a certain percentage of recycled material or supplementary cementitious material (SCM) in production), as the verification processes are not well established by most agencies. If a sustainable product is required or contractor selection is based on a proposed EPD during procurement, then agencies will need to verify that those products that are proposed to meet the EPD are actually incorporated into the project. For example, if an EPD is proposed that includes a percentage of a recycled material (such as recycled asphalt pavement (RAP), recycled concrete aggregate (RCA), recycled tire crumb rubber, or SCM), then the approved mixture designs should also require those same percentages and their use should be verified in production. QA programs currently allow such products provided they meet the current acceptance testing requirements, the material usage quantities (or percentages) as indicated on the EPDs are not currently being verified. Additionally, agencies need guidance on how to approach unacceptable materials. Currently, no guidance exists to support agencies in establishing and using QA and metrics as part of GPP to help meet their sustainability goals (e.g., is an agency getting the environmental benefits they are paying for). Guidance on benchmarks for environmental performance is also needed to assist agencies in establishing criteria for sustainable materials procurement.

Ultimately, harmonized PCRs and improved EPDs are needed to ensure accurate life cycle analyses of transportation projects. Research is needed to support harmonization of PCRs for the materials used in transportation construction. PCRs define the system boundaries, impact categories, and methodologies used for developing and using the EPD. Guidance to improve the consistency and comparability of EPDs for transportation materials is needed to support agencies in assessing tradeoffs and making decisions.

The objective of the research is to develop guidance to support agencies in establishing and using QA and metrics as part of GPP to help meet their sustainability goals. Identify potential future improvements in EPD programs, agency practices, or other areas to maximize the use and benefits from EPDs. Tasks could include:

1. Literature review of publications and specifications associated with EPDs and LCA with a focus on the role of QA in supporting these initiatives to include case studies in industries (such as energy and real estate) that have implemented GPP and EPDs.
2. Collect information from agencies regarding their sustainability goals, GPP, EPDs, and needs to support LCA (define). Emphasis should be placed on metrics that could be used from a quality standpoint to support these efforts, as well as needs that could be met by additional guidance, or by changes in EPD programs. The role of agencies in influencing EPD programs should also be documented; agencies that could serve as champions to implementation will be identified.
3. Identify existing practices used by transportation agencies and industry to support GPP, and related quality management.
4. Develop guidance to support agencies in establishing and using QA and metrics as part of GPP to help meet their sustainability goals.

Additional potential tasks include identifying further work by industry needed to support PCRs and EPDs to support LCAs. Anticipated topics include (a) EPDs coverage/scope to fully meet transportation agency needs, (b) implementation routes and scenarios (such as incentives, benchmarks, go/no-go scenarios, etc.) that are useful in supporting GPP, (c) requirements for third-party verification of EPDs, (d) benchmarks for environmental performance in materials procurement, (e) methods by which agencies can better influence EPD programs, (f) methods by which agencies can improve their verification process between the EPD and the as-constructed product, and (g) expected barriers and challenges to the implementation of EPDs.

Project 10-124
Development of Field Test to Determine Actual Percent Embedment of Chip Seal Aggregate

Research Field: Materials and Construction
Source: Rhode Island Department of Transportation
Allocation: $400,000
NCHRP Staff: Roberto Barcena

Chip seal aggregate embedment has a significant influence on long-term chip seal performance. Too little embedment can cause raveling, revealing bare asphalt (safety and performance are compromised), and too much embedment can lead to bleeding (safety is compromised). Ensuring proper chip seal aggregate embedment should be evaluated as a critical factor when considering the proposed design of a chip seal project. However, there is no method to measure chip seal aggregate embedment quickly and accurately in the field.

The objective of this research project is to develop a rapid, in situ method to determine the embedment depth of chip seal aggregate soon after placement. This information could then be used to address any contractor workmanship issues that may be occurring on the project in near real-time (vs. having to wait until after the project is entirely completed), as well as an indicator of performance relative to the initial chip seal design (target emulsion and aggregate application rates, percent embedment range, etc.)

The results of this research will be used as an objective measure to evaluate initial acceptance of the chip seal project. In addition, the research results could be incorporated into the construction specifications to provide an incentive for contractor workmanship. Specific incentives and disincentives would need to be studied based on percent embedment. All these factors are directly related to the total life cycle and overall performance of the chip seal surface treatment in-place.

Project 10-125
Update to the AASHTO LRFD Bridge Construction Specifications

Research Field: Materials and Construction
Source: AASHTO Committee on Bridges and Structures
Allocation: $800,000
NCHRP Staff: Ahmad Abu-Hawash

In 2020, the AASHTO Committee on Bridges and Structures (COBS) completed a project that investigated the use and effectiveness of the current AASHTO Load and Resistance Factor Design (LRFD) Bridge Construction Specifications (BCS). This project included a questionnaire sent to each state department of transportation (DOT) to determine the use of the document, a review of the document contents, the development of a prioritized approach for reorganization and maintenance of the document, and the development of prioritized recommendations for re-writing the document. The survey revealed that the BCS is being used by many state DOTs on a regular basis, and that there are areas that may be improved:

1. Some reorganization of the sections is needed. Newer sections seem to have been simply tacked on to the end of the document. Several reorganization options were developed, each with its advantages and disadvantages.
2. Most sections in the document have very little commentary. The addition of commentary to the *AASHTO LRFD Bridge Design Specifications* had been a significant improvement over the original *Standard Specifications*. The BCS could benefit from a similar effort.
3. Many of the sections need updating to current standards and practices and reformatting to be consistent with industry and state DOT specifications. Some sections require more attention than others as some have been maintained by AASHTO technical committees since adoption of the document by AASHTO in the late 1990s.

The objective of this proposed research is to bring the document up to current standards and construction practices, which will make it more useful to bridge owners. The final products will be an updated document that may be adopted by the AASHTO Committee on Bridges and Structures.

The wholesale adoption of a national construction specification is not realistic; however, a guide specification can be a useful document in the development of state DOT specific standard construction specifications. Having a national construction guide specification as the basis for state specifications will help to foster uniformity of construction specification across state lines.

There is a need to provide uniformity of construction practices and specification as many contractors work across state lines. A revised AASHTO LRFD Bridge Construction Specification document will help to improve quality, durability and uniformity of bridge construction.

Project 12-125
Earthquake-Induced Bridge Displacements

Research Field: Design
Source: AASHTO Committee of Bridges and Structures
Allocation: $450,000
NCHRP Staff: Ahmad Abu-Hawash

Highway bridges are designed to resist most "normal" loads elastically. For example, steel members are not expected to yield and no permanent deflections result due to the design dead, live or wind loads. On the other hand, seismic demands can be so large that bridges cannot resist these forces elastically. Yield stresses are exceeded and permanent deformations are likely to occur due to earthquake loading.

Seismic design of common bridges using the AASHTO *LRFD Bridge Design Specifications* and the AASHTO *Guide Specification for LRFD Seismic Bridge Design* methodologies rely on an elastic analysis from which inelastic demands are estimated. Seismic bridge response is classified in four Seismic Design Categories (SDC). SDC A is the lowest seismic hazard and presumes an elastic response during the design seismic event. Bridges located in SDC B, C, and D are likely to experience inelastic demands during the design seismic event. About half of the country is subject to SDC B, C, or D seismic demands. The equal displacement assumption has the same consequences on bridges designed using the force-based AASHTO *LRFD Bridge Design Specifications* and the displacement-based AASHTO *Guide Specifications for LRFD Seismic Bridge Design*. This is not just a "seismic state" concern.

It is difficult to perform nonlinear analysis of bridges. Inelastic analysis requires special computer programs that can calculate bridge response due to ground shaking (i.e., accelerograms that are themselves difficult to develop). As with most sophisticated analysis, user knowledge and experience is required to develop, interpret, and verify the computer results. Due to these challenges, engineers (and the AASHTO specifications) use an approximate method of seismic analysis wherein the inelastic bridge response is estimated using an elastic bridge model. These elastic analysis methods are founded on the "equal displacement assumption" in which the "real" inelastic bridge is replaced by a fictitious elastic bridge that never yields.

The equal displacement approximation was introduced over 60 years ago, but is not based upon significant physical validation. Advances in numerical and physical methods suggest that the equal displacement approximation underestimates the "real" seismic displacement demands. Consequently, bridges may not perform as intended when using elastic analysis methods used for most designs. The potential underestimation associated with the AASHTO provisions was verified by the recently completed NCHRP Project 12-106.

The goal of this project is to examine the equal displacement approximation and, if necessary, develop simple, reliable adjustment factors that can modify the elastic displacement predictions to better match the "real" inelastic displacement response. These design recommendations will allow engineers to better predict seismic demands, resulting in safer, more reliable bridges.

The objective of the research is to develop robust yet simple procedures for calculation of inelastic displacement demands in bridges subject to earthquake demands.

Project 14-36(01)
AASHTO Guide to Bridge Preservation Actions Implementation Workshops

Research Field: Maintenance
Allocation: $355,000
NCHRP Staff: Ahmad Abu-Hawash

Bridge preservation is a cost-effective approach to manage an inventory of bridges. Many transportation departments have significant practical experience with bridge preservation and have developed conclusions regarding the effectiveness of bridge preservation actions based on those experiences. However, limited efforts have been made to identify, measure, evaluate, and document the short- and long-term performance of specific bridge preservation actions. Bridge preservation consists of actions to deter or correct deterioration of a bridge to extend its useful service life and does not entail structural or operational improvements beyond the originally designed strength or capacity of the bridge. Often practitioners apply preservation strategies on the basis of judgment or common sense using available resources. However, it is difficult to translate these strategies into coherent and convincing arguments in the absence of a quantitative measurement of bridge preservation effectiveness.

Research was performed under NCHRP Project 14-36 by the University of Colorado Boulder to develop bridge and deck preservation guides for possible adoption by AASHTO. The proposed AASHTO guides were developed based on data collected from representative agencies and include: (1) catalogs of bridge element preservation actions and (2) the criteria and selection methodologies of bridge preservation actions with associated costs and benefits for use in life cycle cost analysis and possible integration into a bridge management system.

The AASHTO Committee on Bridges and Structures balloted and passed for adoption two guides:

- AASHTO Guide to Bridge Preservation Actions (published July 2021)
- AASHTO Guide to Preservation of Highway Bridge Decks (pending publication)

The purpose of this project is to develop and hold implementation workshops for state DOT, local public agency, and consultant bridge practitioners to implement bridge preservation practices, reduce bridge infrastructure life-cycle costs and keep bridges in good or fair condition longer.

Potential tasks include conducting workshops, assessing the potential of a future National Highway Institute course based on the workshops.

Project 15-82
Effects of Operating Speed and Posted Speed Limit in Conjunction with Roadway Geometric Design on Safety Performance for High-Speed Rural Highways and Freeways

Research Field: Design
Source: Washington Department of Transportation
Allocation: $950,000
NCHRP Staff: Zuxuan Deng

Estimating the speed-crash relationship has long been of interest in roadway safety analysis. Because of the many contributing factors – such as roadway geometry and context, weather conditions, human factors, and vehicle type distribution – that influence both speeds and crashes, the relationship cannot be adequately established without considering the corresponding roadway geometric features, the dynamics of the vehicle and tire, and accounting for their effects on speeds and crashes.

While a significant amount of research has been conducted to identify relationships between roadway design elements and crashes, research that has considered the contribution of operating speeds or posted speed is limited. A general subjective understanding of the contribution of operating speed of a highway or freeway, through the dynamics of the vehicle, on the severity of a crash (higher speeds are associated with more severe crashes) is known. What is desired is a quantitative understanding of how speed (both operating and posted) in conjunction with roadway geometry relates to the likelihood of a crash and crash severity.

This research would build on existing research to explore the relationships among design elements, speed, vehicle dynamics, and crashes on high-speed rural highways and freeways. These relationships will help inform future design guidance, posted speed practices, and potential safety countermeasures, which are related to desired outcomes for multiple AASHTO Committees, such as Design, Traffic Engineering, and Safety.

The greater availability of speed data along with innovative statistical analysis techniques provides the opportunity to better consider operating speed in understanding the safety relationships among geometric design, traffic volume, posted speed limit, and crashes. Recent research efforts that should be considered in scoping the plans for collecting and analyzing data for freeways and high-speed rural highways include:

- NCHRP Project 17-79, "Safety Effects of Raising Speed Limits to 75 mph and Higher"
- NCHRP Project 17-92, "Developing Safety Performance Functions for Rural Two-Lane Highways that Incorporate Speed Measures"
- FHWA Project, *Development of Speed Crash Modification Factors (CMF) using SHRP-2 Roadway Inventory Database*
- FHWA Project, *Research Utilizing SHRP2 Data to Improve Highway Safety: Development of Speed–Safety Relationships*
- USDOT, *Rural Speed Safety Pilot Project*
- TxDOT Project, *Develop a Real-Time Decision Support Tool for Rural Roadway Safety Improvements*
- FHWA's *Speed Concepts: Informational Guide* (FHWA-SA-10-001)

The objectives for this research include (1) identifying the relationship(s) among roadway geometric characteristics, speed (posted and operating), and safety for high-speed rural highways and freeways; (2) determining the relative contribution of speed (posted or operating) with various roadway geometric characteristics on safety for high-speed rural highways and freeways; and (3) determining if existing crash modification factors for geometric elements can be modified with a speed component (operational, posted), or if a speed related CMFs can be developed.

To explore the relationships among roadway design, operating speed, posted speed limit, and crashes, tasks could include: (1) conducting a literature review; (2) identifying potential data sources, especially with respect to operating speed data and evaluating the quality of the data sources along with whether they can support the desired evaluation; (3) gathering data; (4) performing statistical modeling and data analysis to identify the holistic relationships among design elements, speed, and crashes on high-speed rural highways and freeways; (5) assessing the effects of study factors (posted and operating speed, and roadway geometry and characteristics) to safety and perform sensitivity analysis with respect to inclusion of covariates, model forms, etc.; (6) developing improved/enhanced CMFs or crash modification functions for geometric elements with consideration of operating speed.

Project 17-111
Speed Management Solutions and Strategies to Improve Pedestrian and Bicyclist Safety on Arterial Roadways

Research Field: Traffic
Source: AASHTO Committee on Active Transportation
Allocation: $550,000
NCHRP Staff: Zuxuan Deng

While the role of speed in traffic crashes is a complex topic, research has found unequivocally that higher speeds lead to higher injury severity for vulnerable road users (Sanders et al., 2019). Notably, the risk of serious injury or fatality for pedestrians increases dramatically as vehicle speed on impact increases, with a roughly 13% change of fatality or severe injury at 20 miles per hour (mph), 40% at 30 mph, and 73% at 40 mph (Tefft, 2013). It is also clear that drivers traveling at higher speeds have less time to react to unexpected situations, less recovery time if distracted, and longer braking distance, which contributes to crashes (Boodlal et al., 2015).

A safe-systems approach to roadway safety requires a robust speed management effort. On lower-volume roadways, traffic-calming strategies with vertical and horizontal deflections (raised speed humps, bumps, chicanes, center turning islands) have been found to be effective at lowering speeds. However, incompatible land uses are often placed next to high-speed roadways, and solutions for traffic-speed management along arterials and higher-speed roadways are more limited and often much more challenging to implement. Research has found that higher-speed arterial roadways are associated with increased frequency and severity of pedestrian and bicycle crashes (Guerra et al., 2019; Lin et al., 2019). There is some evidence that strategies such as road lane reductions, automated speed enforcement, lane width reductions, speed limit reductions, modifications to traffic signal timing, and well-placed landscaping can reduce vehicle speeds. However, the relationship between lowering vehicle speeds and the magnitude of changes in outcomes for pedestrian and bicycle safety are less clear.

Importantly, although the factors relating to the increased risk of speed to people walking will also apply to people bicycling, few studies specifically link bicyclist or pedestrian injury or fatality risk to speed management directly. In addition, research shows that more active travel lowers risk and while research generally suggests that slower motor vehicle speeds encourage more walking or cycling, there is limited research that quantifies this relationship directly.

Research is needed to demonstrate the impacts of speed management efforts on higher-speed roadways, specifically for people walking and bicycling, and provide clear guidance on successful implementation strategies that have balanced lower speeds for some users with safety improvements for others.

The research objective of this project is to produce a guide that can be used as a context driven roadmap to speed management on arterial and higher-speed roadways, and how this can be balanced with appropriate safety improvements for pedestrians and bicyclists on these arterial and high-speed roadways. Potential tasks include:

- Reviewing literature and state-of-the-practice inventory and information.

- Developing case studies and information effort covering all aspects of context-driven speed management—roadway design, enforcement, speed limit setting, use of coordinated signal timing in higher speed corridors, self-enforcing roadways, signs, and traffic calming that are appropriate for a range of speeds and road classifications. Identify the need for any new or additional data.
- Developing a case study toolbox of specific recommendations and guidance to implement effective context-driven speed management efforts on arterial and higher-speed roadways, and how these should be balanced with appropriate safety improvements for pedestrians and bicyclists on these arterial and high-speed roadways.

Combined with results from the forthcoming NHTSA project (Impact of Lowering Speed on Pedestrian and Bicyclist Safety that is scheduled for completion in 2023), this research would be a powerful and useful tool for understanding how to make changes that improve active transportation safety.

Project 17-112
Enhancing Highway Safety Manual Guidance on Pedestrian and Bicyclist Countermeasures (CMF/SPF Development)

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $600,000
NCHRP Staff: Richard Retting

The *Highway Safety Manual* (HSM) 1st edition provides analytic tools and techniques for estimating the effect of changes to the roadway environment on motor vehicle crash frequency, but provides almost no information on their effects on pedestrian and bicyclist crash frequency. NCHRP Project 17-84, “Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual,” is in the process of developing crash modification factors (CMFs) and safety performance functions (SPFs) for pedestrians and bicyclists in support of a future HSM 2nd edition. However, NCHRP Project 17-84 is not comprehensive, and the safety benefits of many (especially newer) pedestrian and bicycle countermeasures will still be unknown after the project is completed. Furthermore, established CMFs focused on vehicle-vehicle collisions do not properly account for possibly adverse safety effects for pedestrians and bicyclists or others outside of the vehicle. In addition, the HSM’s CMFs for roadway lighting generally require updating. Without quantifiable safety prediction methods, it can be difficult to justify countermeasure installation, compare and contrast different countermeasure options, or evaluate tradeoffs in vehicular and multimodal safety (e.g., as part of road cross-section reallocation efforts).

The objective of this research is to develop a guide that will include consideration of how treatments focused on addressing the safety or operational needs of one set of roadway users may have different effects on travelers with vision or mobility impairments. Crash-reduction performance is highly important, but not the only factor governing decisions about the specific countermeasure(s) to be installed at a given location. Other guidance documents (e.g., NCHRP guides on pedestrian analysis (*NCHRP Research Report 992: Guide to Pedestrian Analysis)* and roadway cross-section reallocation (*NCHRP Web-Only Document 318*: *Safety Prediction Models for Six-Lane and One-Way Urban and Suburban Arterials*)) will discuss bigger-picture trade-offs involved in decision-making and can be used in conjunction with the findings from this study for countermeasure selection.

The objectives of this research include quantifying (1) the safety performance (crash-reduction effects) of pedestrian and bicyclist safety countermeasures and (2) the pedestrian/bicyclist crash reduction (or expansion) effects of vehicle safety countermeasures, specifically focusing on the highest-priority countermeasures not addressed by *NCHRP Research Report 992* or *NCHRP Web-Only Document 318*.

Potential tasks include (1) reviewing findings and recommendations from previous research; (2) identifying future research priorities for developing CMFs and SPFs for pedestrian and bicyclist safety countermeasures; (3) conducting a focused literature review on relevant new research (4) prioritizing needs for additional CMFs and SPFs for pedestrian and bicyclist safety countermeasures, as well as new methodologies to predict ped/bike safety outcomes, based on what is available and what is still needed; and (5) preparing a data collection plan (including surrogate safety measures) for selected countermeasures, that will maximize the potential that the project will develop CMFs and SPFs with high-enough ratings for eventual inclusion in the HSM.

Estimating the safety performance of countermeasures and their impacts on bicyclists and pedestrians is critically important to improving safety. The outcomes from this study can inform agencies about the safety performance of various countermeasures and will help them make data-driven decisions regarding treatments to improve bicyclist and pedestrian safety.

Project 17-113
Incorporating Safe System Approach into the NCHRP 500 Series

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

NCHRP Report 500: *Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* identifies proven, tried, and experimental safety strategies for each of the emphasis areas in AASHTO's original 1998 Strategic Highway Safety Plan. FHWA and the state departments of transportation (DOTs) partnered through a pooled fund study to develop reliable estimates of the effectiveness of the safety improvements identified as strategies in the *NCHRP Report 500* guidebooks. While information presented in the NCHRP 500 series guides is still useful and referenced in many national reports, a lot has changed over the last 20 plus years. In 2010, AASHTO published the *Highway Safety Manual*. In 2014, AASHTO adopted *Toward Zero Deaths: A National Strategy on Highway Safety* and in 2018 the National Safety Council published a *Road to Zero: A Vision to Achieve Zero Deaths by 2050*. Technology is advancing at a rapid pace and has the potential to change traffic safety. Many agencies are beginning to implement a Safe System Approach. There is an opportunity to update these guides and provide guidance to agencies on safety strategies and countermeasures of the future.

The objective of this research is to update the guides to align with AASHTO's current priorities and Safe System principles, as well as reflect on the most recent research and identify new innovations to help achieve the goal of zero deaths on the nation's roads. Tasks may include:

1. Gather input on priority crash types and desired toolkit content and capabilities. Priority crash types may address Safe System and consider rural priority crash types.

2. Conduct literature review to identify new and innovative countermeasures, current research on safety effectiveness, and other relevant information.
3. Provide information for each countermeasure, including considerations on implementing the strategy.
4. Propose how the toolkit will coordinate with other tools (e.g., CMF Clearinghouse).
5. Identify options for long-term maintenance of the toolkit.
6. Develop recommended content of priority crash types.
7. Develop, test, and update the toolkit.
8. Develop materials to promote and demonstrate use of the toolkit.

The research will help analysts consider a broader list of countermeasures applicable to the majority of crash types; improve the efficiency of countermeasure selection; link to state analysis tools; enhance usability of the NCHRP 500 guidebooks; provide access to the most current information; advance implementation of the Safe System approach; and increase awareness of a valuable tool for implementing safety projects.

Project 17-114
Integrated Strategies for Managing High Travel Speeds

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

High traffic speeds are arguably the largest contributor to traffic deaths in the United States. High speeds contribute to crash occurrence and their direct influence on impact speeds determine crash severities (Aarts and van Schagen, 2006; Hussain et al, 2018). Moreover, specific populations, i.e., traditionally marginalized and underserved communities, bear a disproportionate burden of the collective traffic injury problem (Hamann, Peek-Asa, and Butcher, 2020). Despite the existence of isolated interventions to curtail higher speeds—e.g., speed safety cameras, traffic calming road design, concordance between land use and road classifications—few of them have been widely and equitably adopted. None get at the deeply rooted and interconnected causes of the problem, such as people's harried lifestyles, thrill-seeking behaviors, the consumption of increasingly more powerful vehicles, prioritizing speed over competing values of concern for self and others, among many other interacting factors.

To manage traffic speeds proactively and over longer periods of time, professionals need to recognize the complexity of this public health issue and to broaden their repertoire of ways to address it. Relevant here are cross-sectoral partnerships and tools to help teams of partners to visualize the complex processes that could be driving an outcome of interest (Arnold and Wade, 2015). To ultimately develop integrated strategies to managing travel speeds in various contexts, teams will need to draw upon traditional data (e.g., crashes, roadway inventory, traffic speed and volume data, freight transport) and less traditional data (e.g., indicators of land use density and mix; perceiving those who speed as "cool"; in-vehicle feedback on drivers' travel speeds; consumer trends privileging vehicles of increasing size, weight, and horsepower; and workplace and social group "culture" and policies surrounding high travel speeds) to consider the interacting elements of the system that influence high travel speeds. These integrated strategies should also be adaptable enough to contend with disruptions that could impact travel speeds, such as global pandemics, siloed funding of disconnected parts of the system, increased awareness of social injustices and inequities in transportation safety and access, natural disasters, and technological breakthroughs.

As mentioned, there are several efficacious speed-reducing tools (e.g., speed safety cameras, traffic calming road design, and concordance between land use and road classifications), yet these are often not widely or equitably applied, and none address the complex array of reasons people drive at high speeds. For example, traffic calmed streets can reduce operating speeds, however, they fail to make people feel less hurried in their lives. This research would build upon a foundation of work focused on speed limit setting (e.g., *NCHRP Research Report 966*; NCHRP Project 17-79), street redesign, traffic signal coordination, and automated speed enforcement toward enhancing pedestrian safety (e.g., *NCHRP Synthesis 535*) to examine the confluence of factors that influence travel speeds. This research would bring to bear a package of promising practices (e.g., speed limit setting, land use, workplace, congestion pricing), transportation investments (e.g., transit provision, speed-oriented school, and workplace practices), communications strategies (e.g., media framing of travel speeds and traffic congestion), and interventions (e.g., intelligent speed adaptation (ISA), speed safety cameras and their equitable placement, operation, and re-investment schemes) that can be incorporated into a unified, adaptable framework for managing high travel speeds. The research should also shed light on strategies that do not work, or that may have unintended consequences to help free agencies from defaulting to costly and ineffectual schemes and to encourage working with partners to improve outcomes.

The research approach could include the following tasks:

1. Synthesize a broad literature on speed reduction strategies, as well as community-based injury reduction interventions.
2. Generate insights on speed-related dynamics (e.g., workplace practices that knowingly or unknowingly incentivize high travel speeds among employees), feedbacks (e.g., sprawling land uses that incite high speeds to cover increasing distances), and potential leverage points for intervention (e.g., incorporating safe design speeds in traffic impact assessment (TIA) procedures).
3. Incorporate strategies into a prototype Integrated Strategies for Speed Management Framework for managing high travel speeds in an integrated manner.
4. Design prospective demonstration studies with local, regional, and state partners on the implementation of the Integrated Strategies for Speed Management Framework. It is anticipated that this prospective demonstration study would seek guidance on best practices for identifying partners, policies, practices, and interventions that, when used in appropriate contexts and in combination, can help manage travel speeds across various spatial and time scales.

Project 17-115
Pedestrian Crosswalk Spacing and Placement Guidance to Improve Safety

Research Field:	Traffic
Source:	AASHTO Committee on Safety and Delaware Department of Transportation
Allocation:	$500,000
NCHRP Staff:	Zuxuan Deng

An estimated 6,205 pedestrians were killed in traffic collisions in the United States in 2019, a 44% increase in pedestrian fatalities since 2010, representing 17% of total traffic fatalities. Over 80% of those pedestrian fatalities occurred at unmarked midblock locations. Roadway safety is a shared responsibility and while some fatalities are due to pedestrian negligence, many cases result from a system that prioritizes automobile mobility at the expense of pedestrian safety. Research has found that locations where pedestrians are most likely to cross outside crosswalks are highly influenced by the surrounding roadway environment and characteristics, such as pedestrian volume, number of bus stops, vehicular volume, distance between crosswalks, and crossing distance. For most pedestrians to walk far out of their way to cross a street at a marked crosswalk would contradict basic human behavior. It follows that safely designed crosswalks properly spaced so pedestrians can practically utilize them should prevent needless fatalities and injuries. While research has established the safety and effectiveness of countermeasures such as refuge islands, pedestrian hybrid beacons (PHBs), and rectangular rapid flashing beacons (RRFBs) and provides guidance (e.g., STEP guide) for selecting countermeasures at uncontrolled crossing locations, current guidance and research regarding midblock crosswalk spacing is limited. The ongoing study NCHRP Project 03-14, "Guidance on Midblock Pedestrian Signals (MPS)" will assess the safety effects of MPS and potentially develop language suitable for inclusion in the MUTCD, but more work is needed to understand suitable spacing of these treatments. This research aims to reduce pedestrian fatalities and severe injuries through a better understanding of appropriate midblock crosswalk spacing.

National crosswalk spacing guidance is ambiguous, with Section 3B.18 of the MUTCD (define?) stating: "Crosswalk lines should not be used indiscriminately. An engineering study should be performed before a marked crosswalk is installed at a location away from a traffic control signal or an approach controlled by a STOP or YIELD sign." Although it is recommended that the engineering study consider the distance from adjacent signalized intersections and the possible consolidation of multiple crossing points, there are no specific criteria offered in terms of spacing and no specific criteria that take varying infrastructure and land use conditions into account.

Several state guidelines for crosswalks refer to the American Association of State Highway and Transportation Officials (AASHTO) Stopping Sight Distance formula. This formula combines a driver's reaction time, braking distance, travel speed, and roadway grade to calculate the distance necessary for a vehicle to make a complete stop. AASHTO recommends that midblock marked crosswalks not be installed where sight distance and sight lines are limited. However, while this guidance identifies where marked crosswalks should not be installed, it does not directly inform where they should be installed and their appropriate spacing.

To ensure efficient traffic operations, many agencies have also adopted requirements that preclude marking a crosswalk within a close distance of another crossing. These requirements generally specify a minimum distance of 200-600 feet between a midblock crosswalk and the next nearest marked crosswalk. While these minimum distances are important to ensure safety and efficient traffic operations, the maximum suitable distance between crosswalks is more critical for ensuring there are adequate crossing opportunities designed appropriately to reduce the risk of pedestrian crashes. More research is needed to provide states and cities with guidance on the important criteria of maximum crosswalk spacing. Providing appropriately spaced crosswalks properly designed for the specific roadway conditions may improve the safety and security of pedestrians.

The objective of this research is to determine the maximum distance pedestrians will travel to use a crosswalk and develop crosswalk spacing recommendations in various contexts, based on pedestrian behavior and willingness-to-deviate. A better understanding of this spacing will help to inform when to add marked crosswalks at uncontrolled midblock locations to discourage pedestrians from crossing at higher-risk locations between crosswalks. In addition to crosswalk spacing, the research will explore factors that influence pedestrians' choice to divert from an unmarked direct crossing path toward a marked crossing in terms of origin/destination proximity, land use context, and crossing need.

Research tasks would include: (1) literature review of existing strategies and research regarding crosswalk spacing compliance and safety outcomes with a focus on human factors; (2) data collection (crosswalk location and land use and transportation context, pedestrian compliance and safety outcomes, roadway environment such as lighting, geometry, facilities, vehicle speeds and volumes, operational details, users, vehicles, etc.); (3) survey pedestrians to explore willingness to deviate to cross at a marked crosswalk across a variety of land-use contexts; (4) identify compliance and safety outcomes related to crosswalk spacing and context; and (5) propose solutions and guidance for agencies on maximum crosswalk spacing.

Project 17-116
Practical Approaches to Quantifying Safe System Concepts

Research Field:	Traffic
Source:	AASHTO Committee on Safety
Allocation:	$450,000
NCHRP Staff:	David Jared

The use of Safe System principles for roadway design and operations is showing significant success worldwide in reducing fatal and serious crashes for all road users, including those who walk and bike. The Safe System approach recognizes that all road users should be treated equitably, in a manner that considers safety tradeoffs for all, and that death and serious injury are preventable when consideration is given to the tolerance of the human body to crash forces. In addition, the Safe System approach applies to all roadways: urban or rural, and under state, local or tribal jurisdiction. Finally, the Safe System approach recognizes that human errors occur and that by designing and operating road infrastructure to account for these errors crash likelihood is reduced.

Searching for opportunities to reverse the upward trend in traffic fatalities, many state departments of transportation (DOTs) are interested in moving towards a Safe System approach and have been looking at practical ways to reduce crash forces at intersections and roadways. In some cases, this has resulted in the development of policy changes in speed management and design directives.

The objective of this research is to investigate the correlation between a Safe System for Intersections (SSI) score and observed fatal and serious injury crash frequency at an intersection so that a benefit/cost ratio or cost effectiveness associated with the SSI score can be determined. This methodology then can be applied to corresponding roadway segments. The research will also recommend how the SSI can be adopted to design and operational criteria for future implementation. Pilot testing of the research results will be used to validate and strengthen the methodology and will provide additional knowledge to those transportation agencies implementing the new model.

This research will help safety professionals more fully understand the relationships between economic, regulatory, vehicle, and infrastructure factors and traffic fatalities and the mechanisms by which they operate to provide state DOTs with insights that can be used to target fatality reduction programs and projects. Moreover, strategies that combine domains will be important for using state resources efficiently to maximize fatality reductions.

Project 17-117
Safety Performance Functions for Horizontal Curves

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $350,000
NCHRP Staff: Zuxuan Deng

Statistics from the Fatality Analysis Reporting System (FARS) indicate that more than 25 percent of fatal crashes occur at horizontal curves, with most of these crashes being roadway departures. In the United States, the average crash rate for horizontal curves is about three times higher when compared to crash rates of other types of roadway segments. Although researchers and practitioners agree that curvature plays a role in crash frequency, crash rate, and crash severity, Safety Performance Functions (SPFs) for horizontal curves have not been thoroughly investigated or widely implemented. The *Highway Safety Manual* (HSM) provides SPFs of various facility types for segments and intersections, but no specific SPFs for curved segments are presented. Rather, curves are handled by applying an Adjustment Factor (AF) to estimate the predicted crash frequency of a curved segment. Unfortunately, not all the SPF models within the HSM have AFs for horizontal curves.

Recent studies have been implemented to develop AFs for curved segments of certain facility types to begin filling this gap. However, applying a horizontal curve AF to an existing segment SPF assumes that the underlying prediction model of a tangent segment only needs to be adjusted to appropriately estimate a horizontal curve's influence on the segment's safety performance. This method may not be the best way to assess the safety performance of horizontal curves. A more thorough investigation may reveal that common geometric attributes used to estimate the safety performance of tangent segments have a different degree of influence on the safety performance of horizontal curves. For example, length has been shown to be an important attribute for predicting crashes on a tangent segment; however, for predicting crashes at a horizontal curve, the length of curve may have less influence and attributes such as curve radius and deflection angle may have stronger influence. Taking this possibility further, the attributes most important for predicting the safety performance of a horizontal curve may differ due to setting (rural vs. urban), facility type (2-lane vs. freeway), or other factors such as lane width, shoulder with, and roadside elements.

Research is needed to better understand the attributes that most influence the safety performance of horizontal curves. Ultimately, this research will lead to the development of SPFs for horizontal curves along a variety of facility types so that the safety performance of most facility types can be predicted more comprehensively by utilization of three categories of SPFs: one for tangent segments, one for horizontal curves, and one for intersections.

Horizontal curves are mentioned in the HSM for some facility types and addressed with a Crash Modification Factor (CMF), which is now referred to as an AF, but no specific SFPs were proposed for curved segments. Recent studies demonstrate that the application of curve CMFs/AFs within the HSM could not properly reflect this roadway element in the safety prediction for some locations and the development of additional CMFs/AFs and SPFs could be beneficial in safety studies (Banihashemi 2015, 2016; Harwood and Bauer 2015; Wu, Lord, and Geedipally 2017, Silva 2017). Moreover, some initiatives have shown that horizontal curves are an important roadway element and need to be addressed separately using a SPF (Anarkooli et al. 2019; Aram 2010; Bauer and Harwood 2014; Findley et al. 2012; Gooch, Gayah, and Donnell 2016; Khan et al. 2013; Miaou and Lum 1993; Montella 2009; Saito et al. 2015; Saleem and Persaud 2017; Vogt and Bared 1998; Xin et al. 2019). A common limitation in previous studies is the lack of a comprehensive sample of horizontal curves. The horizontal curve features were not always available in a roadway database, causing some researchers to collect data by identifying horizontal curves manually, resulting in the use of a small set of horizontal curves for SPF development. However, there is now an opportunity to use horizontal curve features from automated data collection methods to address this gap in knowledge and practice through this proposed research.

The objectives of this research include:

1. Investigate a wide variety of roadway and traffic attributes to better understand which attributes, or combination of attributes, have strong correlation with the safety performance of horizontal curves for various facility types.
2. Explore the impact new data sources might have on the predictive results of horizontal curve SPFs. Potential data sources could include, but are not limited to: measured operation speed (e.g., INRIX data), continuous pavement friction measurement (e.g., SCRIM), and curve advisory speed and other curve data (e.g., CARS).
3. Evaluate various SPF model forms to determine which have the best fit for various facility types. Consideration should be given to the SPF models described in the SPF Development Guide (Srinivasan and Bauer 2013).
4. Develop horizontal curve SPFs for a variety of facility types, including rural and urban freeways, rural and urban multilane divided roadways, rural and urban multilane undivided roadways, and rural and urban 2-lane undivided roadways.

Project 17-118
Understanding the Impacts of Operational Changes on Safety Performance

Research Field: Traffic
Source: AASHTO Committee on Safety
Allocation: $450,000
NCHRP Staff: Richard Retting

Mobility and safety are often identified in transportation agency mission statements as core values. Traffic operations management has many metrics including level of service, volume to capacity ratio, and travel time reliability measures. Safety performance is often measured in the number of crashes and the injury outcome of crashes. Operational improvements aim to keep vehicles moving freely, often resulting in higher vehicle speed. As agencies consider the Safe System approach, which has a focus on reducing vehicle speed to reduce crashes and the impact energy when crashes do occur, competing interests between safety and operations could arise. These seemingly opposed goals of safety and mobility need to be balanced.

The safety performance functions (SPF) included in the AASHTO *Highway Safety Manual* (HSM) indicate that as capacity increases, crashes will typically be reduced in frequency and severity on freeway and arterial segments. Vehicle speed is another metric that can be used to understand both operational improvements and changes in crashes. In addition, systemwide changes in factors related to use of the roadway network, such as traffic volume, peak hours, mode choice, and road user risk factors, can affect the safety performance of the system and of individual facilities.

The objective of this research is to produce a tool to assess how implementation of operational measures impact crash outcomes and to develop associated guidance and procedures that will improve the understanding of the complex relationship among existing operational and safety performance measures. This research has the unique opportunity to use data from the pandemic period to assess how unintended changes in operational performance led to negative impacts to safety performance. This assessment could provide insight into how operational improvements—that lead to reduced congestion, improved travel times, and changes in peak period traffic—affects crashes in a real-world environment.

Suggested research activities include: (1) compile existing research findings regarding the relationship and correlation between operational measures and safety performance measures; (2) investigate how crash frequency and severity changed due to various types of projects that improved operations—such as projects to alleviate congestion and bottlenecks to improve travel time reliability—and produce an outcome model exhibiting the findings; (3) develop a quantitative analysis procedure to understand the tradeoffs between capacity improvements (or societal changes that impact traffic volumes) and resulting change in crash frequency or severity; (4) complete an analysis of the level of service during peak hours and off-peak hours and change in crash typology and severity to produce a quantitative or graphical representation of this relationship; (5) produce an operational and safety performance measure correlation model to be used as decision-making and countermeasure prioritization tool; and (6) develop outreach materials to support transportation agencies' use of the research results, including items such as models, worksheets, analysis tools and presentations.

Transportation agencies need tools to support decisions concerning the impacts of mobility, capacity, and crashes and to help understand the systemwide impacts of changes in external factors that affect use of the system. Corridor operational improvements have led to many research studies that show mixed results with respect to reducing crash frequency and severity. This research will provide clarity to this topic.

This research is needed to analyze the performance of the roadway system more thoroughly from the perspective of various safety and operational performance measures, and to develop a tool to assist transportation agencies in performing this type of analysis for decision-making. This research will help transportation safety professionals more fully understand the relationships between operational performance measures and traffic fatalities and to provide agencies with insights on the competing or complementary nature of the performance measures. This knowledge can be used to combine performance measures and will be important for using state departments of transportation resources efficiently to maximize fatality reductions while still prioritizing mobility for all road users.

Project 17-119
Conflict-Based Crash Prediction Method for Intersections

Research Field: Traffic
Source: AASHTO Committee on Design, Technical Committee on Geometric Design
Allocation: $550,000
NCHRP Staff: Zuxuan Deng

As the number and prevalence of intersection forms and configurations increase, it has become more challenging for practitioners to quantify the safety effects of constructing these designs. Currently the *Highway Safety Manual* (HSM) provides safety performance functions (SPFs) for a few conventional intersections based on empirical research, but any deviation from the basic assumptions in the HSM requires the application of one or more crash modification factors (CMFs). Although there are a high number of CMFs from various sources, some apply to alternative intersection forms and fewer apply to complex traditional intersection that very from the basic intersections in the HSM. Intersection control evaluation (ICE) policies and efforts typically promote the consideration of alternative intersections not covered in the HSM, which has limited the ability of practitioners to compare these alternative intersections with conventional designs.

One measure of safety common to all at-grade intersections is the conflict point, or the point where two or more vehicle paths may cross. Conflicts may be classified as crossing, merging, or diverging based on the angle between vehicle paths. Previous research has demonstrated the relationship between the number of conflict points at an intersection and the number of resulting crashes over a given time-period. Similarly, crash severity can be roughly correlated to conflict type/angle/speed differential. Alternative intersections have been put forward as an improvement in safety over conventional forms due to a reduction in total conflict points, conversion of angle conflicts to merge/diverge conflict points and/or reducing speeds at conflict points.

The product of the research will be a series of crash prediction models with not only the typical rural, urban/suburban setting types, but conflict point frequency, type (merge, diverge, crossing), and speed differential as independent variables, applicable to all intersection forms, and implementable within the HSM Part C methodology.

The objective of the research is to identify and quantify the relationships between each basic conflict point and type of conflict within an intersection to the overall crash frequency of the intersection. The research will result in a methodology to develop new SPFs to supplement those in the HSM Part C models.

Project 17-120
Improved Method to Link Crash, Emergency Medical Service, and Trauma Registry Data to Expand Safety Data Analyses and Safety Program Development

Research Field: Traffic
Source: Washington Department of Transportation
Allocation: $400,000
NCHRP Staff: Richard Retting

NCHRP Web-Only Document 302: Development of a Comprehensive Approach for Serious Traffic Crash Injury Measurement and Reporting Systems, provides a roadmap for state departments of transportation (DOTs) to develop comprehensive crash-related data linkage systems. A particular focus of the research was defining and measuring serious injuries in crashes. Since the completion of the research in 2017, newer versions of related systems have been released, additional research has been performed, and technological developments have advanced capabilities in this area. For example, it is now possible to use a Universally Unique Identifier (UUID) to perform deterministic linkage between two records in emergency medical service and trauma registry databases. Applying this method to crash records to link them to EMS, trauma registries, and other types of data will increase the availability of these linkages, allowing for advancements in traffic safety data analysis, which in turn will lead to development of more effective and comprehensive traffic safety programs. In addition, this research would support more sophisticated safety target setting, as well as safety performance monitoring and management.

The objective of this research is to further refine an approach proposed by the joint National Association of State EMS Officials – American College of Surgeons policy statement, "A Novel Approach to Data Linkage: EMS and Trauma Registry Data" to use a UUID to link traffic crash report data with other data systems. This will allow state agencies to measure serious injuries by linking crash data at the state level with the EMS and hospital trauma registry data, providing more detailed quantification of crash outcomes in terms of injury severity scoring, hospitalization costs, length of stay, and permanent disability. This research will be especially important for vulnerable road users such as pedestrians and bicyclists–who typically experience low reporting rates in police collision datasets–since EMS and trauma registry records are not limited to the incident types for which police records are filed.

Tasks may include: (1) analysis of changes in traffic safety related data and advancements in traffic safety data analyses since the research conducted to produce *NCHRP Web-Only Document 302* was completed in 2017; (2) further development of the method of deterministic linkage of EMS and trauma registry data using a UUID to perform similar linkages with crash report databases; (3) specifying the "landing spot" for the UUID in various existing data standards (e.g., MMUCC define), and assessing and applying previously developed relevant methodology or related research; and (4) development of an implementation plan that provides a potential path for nationwide outreach, implementation, and guidance for agencies collaborating in individual states to implement the research results, depending on their current readiness to adopt proposed data linking methodology.

This research would support informed, data-driven decisions that affect safety, and would further enable state DOTs to collaborate with traffic safety stakeholders. Reducing the complexity of database linkage practices will allow states to more fully assess the total crash event and the continuum of care offered to patients after the crash. Current data linkage practices are complex and dependent on the availability and quality of "like" elements within disparate datasets. Specifying and promoting use of a UUID to link records (with no use of protected health information or personally identifying information) will greatly enhance the reliability and precision of records linkage and will facilitate record linkage among states and governmental entities.

Project 17-121
Using Advanced Technologies to Reduce Commercial Motor Vehicle Crashes in Work Zones

Research Field: Traffic
Source: Federal Highway Administration
Allocation: $500,000
NCHRP Staff: Camille Crichton-Sumners

Commercial motor vehicles (CMVs) have been overrepresented in work zone fatal crashes for many years. While CMVs have been involved in approximately 13 percent of overall fatal crashes nationally outside of work zones, they have been involved in about 32 percent of fatal crashes in work zones. The issue is even more significant on rural interstate facilities, where nearly 56 percent of fatal work zone crashes involve a CMV. Work zones can also create significant congestion and advanced technologies can help CMV drivers avoid these congestion locations as well. Advanced technologies may better warn and inform CMV drivers in real-time about work zones they are approaching (e.g., through electronic driver logging or other in-cab devices) so that they can be better prepared to take appropriate actions. Opportunities also exist to utilize advanced technologies to help drivers of personal vehicles as well as highway workers better anticipate and accommodate CMVs operating in work zones.

Smart work zone (SWZ) technologies are available that are designed to detect when construction-related CMV (or other vehicles) are exiting the work space and providing warning to motorists upstream of the work zone so that they can change lanes or otherwise prepare for the vehicle entering at a slower speed. Similar type systems can warn when CMVs are slowing to enter into a work space. Although implemented on a few projects nationally, such systems have yet to be rigorously evaluated in terms of their ability to improve safety and reduce CMV-involved crashes in work zones. Research is needed to identify functional requirements and develop evaluation methods to aid state DOTs in selecting advanced technologies to deploy.

The objectives of this research are to identify available advanced technologies to mitigate CMV crashes in work zones and prioritize them in terms of implementation readiness criteria, support systems, required stakeholder collaboration, and anticipated effectiveness.

Project 17-122
Evaluation of Trespassing Detection and Warning Systems in the Vicinity of Highway-Rail Grade Crossings

Research Field: Traffic
Source: AASHTO Council on Rail Transportation and Indiana Department of Transportation
Allocation: $450,000
NCHRP Staff: Amir N. Hanna

Highway-rail grade crossings have always presented a significant safety challenge for road authorities and railroads across the United States and historically have been the source of most of the railroad-related deaths. Implementation of a dedicated federal funding program in the early 1970s resulted in tremendous reductions in highway-rail grade crossing fatalities, from 888 in 1975 to 197 in 2020, according to the Federal Railroad Administration (FRA). Still a major focus for safety improvements, highway-rail grade crossings now represent the second highest source of railroad-related fatalities behind trespassing.

Trespassing, including suicides, now represents approximately 70% of all railroad-related deaths and is trending upward. The FRA Office of Safety Analysis data demonstrates trespassing fatalities increasing over 31% the past 10 years to 525 fatalities in 2020, a number far exceeding the 197 fatalities at highway-rail grade crossings. According to FRA, the 9,363 reported trespassing accidents during the 2012 and 2016 period were associated with a societal cost of $43.2 billion in fatalities and injuries and more than $56.0 million losses in travel time delays in trains. Additionally, the FRA reports that about 74% of deaths and injuries related to rail trespassing (excluding suicides) and 73% of suicide attempts occur within 1,000 feet (<0.25 mile) of a highway-rail grade crossing. These incidents occurring in the vicinity of highway-rail grade crossings also cause significant delays to motorists, their passengers, and other roadway users at the crossings.

Crossing the rail property because that provides the most direct route to a desired destination, and trespassers not fully aware of the dangers involved in trespassing behavior, are among the reasons behind most trespassing behavior. Lack of deterrents, poor community planning, and lack of grade crossings in large sections of track all contribute to an increased number of trespassing. Community decisions such as the placement of public buildings, services, and bus stops relative to safe crossing paths could affect people's choices of trespassing the rail property.

In addition to enhancing law enforcement, education, community, and roadway planning, new technologies can be applied to railroad and highway right-of-way (ROW) to prevent trespassing from happening in the vicinity of highway-rail grade crossings. Surveillance systems can be installed to detect and warn trespassers. At present, there is extensive knowledge concerning how to detect intruders in terms of general security sensitive installations, such as utility plants, banks, etc. However, technologies and systems used to detect trespassers in the vicinity of highway-rail grade crossings are limited and the effectiveness and scopes of implementation of new technologies on such tasks have not been thoroughly evaluated. The unclear effectiveness and range of applications of these detection and warning systems could provide limited, if not misleading, information to decision makers when choosing the appropriate systems to implement. Therefore, systemic evaluations of the trespassing and suicide detection and warning systems along rail ROW particularly in the vicinity of grade crossings has significant impacts on the health of the integrated multimodal transportation system. The Federal Highway Administration (FHWA) Rail-Highway Crossings Program provides funds for "the elimination of hazards at highway-rail grade crossings" and "eligible projects include those involving all public rail crossings: roadways, bike trails, and pedestrian paths." Half of a state's apportionment is prescribed for installing protective devices at crossings, while the remaining can be used for other hazard elimination projects, and the installing of detection and warning systems could be an effective solution for preventing trespassing and suicide in the vicinity of grade crossings. Highway authorities have an opportunity to work together with rail authorities to improve the grade crossings safety by choosing and implementing effective detection and warning systems and technologies at grade crossings.

Although there are some existing studies on technologies and systems that can be used for detecting trespassers on rail ROW, the research is either outdated or has only focused on a specific technology prototyped/tested in selected locations. Research on more accurate, efficient, and cost-effective infrastructure-based technologies and systems that can be applied to grade crossings is especially lacking. Considering the extensive railroad lengths in the United States and the overrepresentation of trespassing and suicide events in the vicinity of highway-rail grade crossings, investigation of such technologies and systems that can be applied to grade crossings has significant importance. With newer technologies being available in image detection, radar, LIDAR, infrared, UAV, and so on, it is necessary and urgent to conduct a systemic evaluation of such technologies to be used in detecting and warning trespassers as well as giving advance warnings to rail staff and train operators.

The objective of this project is to identify functional requirements and evaluation methods to aid state DOTs in selecting appropriate systems based on different needs and conditions. The following tasks should be considered:

1. Identify potential intruder detection and warning technologies that can be applied to rail ROW in the vicinity of highway-rail grade crossings.
2. Provide for each of the technologies: engineering description of the necessary hardware and technologies; indication of types of automated warnings; discussion of software and analysis technologies (e.g., artificial intelligence) necessary to interpret and collate data collected to assist with decision-making; and discussion of costs of hardware, software, maintenance and staffing.
3. Investigate the circumstances under which the varied systems and technologies are applicable, including but not limited to funding considerations, environmental characteristics, infrastructure requirements, etc.
4. Provide guidance to decision makers on choosing the appropriate warning systems and the roles and responsibilities of the roadway authority.

Project 19-22
Future Equity Impacts of Existing Fuel Taxes

Research Field: Administration
Source: AASHTO Committee on Funding and Finance
Allocation: $450,000
NCHRP Staff: Camille Crichton-Sumners

The current fuel tax mechanism for funding surface transportation will likely remain in place for years to come, despite some movement toward future implementation of a mileage-based fee. As a fixed per-gallon fee, the federal fuel tax represents a larger share of income the less a payer makes. This research will explore how this disparity may widen as the vehicle fleet becomes increasingly fuel-efficient and alternative fuel vehicle ownership increases, including electric vehicles.

Improvements in vehicle fuel efficiency are developing at a rapid pace. Auto manufacturers are expanding production of electric vehicle models and states have set ambitious goals for new electric vehicle ownership. Meanwhile, lower income drivers tend to replace their vehicles less frequently and will continue driving less fuel-efficient vehicles. The equity disparity around what proportion of an individual's income contributes to fuel costs will continue to grow under the current fuel tax structure. This research relates to AASHTO's strategic goal of advancing equity in transportation, and will benefit state departments of transportation (DOTs) that depend on fuel tax revenue forecasting to allocate resources and make spending decisions.

The objectives of this research are to quantify the long-term user equity impacts of the current fuel tax mechanism in order to aid state DOTs in revenue forecasting; perform a detailed economic analysis of vehicle manufacturing and purchasing trends of new and used vehicles over the next several decades and the resulting equity impacts; identify obstacles for low-income users to access plug-in vehicle infrastructure; explore vehicle use trends for low-income users; and develop a revenue forecasting methodology that incorporates these elements.

Project 19-23
New Mobility and the User Fee Concept

Research Field: Administration
Source: AASHTO Committee on Funding and Finance
Allocation: $450,000
NCHRP Staff: Dianne Schwager

New mobility services offer the potential for innovative revenue collection methods. Whether through dedicated fees or an increased reliance on sales taxes, e-commerce, and other automated delivery services, transportation network companies, car sharing, and other new mobility and micromobility options offer the potential for alternative transportation user fees. State departments of transportation (DOTs) will need to explore increased contributions from these sectors because of the additional strain they put on the transportation system through congestion, travel time delays, and vehicle size and weight.

As state DOTs strive to address additional strains on the surface transportation network and look more holistically at transportation usage fees, this research will support an understanding of how new models for user fees can address long-term investment needs. This research will benefit state DOTs examining new approaches to recover the costs of serving new mobility from user fees or similar revenue structures.

The objective of this research is to examine the manner in which revenue can be collected from the new mobility sector and support the user fee model.

Research tasks and activities could include (1) develop a roadmap for state DOTs on how to implement fees on new mobility and the new economy; (2) conduct a detailed examination of the potential for mobility user fees beyond what is currently in place; and (3) forecasting new mobility and micromobility use and potential revenue collections.

Project 22-57
Development of MASH Full-Scale Test Matrices for Additional Roadside Safety Devices

Research Field: Design
Source: AASHTO Committee on Design and Technical Committee on Roadside Safety
Allocation: $500,000
NCHRP Staff: David Jared

The *Manual for Assessing Safety Hardware* (MASH) has developed test matrices for various hardware based on an approach of "worst practical conditions." This approach is based on selecting the worst or most critical conditions when defining a test matrix. Tests within a matrix need to evaluate different vehicle types, impact conditions, failure types and vary the evaluation criteria. A matrix also needs to allow multiple design alternatives for a roadside feature. Finally, test matrices must also be practical such that roadside features evaluated through the test matrix are cost effective and provide increased safety benefit without being a financial burden to end users.

While MASH has matrices for most roadside features, several devices lack a matrix, or the matrix needs clarity. There are no formal procedures to develop or evaluate a new matrix, nor are there procedures to evaluate or update an existing matrix. This lack of procedure makes it difficult for AASHTO's Technical Committee on Roadside Safety (TCRS) to balance safety, cost, and practicality.

The objective of this research project is to develop potential methodologies and procedures to evaluate the (a) newly developed matrices; and (b) modification of test matrices. The developed methodologies and procedures would be applied to selected devices to develop or modify test matrices for them. Methodologies and procedures to evaluate new matrices and modify existing one could improve the effectiveness of roadside features, increase efficiency in developing and maintaining matrices, and provide a consistent and defendable roadside hardware evaluation process.

Project 22-58
National Guidance for Defining Acceptable Roadside Hardware Field Performance through In-Service Performance Evaluations (ISPEs)

Research Field: Design
Source: AASHTO Committee on Design and Technical Committee on Roadside Safety
Allocation: $400,000
NCHRP Staff: Roberto Barcena

One reoccurring theme in re-writing crash test and evaluation procedures over the last 40 years is the recommendation to conduct in-service performance evaluations (ISPEs) of roadside safety features.

The laboratory performance of roadside safety hardware is tested and evaluated using criteria published in MASH (define). The site location and installation of roadside safety hardware is guided by criteria published in the AASHTO *Roadside Design Guide* (RDG). ISPE criteria has only just become available under NCHRP Project 22-33, "Multi-State In-Service Performance Evaluations of Roadside Safety Hardware" Guidance is needed, at the national level, for defining acceptable field performance.

The objective of this research is to develop guidance that defines acceptable field performance thresholds for roadside hardware. Performance thresholds defining acceptable performance should be developed for each of the evaluation criteria established under the NCHRP Project 22-33. Guidance for the use of ISPEs for establishing or updating existing guidelines and for establishing crashworthiness should also be developed.

The research will produce information to better understand and more consistently evaluate the field performance of roadside hardware.

Project 23-29
Enterprise Data Warehouse Implementation Guide

Research Field: Administration
Source: AASHTO Committee on Data Management and Analytics

Allocation: $350,000
NCHRP Staff: Roberto Barcena

As part of a robust data governance strategy, agencies must decide how to best manage storage, access, and dissemination of data products and services for internal use/reuse and external distribution within its data architecture. An important piece of a modern data architecture is an enterprise data warehouse, which, conceptually, will provide a way to reduce data redundancy, improve data consistency, and enable data usage for better decisions. Effective implementation of a data warehouse is complex, especially when an entity has highly diverse data sets and technology infrastructure. Thus, departments of transportation (DOTs) will benefit greatly from guidance on how to best architect and implement an enterprise data warehouse strategy that will meet diverse business needs while remaining performant. However, the industry lacks a guidebook on how to develop and implement a comprehensive data warehouse for DOTs.

This research is intended to develop a guide on data warehouse implementation to support efficient use, sharing, and reporting of data and address transportation agency business needs. The deployable product from this research is a best practice guide for state DOTs to use in guiding the development and implementation of an enterprise data warehousing strategy that encompasses data in structured (tabular), semi- or un-structured (non-tabular), and geospatial file formats (includes geometry).

Benefits of data warehousing include routine decision-making by improving data quality and increasing accessibility and security through using inventory best practices and improving organizational productivity through improved interoperability of data and automation of common analysis and reporting activities. Additional value is realized through time and cost savings to agencies by providing guidance on enterprise data warehouse strategies that can be quickly applied to improve the current state of data, rather than duplicating efforts with multiple or unknown outcomes. Moreover, collaboration and sharing of data across business units and agencies will be timelier and more efficient by adopting common standards.

Project 23-30
Knowledge Strategies to Support the Research Lifecycle and Application of Research Results

Research Field: Administration
Source: AASHTO Committee on Knowledge Management
Allocation: $400,000
NCHRP Staff: David Jared

The transportation research community has invested a significant amount of effort to support implementation of research results. The efforts included practices to incorporate implementation expectations in problem statements, contracts, and reports; studies on how to communicate research results and practices to document the value of research; and surveys to capture the use of research products. However, adoption of research findings is still slow, and some are concerned that the value of research isn’t commensurate with the investment in research. This affects the transportation sector as a whole.

The slow adoption of applied research findings in the implementation phase is not unique to the transportation sector. The National Institute of Health has established the National Center for Advancing Translation Science to advance knowledge translation (KT) as a practice that "transforms the translational process so that new treatments and cures for disease can be delivered to patients faster." The National Institute for Health describes knowledge translation science as "focused on streamlining the process of moving ("translating") … findings into … practice." The practice of KT maps the lifecycle from research idea to implementation and evaluation of the products, through adoption in real world communities. KT emphasizes the engagement with stakeholders that are closely involved in the target implementation community in order to achieve effective adoption of research. KT also expands the traditional research lifecycle to include feedback to researchers at each stage of the process, and particularly from community adoption. This continual feedback helps researchers and developers improve projects, services, explanations, and adaptions for current and future work. An effective KT cycle helps foster nimble organizations that can respond more quickly to disruptions in practice, use of emerging technology and practice, and changing policy.

The objective of this research is to provide a guide that includes: (a) definition of KT, identification of sectors that are currently leveraging KT methods, and a summary of the current uses of KT variations in application; (b) explanation of the KT practices, including participants, activities, and resources needed at each stage of the KT life cycle; (c) review of current state DOT practices to integrate research and new practice; (d) comparison of current methods with the KT lifecycle to identify leverage points and improvement opportunities; and (e) actions to strengthen KT practices within the transportation life cycle and technical disciplines.

Project 23-31
Lessons Learned from Two Decades of Knowledge Management

Research Field:	Administration
Source:	AASHTO Committee on Knowledge Management
Allocation:	$250,000
NCHRP Staff:	David Jared

Knowledge management (KM) is rooted in the work of management thought leaders such as Peter Drucker and W.E. Deming. In 1968, Drucker identified knowledge as the central capital of the economy. By 1990, KM as a practice began to emerge simultaneously with the technology boom. Since then, KM has continued to evolve in support of business practices and the need to address complex, multidisciplinary, and multiorganization knowledge flows.

The transportation sector began to take note in the 1990s. In 1998, the Federal Highway Administration initiated a Knowledge Sharing Initiative to examine the use of communities of practice. State departments of transportation (DOTs) began to explore KM in the early 2000s. Since then, several state DOTs and U.S. DOT Administrations have implemented KM activities. NCHRP has conducted several KM research projects, and several journal articles and papers have been written addressing KM in various disciplines. Despite the number of activities and substantial body of information on the use of KM in transportation, awareness of the practice within state DOTs remains limited. Furthermore, state DOTs are losing institutional knowledge due to retirements and employee turnover. Some state DOTs are trying to quickly develop KM practices to capture this institutional knowledge, but have limited resources for the effort. Research is needed to follow up with the organizations that conducted previous KM initiatives and studies to learn about the value of the practices on their work and document lessons learned.

The objective of this research is to extract lessons learned from previous KM activities in the transportation sector by: (a) reviewing literature to identify types of work conducted, the organizations that implemented them, and subject/discipline in which KM was implemented; (b) follow up with organizations involved to learn whether the KM practice has persisted and gather lessons learned from implementation; and (c) review the feedback, summarize factors that contributed to the success or demise of the practice, extract lessons learned, and prepare case studies that illustrate common themes derived from the review. This information will help state DOT's develop actionable strategies for deploying KM.

Project 23-32
Development of the AASHTO Transportation Asset Risk & Resilience Manual: Phase 1

Research Field:	Administration
Source:	AASHTO Committees on Performance Based Management and Transportation System Security and Resilience
Allocation:	$4,000,000 (includes $500,000 provided by the U.S. DOT Office of the Assistant Secretary for Research and Technology)
NCHRP Staff:	Ahmad Abu-Hawash

The United States experienced 308 weather and climate related disasters since 1980, exceeding $2.085 trillion in physical losses and the loss of 14,492 lives. Between 1980 and 2020, the average number of billion-dollar events per year was 7.1; that number ballooned to 16.2 billion-dollar events per year on average between 2016 and 2020 (adjusted for Consumer Price Index). The most billion-dollar weather and climate related disasters occurred in 2020, with 22 billion-dollar events totaling $246.7 billion in losses and 553 deaths. As of September 2021, the current year is looking to break the record set in 2020, having experienced 18 billion-dollar events to date (Billion-Dollar Weather and Climate Disasters: Overview | National Centers for Environmental Information (NCEI) (www.noaa.gov)). In addition, the recently published TRB Consensus Study on Resilience Metrics notes that six of the world's 10 most costly natural disasters in 2020 occurred in the United States (TRB Resilience Metrics Consensus Study, 2021). With this level of impact on the nation's infrastructure, transportation agencies need consistent methods to support decision-making to address stressors such as extreme weather and climate change in planning, design, maintenance, and operations.

The TRB Resilience Metrics Consensus Study 2021 calls for the establishment of standard methods of analysis to support benefit-cost assessment to allow agencies to understand the "buy-down" of risk from capital and maintenance investments. In addition, the study calls on Congress to consider requiring all federal funding candidate projects that involve long-lived assets requirement undergo well-defined resilience assessments that account for changing risks of natural hazards and environmental conditions stemming from climate change. The proposed project will enable the development of industry adopted standard methods of quantitative analysis.

A concerted level of commitment is needed to develop a single manual to serve as the "go-to" for quantitative analysis of financial risk to agency assets and the traveling public from extreme weather and climate change. Like the *Highway Capacity Manual* and the *Highway Safety Manual*, a single resource is needed to ensure consistent methods of analysis between projects and agencies, and to ensure adoption of robust quantitative methods to support benefit-cost analysis and decision-making. A single manual can enable stakeholders at all levels to compare project investments on a level playing field—using the same models, same assumptions, and same thresholds of performance. A single manual also can support the instruction of how to address extreme weather and climate change in planning and engineering curriculum at universities ensuring future transportation professionals are equipped with the skills needed to support the adoption of such methods into practice. Finally, a single manual can enable the incorporation of extreme weather and climate change considerations in professional engineering examinations to further institutionalize these concepts in future design and decision-making.

This project will be Phase 1 of a multi-phase project. The conceptual framework for the new manual and the additional research needed beyond Phase 1 was developed in NCHRP Project 23-09, "Scoping Study to Develop the Basis for a Highway Standard to Conduct an All-Hazards Risk and Resilience Analysis" and NCHRP Project 20-123(04), "Development of a Risk Management Strategic Plan and Research Roadmap." This undertaking will result in an industry "standard" for all-hazards risk and resilience analysis for use in design, maintenance, and planning decision-making.

The objective of this project is to complete Phase 1 and should include the development of the AASHTO *Transportation Asset Risk and Resilience Manual* and should (1) establish quantitative assessment methodology for top priority threats and assets (e.g., culverts and flooding); (2) develop historical data capture process quantitative analysis methods; (3) develop quantitative resilience assessment methodology; and (4) establish performance metrics and thresholds for resilience and risk tolerance, and provide guidance on reducing risk and improving resilience.

Subsequent phases may focus on implementation of the Phase 1 *Transportation Risk and Resilience Manual*, development of tools and resources to support the Manual, and development of stand-alone, open source computer script that can work within a GIS (define) environment to automate Manual calculations across multiple assets and threats in a geo-spatial setting. Other topics to be considered in future phases include developing spreadsheet-based tools to automate Manual calculations across multiple assets and threats in a spreadsheet application, selecting performance metrics for evaluating the effectiveness of risk mitigation, incorporating risk management into maintenance practice, developing new performance metrics for risk management, and assessing the impact of common risks on federal reporting metrics.

Transportation owners and operators are responsible for the transportation system and the delivery of services and functions through the management of that system. There are inherent risks involved with the management of these systems, notwithstanding aging infrastructure, and fiscally constrained resources. Many agencies are moving toward performance-based resource allocation while simultaneously recognizing risks that may undermine their strategic goals. As these risks affect every component of a transportation system, accurately accounting for and addressing these risks within a transportation agency's enterprise-wide management program is the goal that currently lacks analysis tools.

Investing in risk and resilience strategies and enhanced recovery to reduce or eliminate the impact of external events is also paramount to ensure a thriving, viable transportation system. Risk management requires the identification and assessment of potential threats and hazards, asset vulnerabilities from applicable threats, an evaluation of potential mitigation actions to reduce risk, a clear and easy to implement process to prioritize mitigation activities, and investment that aligns with agency strategic and performance goals. Asset management, and more recently performance management, has been an ongoing focus of many research efforts. However, guidance for analytical risk assessment methods to support risk-based asset management processes is lagging. Risk assessment processes, methods, and tools are needed to integrate risk management into asset and performance management systems. In addition, an understanding of the relationship between risks and system resilience is lacking.

Future research can expand threats analyzed; assets analyzed; climate projections; life cycle cost; remaining life consideration of assets; environmental impacts, etc.

The $4,000,000 project allocation includes $500,000 provided by the U.S. DOT Office of the Assistant Secretary for Research and Technology.

Project 23-33
Guidance in Planning for Managed Retreat as an Extreme Weather and Climate Adaptation Strategy

Research Field: Administration
Source: AASHTO Committee on Transportation System Security and Resilience
Allocation: $500,000
NCHRP Staff: Camille Crichton-Sumners

Climate change impacts increasingly affect transportation systems in the United States. Transportation agencies across the country already face substantial impacts from extreme weather and other climate events, with future projections suggesting this trend will continue and possibly increase. Impacts to transportation infrastructure from such events can cause immediate or longer-term changes in the way people use local infrastructure and where they choose to permanently locate or relocate. State and local governments often allow development in known high-risk areas, requiring ongoing investment from transportation agencies to repeatedly repair or maintain such assets. Such development can also exacerbate risks in neighboring areas if they displace natural protections such as wetlands or greenspace. State departments of transportation (DOTs) will ultimately have significant financial and operational responsibility with respect to these assets as their exposures increase. Abandoning infrastructure assets may be as challenging and expensive as migrating the transportation infrastructure itself.

Managed retreat—movement of assets and people away from risks—needs to be a strategy available to transportation planners. It includes evaluation of alternative routes, structures, contexts, and other considerations to more efficiently use transportation funding while preserving critical access to people, freight, and emergency services. It also requires a complex understanding of place attachment, the community in which the transportation system exists, the interconnectedness of the infrastructure at issue with other systems and people, and whether laws and regulations authorize a state DOT to make managed retreat decisions. There is a need for research that develops information about managed retreat strategies in a way that supports state DOT transportation systems decision-making. A successful managed retreat plan can decrease risk to the entire system, save valuable resources that may be better allocated elsewhere, and protect lives and livelihoods. Moreover, embedded in these decisions are social justice issues to consider and state DOTs often do not have the experience and tools needed to approach these issues.

The research will develop a practice-ready managed retreat framework and guidance targeted to state DOTs, enabling an informed approach to discuss and to facilitate decision-making. It will provide guidance for how to determine and measure transportation performance thresholds and which retreat strategies should be implemented. The final product will draw from experiences and outcomes across the United States and abroad, written from the perspective of managed retreat as a viable resilience strategy that can have positive, long-term benefits.

Project 25-66
Update the National REMEL Database Used in FHWA Traffic Noise Model

Research Field:	Transportation Planning
Source:	AASHTO Committee on Environment and Sustainability
Allocation:	$1,000,000
NCHRP Staff:	Zuxuan Deng

The Reference Energy Mean Emission Level (REMEL) database is an inventory of different vehicle pass-by noise levels that is the basis for the FHWA Traffic Noise Model (TNM) analysis software. It is 25 years old and in need of updating. Internal combustion engines have become more efficient, overall vehicle technology has evolved, truck exhaust stack noise has decreased, truck exhaust stack locations are changing, and electric and hybrid vehicles are entering the vehicle population. Newer noise measurement technology has also evolved, and it can be applied to locate and quantify noise generators on a moving vehicle. The old REMEL database positions and distributes a significant amount of vehicle noise energy at 5 and 12 feet above the pavement. Recent NCHRP research shows that most vehicle noise energy is at the tire/pavement interface or only 3.3 feet above the pavement. The 5- and 12-foot energy distributions used in TNM strongly biases analysis toward tall, and expensive, sound walls, and it underestimates noise reductions that shorter berms and concrete safety barriers can provide. The old REMEL database also underestimates the acoustic variation caused by different pavements and how the different pavements influence roadside noise levels. This outdated REMEL database adversely impacts sound wall analysis and limits available design options. Tall sound walls are about $2M/mile and shorter less-expensive noise barriers would provide state departments of transportation (DOTs) more design flexibility in mitigating highway noise impacts. Quieter pavement strategies keep money in the road, not in barriers. More design options would help DOTs better address noise-related inequity issues also.

This research will use the two new highway acoustic measurement technologies of OBSI and acoustic beamforming, in combination with the old measurement process – SPL, to develop a new REMEL database for the current vehicle fleet. The five basic acoustic vehicle classifications (heavy truck, medium trucks, passenger cars, buses, and motorcycles) will be re-measured and updated. The beamforming will show the relative amount and location of vehicle noise in the vehicle profile and OBSI will more accurately measure the pavement acoustics and how it correlates to roadside noise. These two new measurement processes will be combined with the old-school, roadside SPL measurements. Based on previous NCHRP research, this will reduce noise contributions from the old-and-outdated 5 ft and 12 ft vehicle sub-source positions currently used in TNM, and more accurately distribute the noise energy in the vehicle profile.

Highway noise is always a top environmental concern with the public on any highway project. Updating and improving the 25-year-old vehicle noise REMEL database will improve the accuracy of traffic noise analysis. This will provide state DOTs with more design options and flexibility to mitigate the environmental impacts of highway noise. The use of shorter, less expensive noise barriers and quieter pavement strategies will also help address equity related issues and would save a significant amount of taxpayer dollars.

The final product will be an updated vehicle noise REMEL database based on the current vehicle fleet and measured with both old and new acoustic measurement technologies that will better quantify and position the vehicle noise sub-sources: mechanical, exhaust, tire/pavement. A preliminary analysis will also be included with the database to discuss the differences between the new REMEL database and the older REMEL data.

Pass-by noise levels will be measured for different acoustically isolated individual vehicles operating under different conditions using SPL, OBSI, and beamforming acoustic measurement technology. The measurement matrix would include different vehicle types, different speeds (10 to 80 mph), cruising, acceleration/deceleration, flexible and rigid pavements, and different road grades.

The REMEL database should be thoroughly documented and the data made available in an open-source format for immediate use by state DOT engineers and noise analysts and other third-party noise simulation software vendors. To better accommodate future updates and improve accuracy and limit computational adjustment factors, the REMELs will be based on source measurements and referenced relative to the vehicle position in the traffic lane and will not be based on measurements taken at a distant receptor position. Most noise barrier design is performed on federally funded public works transportation projects and the REMEL database directly impacts structural noise barrier design. All stages and phases of the development of the REMEL database will be managed and reviewed by an experienced and responsible registered engineer. Implementation into the FHWA TNM software is not included in this research.

Project 25-67
Cultural Resources Mitigation: What Works and What Doesn't?

Research Field:	Transportation Planning
Source:	AASHTO Committee on Environment and Sustainability
Allocation:	$500,000
NCHRP Staff:	Jennifer Weeks

When a transportation project has an adverse effect to historic properties under Section 106 of the National Historic Preservation Act, the project sponsor is required to complete mitigation measures. Development of mitigation is done in consultation with the Section 106 stakeholders. Mitigation measures, such as Historic American Buildings Survey (HABS), Historic American Engineering Record (HAER), Historic American Landscapes Survey (HALS), archaeological data recovery and associated research, and educational publications are considered typical mitigation. Different, new, or creative mitigation measures are not normally considered due to time constraints and funding limitations. Recent years have seen a shift to greater consideration of creative mitigation alternatives; however, the degrees of success of implemented mitigation are rarely discussed. Research is needed to identify and assess the effectiveness of new and creative mitigation approaches.

The objective of the research is to identify and assess the success of creative or atypical mitigation strategies previously implemented in producing a public benefit. The following approach is a potential means of completing this research objective: (1) provide a list of types of historic properties adversely affected by transportation projects and the nature of the impacts; (2) identify common and more creative mitigation measures that have been applied for addressing the potential identified impacts; (3) identify the degree to which mitigation measures were successful in producing a benefit to the public and the possible reasons for the degree of success, as well as any impediments to that success; and (4) summarize the best practices for mitigation development and implementation.

State DOTs struggle with developing cultural resources mitigation to meet the current expectations of the public and the requirements of their State Historic Preservation Office (SHPO). This research would be highly beneficial to cultural resources professionals (SHPOs, state and federal departments of transportation staff and their consultants) seeking to implement successful mitigation for environmental compliance and documentation of transportation capital projects in accordance with the National Environmental Protection Act and the National Historic Preservation Act.

Project 25-68
Successful Practices in Tracking and Implementing Environmental Commitments

Research Field:	Transportation Planning
Source:	AASHTO Committee on Environment and Sustainability
Allocation:	$350,000
NCHRP Staff:	Jennifer Weeks

State departments of transportation (DOTs) and other transportation agencies routinely establish formal and informal commitments to specific environmental avoidance and mitigation techniques as part of project planning and design under the National Environmental Policy Act and related federal and state laws and regulations. Federal agencies and state DOTs are responsible for ensuring these legally binding commitments are implemented throughout the life of a project and ultimately fulfilled. Proper implementation of environmental commitments affect all phases of project delivery including planning, design, construction, and post construction.

Tracking environmental commitments is considered the main tool for ensuring specific commitments are implemented. However, the quality of the tracking is dependent on the tracking system that exists and the individuals responsible for following that system. Reaching an environmental commitment often is done openly and transparently and creates a public expectation it will be met. Yet, DOTs nationwide face challenges in the successful management and implementation of such commitments. Common challenges include language differences in memorandums of agreement or understanding, and the need to ensure that commitments are incorporated into appropriate design and construction tracking. State DOTs have started developing resources and practices to minimize these challenges and ensure quality control and proper implementation, but no nationwide summary of these approaches exist.

The objective of this research is to produce a compendium of formal (e.g., digital tracking applications, DOT standards, handbooks, environmental plan sheets, punch lists) and less formal (e.g., pre-construction meetings, on-site inspections) environmental commitment processes and documentation used by state DOTs, successfully adopted practices in standard environmental specifications, and suggestions for improving the overall systems adopted by DOTs for meeting environmental commitments.