National Cooperative Highway Research Program

Fiscal Year 2008 April 2007

Announcement of Research Projects

The annual "Announcement of Research Projects" is no longer mailed to individuals. Instead, e-mail notification is made. Recipients are encouraged to share this announcement with colleagues.

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

Each year, AASHTO refers a research program to the TRB consisting of high-priority problems for which solutions are urgently required by the states. The AASHTO program for FY 2008 is expected to include 23 continuations, 41 new projects, and 8 projects contingent on additional funds becoming available.

This announcement contains preliminary descriptions of only those new projects expected to be advertised for competitive proposals. Detailed Project Statements (i.e., Requests for Proposals) for these new projects will be developed beginning in August 2007.

Please note that NCHRP Research Project Statements for soliciting proposals are available only on the World Wide Web. Project Statements are not mailed. Those who have an interest in receiving Research Project Statements must periodically browse the NCHRP World Wide Web site or register on the website (http://trb.org/nchrp) if you have not already done so. Upon registration, you will receive an e-mail notification of every Project Statement posting and an e-mail notification of new anticipated projects in future years.

Because NCHRP projects seek practical remedies for operational problems, it is emphasized that proposals not evidencing strong capability gained through extensive successful experiences in the relevant problem area stand little chance of being selected. Consequently, any agency interested in submitting a proposal should first make a frank, 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 quite strict and are set forth in the brochure entitled *Information and Instructions for Preparing Proposals*. **Proposals will be rejected if they are not prepared in strict conformance with the section entitled "Instructions for Preparing and Submitting Proposals."** The brochure is available on the Internet at the website referenced above.

Address inquiries to:
Crawford F. Jencks, P.E.
Deputy Director
Cooperative Research Programs
Transportation Research Board
cjencks@nas.edu

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 2008. Meanwhile, to ensure that research contracts can be executed as soon as possible after the beginning of the fiscal year, the NCHRP is proceeding with the customary sequence of events through the point of agency selection for all projects. The first round of detailed project statements will be available in August and September 2007; proposals will be due in October and November 2007, and agency selections will be made in November and December 2007. 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 2008 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
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♦ Project 01-46
Development of an AASHTO Pavement Handbook

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

The AASHTO Joint Technical Committee on Pavements (JTCoP) is responsible for the development and update of a number of AASHTO guides, policies, and standards related to pavement design and pavement management. Currently, the JTCoP guide responsibilities include

- *Guidelines for Skid-Resistant Pavement Design*, 1976;
- *AASHTO Guide for Design of Pavement Structures*, 1993;
- *Supplement to the Guide for Design of Pavement Structures*, 1998;
- *Pavement Deflection Data Exchange: Technical Data Guide*, 1998; and
- *Pavement Management Guide*, 2000.

In 2004, NCHRP Project 1-37A, *Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II*, was completed and produced a mechanistic-empirical pavement design guide for potential balloting by AASHTO. It is anticipated that in spring of 2007, Project NCHRP 1-40, *Facilitating the Implementation of the Guide for the Design of New and Rehabilitated Pavement Structures*, will provide two additional documents, a user's guide and a local calibration guide for the mechanistic-empirical pavement design guide and software, for potential balloting by AASHTO. The JTCoP is also reviewing the report from NCHRP Project 1-43, *Pavement Guide for Friction*, for potential balloting by AASHTO.

The JTCoP, through various standards and policies, is also responsible for or has the potential to be responsible for the following topics:

- Accelerated pavement testing,
- FWD analysis and back-calculation,
- Life-cycle cost analysis,
- NCHRP Project 1-39 products (i.e., TrafLoad software),
- Pavement-tire noise,
- Pavement drainage practices and procedures,
- Pavement type selection process,
- Preservation treatments and timing,
- Smoothness, and
- Use of recycled materials.

To date, many of these topics have not been fully described or incorporated into the existing JTCoP guides. However, many of these topics are well understood and can be incorporated into an AASHTO publication.

The objective of this research is to develop an AASHTO pavement handbook that includes the topics described above (e.g., design, management, rehabilitation, preservation, friction, noise, smoothness, and FWD analysis and back-calculation). In this manner, all pavement-related topics would be contained in one comprehensive publication.

With the soon to be completed guide(s) for the design of pavement structures, the JTCoP needs to have a document that incorporates all aspects of pavements, not just pavement design or pavement management. State DOTs are responsible for all phases and aspects of the roadway pavements (e.g., design, material selection, construction, performance, rehabilitation, and reconstruction). The development of a comprehensive pavement handbook would be extremely beneficial to state DOTs, local agencies, and consultants in all facets of the pavement structure. It is anticipated that the handbook would provide guidance in areas that have been researched and validated, as well as provide a platform for including any future validated pavement research topics or enhancements.

♦ Project 03-88
Ramp and Interchange Spacing

Research Field: Traffic
Source: AASHTO Technical Committee on Geometric Design
Allocation: $500,000
NCHRP Staff: Christopher J. Hedges

Interchanges are essential components of freeways for providing reasonable access and mobility. However, interchanges can greatly diminish

the traffic operations, safety, and capacity of the through lanes of the freeway. Transportation agencies are tasked with the construction of new freeways with interchanges, reconstruction of existing freeways and interchanges, and the addition of interchanges to existing freeways.

The AASHTO Policy on Geometric Design of Highways and Streets contains guidelines on the distance between successive ramp terminals. On urban freeways and other facilities that carry large traffic volumes, two or more ramp terminals are often located in close succession. To provide adequate space for signing, adequate gaps for entering motorists, and sufficient weaving lengths, the AASHTO policy provides minimum ramp terminal spacing dimensions for various ramp pair combinations. Spacing between successive ramp terminals depends on the classification of the interchanges involved (system vs. service), the function of the ramp pair (entrance vs. exit), and the potential for weaving. The recommendations provided in the AASHTO policy are acknowledged to be based on operational experience and should be evaluated based on appropriate Highway Capacity Manual procedures and/or micro-simulation to provide acceptable traffic operations.

Although the location and spacing of interchanges (and ramps) on freeways has a major effect on the ability of a freeway to carry traffic effectively, this is a topic for which little research or literature has been published. The AASHTO guidelines are based on experience and knowledgeable engineering judgment to a large extent, and more information is needed based on operational conditions experienced on a freeway network. Recent research indicates that a majority of freeway accidents occur at interchanges and in weaving sections between closely spaced entrance and exit ramps. The spacing of interchanges on an urban road network often results in tradeoffs between providing adequate service and access with both safety and operations. The issue of interchange spacing is a complex issue and, consequently, a candidate for basic research.

The objective of this research is develop ramp and interchange spacing criteria based on quantitative information obtained from actual field observation, theoretical considerations, simulations, or a combination of the three approaches. Research should highlight the safety, operational, and other trade-offs associated with varying ramp and interchange spacing dimensions for the full range of interchange types (system and service) and facility types (freeway, expressway, collector-distributor roads).

The research should include a literature review of previous research and current practice in regard to ramp and interchange spacing, development of a work plan to achieve the research objectives, collection of applicable field data and other information, evaluation of the safety and operational effects of various combinations of ramp and interchange spacing, and preparation of a final report. The final report should include proposed changes to AASHTO policy, if results support a change.

♦ Project 03-89
Right-Turn Interactions and Channelized Right-Turns

Research Field:	Traffic
Source:	AASHTO Technical Committee on Geometric Design, Texas
Allocation:	$500,000
NCHRP Staff:	B. Ray Derr

Better information is needed about the effects of channelized right-turn lanes in the urban street environment on motorist (i.e., cars, trucks and busses), pedestrian, and bicyclist safety. Many agencies use channelized right-turn lanes to improve operations at urban intersections, particularly on urban arterials. Previous research found no reliable evidence to verify the assumption that channelized right-turn lanes provide safety benefits to both motor vehicles and pedestrians. Since concerns about the accessibility of these turn lanes to pedestrians with vision impairments have arisen, research is needed to determine whether channelized right-turn lanes do or do not enhance safety for motorists, pedestrians, and bicyclists. In addition, where a channelized right-turn lane is provided, there are differences of opinion about where the striped crosswalk, if provided, should be located. Some advocate putting it near the entry of the channelized right-turn lane so pedestrians are more in the field of vision for approaching drivers. Others advocate putting the crosswalk near the end of the channel-

ized right-turn lane because pedestrians with visual impairments will tend to cross the right-turn lane close to the parallel flow of traffic.

The Americans with Disabilities Act (ADA) requires that public rights-of way, including sidewalks and crosswalks, be accessible to pedestrians with disabilities. The U.S. Access Board has published draft rights-of-way guidelines requiring pedestrian signals at channelized turn lanes. Research in NCHRP Project 3-78 will be investigating crossing solutions for pedestrians with vision impairments at channelized right-turn roadways. Whatever the degree of success of that research, one response of highway agencies to the forthcoming regulation may to be remove existing channelized right-turns and avoid constructing new ones. There are no reliable data on whether such actions would be positive or negative for overall safety.

The objective of this research is to recommend whether design policy related to right-turn design should be modified, based on the safety impacts of various designs on different user groups. Exploration of the proper balance among the needs of passenger cars, trucks, busses, pedestrians (including pedestrians with vision impairments), and bicycles is central to achieving the objectives of the research.

Accomplishment of the project objective will include at least the following tasks: (1) Review the existing geometric design, traffic control, and other relevant literature (both domestic and international) to (a) document the current state of practice with respect to pedestrian, bicycle, and vehicular control at channelized right-turn lanes; (b) document the safety of various designs on the various modes; and (c) determine engineering policies and practices that may need to be revised as a result of the anticipated recommendations from this research effort. (2) Select an appropriate number of sites with and without channelized right-turn lanes and conduct field studies. Sites should be those utilized by as many different modes as possible and the interactions between the modes should be documented. (3) Analyze accident/crash reports for the above sites and document the number and type of accidents and the modes involved at each location. (4) Simulate the impact on various modes for different designs of channelized right-turn lanes and develop recommendations for design policy. (5) Submit a final report that documents the entire research effort, recommends design criteria for right-turn lanes on various classes of roadways, and includes the products of Tasks 1 through 4. Where appropriate, the report should include appendixes with recommended language for the *AASHTO Policy on Geometric Design of Highways and Streets*; the *AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities*; the *AASHTO Guide for the Development of Bicycle Facilities*; and other documents as appropriate.

♦ Project 03-90
Traffic Signal System Control for Congested Conditions

Research Field: Traffic
Source: Illinois
Allocation: $600,000
NCHRP Staff: B. Ray Derr

The *Highway Capacity Manual* (HCM) contains extensive procedures for assessing the operations of signalized intersections and arterials. In early versions of the HCM, the procedure for signalized intersections only assessed undersaturated conditions. Later versions of the manual have made significant modifications to address oversaturated conditions, but these modifications have continued to use the undersaturated case as the base model for developing timings. Urban and suburban intersections operating in oversaturated conditions are now very common and are expected to become even more prevalent. As a result, there is an urgent need to explicitly address such conditions. An essential aspect is how to minimize congestion in space and time without unduly affecting mobility.

Oversaturation has two major causes: (1) poor allocation of available green time (capacity) and (2) too much demand to be satisfied by available signal capacity. Often, it is difficult to distinguish between the two, and congested conditions at one critical intersection often propagate to adjacent intersections. Practitioners need procedures to identify the onset of oversaturation, proactive strategies for operating signals in such conditions, and guidelines on how to implement these strategies on a system basis. Practitioners also need guidelines on how to (1) utilize detectors for maximum system effi-

ciency and (2) modify detector layout for better operations during congested conditions.

An important first step is a new project by the FHWA, "Signal Timing Under Saturated Conditions," scheduled to be completed in the spring of 2008. That project will focus on individual intersection oversaturation and will lay the foundation for the proposed research effort that extends to more complex system operation. The FHWA effort is of modest size, and field work will likely be limited in scope.

The objective of this research is to investigate and develop strategies and methods for operating traffic signals in oversaturated conditions on a system basis. The first task is to develop, in conjunction with the project panel, a consistent definition of what it means to be "oversaturated" in a signal system, including thresholds in physical extent and time duration. To the degree possible, the benefits of avoiding oversaturation, in terms of travel time and delay savings, should be quantified.

Using the results of a literature review and discussion with practitioners, the research should develop a catalog of strategies that have been proposed or deployed around the world to manage traffic signal operations during oversaturated conditions. For each deployed strategy, the catalog should include information about (1) scope of project, (2) before traffic conditions, (3) details of selected strategy, (4) when and how it was implemented at the intersection(s), and (5) how effective it was at addressing the oversaturated conditions. The control objectives and performance measures used in the evaluation of these strategies should be explicitly identified. Ideally, the research should develop a case study analysis of different locations where specific strategies were deployed and should document the lessons learned during the evaluation process.

The research should then develop a procedure for identifying the onset of oversaturation, drawing on the results of the ongoing NCHRP Project 3-79. Next will be selection of appropriate control objectives (for example, minimizing queue length and queue growth, limiting cycle failures, balancing the physical extent and time duration of congestion) for signal systems in oversaturated conditions. Appropriate performance measures for each control strategy will need to be identified.

The research should develop a step-by-step methodology for determining system timing plans, addressing the type of data to be collected and tools that can be used to assess strategy effectiveness. This should include alternate configurations of detector inputs, both local and system, in real time, and potential use of on-line traffic simulation. The procedures should also identify and test how existing special controller features can be used to mitigate oversaturation, as well as propose new features to serve this purpose. This task will require contacts with major controller suppliers to ensure realistic concepts are developed. Proof-of-concept testing must include field evaluations to demonstrate, evaluate and refine the procedures.

The work needs to address the issue of how oversaturation affects the design of the detection system normally installed at signalized intersections in system. Generally, detectors are designed to operate assuming free-flow or undersaturated conditions. However, during oversaturated conditions, queues can often extend well beyond the limits of the detection system, rendering it of limited value and effectively resulting in fixed-time control. Compounding the problem, the control objective may change from minimizing delay or improving progression to another control objective, such as managing queue growth, maximizing throughput, or shortening the duration of oversaturation.

The research should therefore examine the impacts of operating signal systems with current detection strategies and configuration, and then develop alternate configurations that address the different control objectives. Features in the controllers, such as detector switching on both a local and system basis, should be investigated to overcome some of the deficiencies with current detection schemes. Alternate detector configurations should be validated through "hardware-in-the-loop" simulation or field deployments.

This research should produce, as its final product, a foundation and practical guidelines for signal systems during oversaturated conditions. Appropriate flowcharts and pseudo-code should be provided, for full development by others. The following should specifically be addressed: (1) Procedures for determining if a signal system is truly oversaturated (excess demand) vs. a result of poor traffic signal timings (poor capacity management). (2) Guidelines on the placement and configuration

of detectors and detector settings for correctly assessing traffic conditions for critical intersection and system control, including detector switching to modify the area of detection. (3) Methodologies for correctly characterizing operational problems such as queue spillback, phase starvation, cycle failures, and insufficient storage space. (4) Guidelines for selecting appropriate control objectives in real time (for example, minimizing queue length, limiting cycle failures, and reducing the duration of oversaturation). (5) Methodologies for determining strategies and timing plans for operating signal systems during oversaturated conditions, including transition programs. (6) Use of special controller features to mitigate the impacts on a system basis. (7) An overall implementation plan for fully developing the procedures into working products, defining next steps by equipment suppliers, academics, and the government.

♦ Project 03-91
Guidance for the Provision of Left-Turn Lanes at Unsignalized Intersections

Research Field:	Traffic
Source:	Minnesota, Kansas, Florida
Allocation:	$350,000
NCHRP Staff:	B. Ray Derr

Every left-turn location contributes to travel delay and decreases the safety of the motorist along roadway. During peak hours, inadequate left-turn capacity has a detrimental impact on safety during periods of highest capacity needs. Left-turns from a through-traffic lane present even more potential safety and operational problems. Deciding when to require an exclusive left-turn lane on two- or four-lane undivided roadways or on a multilane divided highway remains a frequent question for highway agencies, both for reconstruction projects and for the permitting of new access points. New guidance is called for based on current design practices, traffic volumes, and vehicle speeds.

The last truly original research on this subject, and the basis for most existing guidance on left-turn warrants, was done in 1967 by Professor M. D. Harmelink (a research engineer at the Ontario, Canada Department of Highways) in his work "Volume Warrants for Left-Turn Storage Lanes at Unsignalized Grade intersections." The Harmelink methodology is rational; however, the values used are no longer valid nor were they based on U.S. data. Recent research indicates that the average time to make a left turn from a two-lane highway is about 4.3 seconds (not 3.0 seconds as used by Harmelink). The "Highway Design Handbook for Older Drivers" (Report No. FHWA-RD-01-103) indicates that older drivers take even longer. This also suggests the critical gap in the opposing traffic stream needs to be longer than the 5.0 seconds used by Harmelink for two-lane roadways (6.0 seconds for four-lane roadways). The Harmelink research was based on vehicle delay and did not thoroughly address safety issues.

Since 1967, additional guidance has been developed by others. Standards used by the Colorado DOT, based on safety, have been adopted by various state and local agencies. K. R. Agent (*Transportation Quarterly*, 1983) has also proposed left-turn lane criteria. The 1996 analyses by the Texas Transportation Institute utilized a methodology considering opposing volume, advancing volume, and left-turning volume but which is different from that of Harmelink.

Maximizing the potential capacity of existing roadways is becoming a priority in light of growing volume demands and the diminishing resources to develop more capacity. The decision to install a left-turn lane is a complex decision for many state and local agencies as they weigh the cost of the installation, the anticipated benefits in delay and crash reduction, and the demands for left turns from abutting land development. Clear justification for developer-funded turn-lane improvements is necessary for maintaining design consistency and mitigating the detrimental impacts of new left-turn activities as new development occurs along highways.

The objective of this research is to determine all aspects of unsignalized left-turn maneuvers under a range of conditions. This research information could then be used by agencies to assist in determining how a left-turn demand should be managed. Treatments might include the denial of left turns by the use of a restrictive median, the allowance of a left-turn bay of a specific design and length, or the decision not to require any additional improvements and allow the left turn to proceed from the through lane.

The range of conditions would include different functional classes of roadways, such as arterial, collector, and local; both rural and urbanized conditions; roadway volumes from very low to very high; speeds from low to high (25 to 65 mph); and the cumulative impacts of median opening spacing. In addition to ranges in roadway conditions, the range of driver performance variables would be included. Although the research would not develop left-turn median opening designs, it would study the effects of deceleration in the through stream of traffic and the effect of various auxiliary deceleration lane lengths. The information developed would aid state departments of transportation and local governments in the preparation of standards and practices.

The research will accomplish the objectives through the following tasks: (1) Conduct a review of domestic and international literature and current practice pertaining to the decision to allow and design left turns; (2) Develop a synthesis of practice including completed and in-progress research; (3) Develop and critically evaluate various methodologies that can be used to develop data and information that addresses all aspects of left-turn maneuvers, including operations, safety, and driver abilities; (4) Methodologies should include original field research, models, and acceptable previous research and analysis; and (5) After completing the research, determine graphic and textual methods to present the information developed in a form most useful to decision-making agencies.

♦ Project 03-92
Production of the Year 2010 Highway Capacity Manual

Research Field: Traffic
Source: Wisconsin
Allocation: $1,000,000
NCHRP Staff: B. Ray Derr

The current *Highway Capacity Manual* (HCM) has been a great success with over 16,000 copies distributed in the United States and the World since 2000. The HCM has become the model for similar capacity manuals in many other countries. The current HCM, however, is now 7 years old and since its publication, great strides have been made in microscopic traffic simulation, operations analysis, and the management and control of traffic facilities. In addition, there is a greater need to further address in the manual the capacity and operational implications of context-sensitive design. The manual in particular needs to provide the engineer, planner, and manager with more tools for evaluating reliability and over-capacity conditions so that cost-effective capital and operations improvements can be considered for better managing and reducing severe congestion conditions prevalent on the highway facilities in many of our urban areas. These tools must include non-motorized and transit alternatives.

Recognizing the continuing need to update the current Year 2000 HCM, AASHTO has funded 8 projects for $4.5 million over the last 6 years: NCHRP Project 03-60, Capacity and Quality of Service of Interchange Ramp Terminals; NCHRP Project 03-64, Highway Capacity Manual Applications Guide; NCHRP Project 03-65, Applying Roundabouts in the United States; NCHRP Project 03-70, Multimodal Level of Service Analysis For Urban Streets; NCHRP Project 03-75, Analysis of Freeway Weaving Sections; NCHRP Project 03-79, Measuring and Predicting the Performance of Automobile Traffic on Urban Streets; NCHRP Project 03-82, Default Values for Capacity and Quality of Service Analyses; and NCHRP Project 03-85, Guidance for the Use of Alternative Traffic Analysis Tools in Highway Capacity Analyses.

Collectively, this research (most of which will be completed in 2007) will result in major updates to five key chapters of the HCM. These individual chapter updates (especially the one on alternative analysis tools) will incorporate new concepts that will conflict with the older material in many of the remaining chapters in the manual. An overall HCM production research project is needed to pull this information together and update the remaining chapters so that the HCM continues to be a consistent and coherent guide to the latest accepted capacity and operations analysis practice for the United States.

The objective of this research is to develop an up-to-date HCM that is more directly relevant to the system and facility planning and design needs of engineers and planners in 2010. The manual will provide a comprehensive set of methodologies for quantifying congestion and an integrated systems

analysis approach for sizing facilities and for determining geometric design parameters, when given a target level of service and a given set of demands and traffic control parameters. The approach will be applicable to automobile, truck, bus, bicycle, and pedestrian travel on a highway, street facility, sidewalk, or shared use path in the public street or highway right of way for the planning or design of the facility, its segments, and its intersections.

The research is expected to include the following tasks: (1) Conduct a state-of-the-art review to inventory and summarize domestic and international experience on analysis of capacity and quality of service since 2000. The review should include literature, software, practice, and research and may also include interviews with key researchers. The review should include ongoing NCHRP research projects for specific chapters of the HCM and should identify needed coordination and gaps in that coordination among the projects. In addition to the relevant NCHRP research, the literature review should include applicable FHWA, State-sponsored, and International research that may add value to the HCM. (2) Design, test, conduct, and analyze an HCM user survey. The objective of the survey is to confirm user needs, user-perceived gaps in the HCM, and potential needs for supplemental methodologies. The survey should target practitioners employing HCM-based software for planning and design, HCM-based software developers, and academics/students using the HCM as an educational tool. (3) Review purpose, objectives, target users, and target usage for the 2010 HCM and identify major gaps in knowledge or techniques and recommend research needed to fill the gaps for the 2010 HCM. The recommendations should, in addition, address the need for a comprehensive set of methodologies for planning of the facility, its segments, and its intersections. The recommendations should address multimodal analysis needs. The recommendations should address reliability analysis needs. The recommendations should identify which gaps can be filled in the short term (before 2010) and which should be deferred to a later HCM update. (4) Submit an interim report presenting the results of Tasks 1 through 3 and a recommended outline for the 2010 HCM. Include a recommended Phase II work plan for the remaining tasks to deliver the HCM by the year 2010. Report on the progress and findings to the TRB Highway Capacity and Quality of Service (HCQS) Committee Meeting. (5) Conduct supplemental research to fill the gaps within the HCM. If these gaps are minor in scope (they can be completed within the time schedule and budget for updating the HCM by 2010), it would be highly desirable to complete the research as part of this project. To the extent the gaps require research efforts beyond the time and budget constraints of this project, draft research problem statements will be prepared. (6) Coordinate relevant research efforts of ongoing NCHRP projects addressing individual chapter updates. (7) Prepare sample problems, drawing from those in the Year 2000 HCM and the HCM Application Guide. Develop software as needed to prepare sample problems. Deliver software to TRB. The software is intended for use by the contractor and the HCQS Committee. It will be important for the contractor to develop and apply a method for independently verifying sample problem results. (8) Prepare draft HCM chapters and present them to the TRB HCQS Committee. Revise the draft chapters based on comments from Panel and Committee. (9) Update example problems in HCM Applications Guide. (10) Prepare an HCM 2010 document with text, graphics, and sample problems in electronic format and deliver to TRB. Present them to the TRB HCQS Committee for approval.

♦ Project 03-93
Automated Enforcement for Speeding and Red Light Running

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$150,000
NCHRP Staff:	David A. Reynaud

There is a major national emphasis on highway safety and the attainment of aggressive reductions in traffic fatalities. Among other issues, speeding is a major contributor to the safety problem in the United States and requires specific attention, being a contributing factor in around 30% of all fatalities. Speed is a common factor in fatal motorcycle crashes, which have been increasing at an alarming rate in recent years. There is a growing consensus that we are not making the desired progress in safety, in part, because increases in

speed are counteracting the benefits of many of the safety treatments we are implementing.

In addition, intersection crashes contribute significantly to the overall safety fatality numbers in the United States, being over 21% of overall fatalities. There are an estimated 900-1,000 traffic fatalities each year in this country due to motorists running red lights.

In both of these cases, technologies have been developed and used in the United States and many other countries to automatically detect speeding and intersection infractions related to red light running. Limited law enforcement personnel resources make technological solutions particularly important. Previous research has shown that safety benefits can be attained utilizing these technologies.

In 2004, the AASHTO Board of Directors passed a policy resolution to build broad public support for automated traffic law enforcement, to promote the enactment of automated traffic enforcement laws based on the NCUTLO model law, and to support the use of automated enforcement technologies, in concert with engineering analyses and public information campaigns, to reduce the number of deaths resulting from traffic law violations. A 2006 AASHTO SCOHTS resolution reinforces the resolve on this issue.

The proposed project will produce a report documenting existing laws and ordinances, ongoing automated enforcement activities in the United States, best practices among State and local jurisdictions, research on the effectiveness of automated enforcement, surveys of public opinion, as well as public information, education, and legislative approaches. The project would update a recent synthesis on red light running cameras and provide new coverage of automated speed enforcement (in work zones, school zones, and other corridors) and automated enforcement at highway-railroad grade crossings. The resulting report will support continuing efforts to assist States in efforts to expand the implementation of automated enforcement programs in an effective and efficient manner. The research will examine existing State laws and local ordinances in the United States that allow automated (primarily camera) enforcement; identification of likenesses and differences in the laws; and creation of a database of the legal and regulatory requirements and limitations relative to the use of these technologies. The study will identify and catalog all those States and localities that permit (or prohibit) specific types of automated enforcement, including any special circumstances (e.g., only in work zones or only in school zones). Based on the results of a separately proposed domestic scan, the study will also catalog those jurisdictions that had automated enforcement in place at one time but decided to remove it and summarize lessons learned. Existing effectiveness information from implementation of automated enforcement (in terms of crash and crash severity reductions, violation reductions, citations, etc.) would be summarized and documented when available. The study will also identify best practices and develop guidance on cost-benefit analyses, model procurement specifications for hardware and software systems, operating and management procedures necessary for successful implementation, development and conduct of training for implementation staff, and conduct of evaluation studies based on crash reduction and other success metrics. The research will compile information on the approaches and best practices followed by implementers of these technologies to inform and enlist elected officials and other decision makers in the deployment of these technologies as well as approaches and methodologies for educating the public and winning support for these technologies in both the legislative development stage and following activation of a program. The final report will document findings as well as provide guidance for implementing automated enforcement programs and make recommendations for standards, strategies, and other guidance that could be developed and can lead to a “next generation” of automated enforcement programs at the State and local levels. It will include model legislation for allowing automated enforcement of speeding and red light running and recommended contract provisions for implementing such systems, plus a discussion of the costs and benefits of operating such a system.

The objective of this project will be to create the basis for the accelerated adoption of automated enforcement programs by sharing best current practices and spurring the development of more detailed and targeted guidance for implementing agencies.

Several states are pursuing (or wish to pursue) automated enforcement programs. Several

national organizations would like to emphasize these technologies as effective countermeasures and are being sought out for policy and program positions to support state and local implementers. Finally, the proposal is fully in line with the recommendations of the CEO-level participants of the international scan on Safety and ITS. The payoff could be great in terms of new countermeasures that can save lives being implemented sooner than might otherwise occur. Implementation of the findings is also more certain because of the active support and interest of both AASHTO and FHWA in getting the information deployed to those who can use it. This research effort also supports the strategies of the USDOT Speed Management Strategic Initiative by providing information and best practices to assist States in making decisions on implementing automated enforcement.

♦ **Project 04-35**
Enhanced Test Method for Specific Gravity and Absorption of Coarse and Fine Aggregate

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$350,000
NCHRP Staff:	Edward T. Harrigan

The objectives of this project are to (1) review existing and proposed methods of accurately and precisely measuring the specific gravity and absorption of coarse and fine aggregates and (2) develop a new or revised standard method of test for aggregate specific gravity and absorption for consideration by the AASHTO Highway Subcommittee on Materials. The test method shall provide improved (1) accuracy, repeatability, and ruggedness; (2) ease of use in field and lab environment; and (3) cost of running the test, compared with present methods.

The following tasks are anticipated to accomplish these objectives: (1) conduct a thorough review of the worldwide literature to identify existing and proposed test methods for measuring the specific gravity and absorption of coarse and fine aggregate and identify candidate test methods for evaluation; (2) prepare a detailed work plan, budget, and schedule for a laboratory evaluation program to select one or more test methods from among the most promising candidates identified in Task 1; (3) conduct the work plan and recommend one or more test methods; (4) assess the sensitivity of the recommended test methods for application in normal construction operations, including quality control; and (5) prepare a final report that documents results, summarizes findings, draws conclusions, and presents the recommended test method(s) in draft AASHTO format.

Note: The AASHTO Standing Committee on Research requested coordination with existing efforts by the Federal Highway Administration.

♦ **Project 08-65**
Identification of Results-Oriented Public Involvement Strategies Between Transportation Agencies and Native American Tribal Communities

Research Field:	Transportation Planning
Source:	Arizona
Allocation:	$200,000
NCHRP Staff:	Christopher J. Hedges

Throughout the United States, thousands of miles of roads operated by state, county, and regional agencies traverse lands under the jurisdiction of Native American tribes. As the need arises for the planning and construction of transportation improvements, so does the need to conduct extensive and meaningful public outreach to the members and governing bodies of these tribes.

Historically, the relationship between government agencies and Native American tribes has often been viewed as tenuous. When transportation projects are undertaken by state and county agencies on tribal lands, successful communication, cooperation, and coordination are vital. The need for meaningful public involvement with tribes is especially acute in regions that are experiencing a high rate of population growth. In such regions, urban areas are increasingly abutting and even encircling tribal lands that once stood distant and isolated from such development.

Despite widespread agreement by parties on all sides that outreach to tribal communities has often been less than successful in reaching mutually

beneficial results, research designed to identify the underlying causes and to develop practical solutions for achieving such results appears scarce.

Transportation projects increasingly impact—and are impacted by—Native American tribal communities. With 562 federally recognized Native American tribes located in 34 states across all regions of the country, there is a significant need for results-oriented strategies for public involvement, including consultation. The urgency of this need is highlighted by the Federal Highway Administration's newly proposed rules for consultation with Native American tribes during the development of metropolitan transportation plans, statewide long-range transportation plans, and State Transportation Improvement Programs (STIPs). The products of the research proposed by this statement would be appropriate for immediate implementation by states and metropolitan areas working to meet the new requirements.

A number of studies on the topic of transportation-related outreach to and consultation with Native American tribes have been identified below. While these documents do provide brief case studies and overviews of procedures implemented in various states, they do not represent original research. The research proposed by this statement would extend beyond a comprehensive compilation of relevant case studies to include the development of results-oriented strategies.

- Conference on Transportation Improvements: Experiences Among Tribal, Local, State, and Federal Governments (panel presentations). *Transportation Research Circular E-C039*, September 2002.
- New Mexico Tribal/State Transportation Summit, Summary of Proceedings. University of New Mexico, Alliance for Transportation Research Institute, 1999.
- Iowa Tribal Consultation Process: Initiatives and Recommendations. Iowa State University, Center for Transportation Research and Education, 2002.
- "Building on Common Desire for Better Tribal-State Governmental Relationships." J. Kozak and M.E. White, *Transportation Research Record 1848*, 2003.
- "Strategies for Streamlined Participation by Native American Governments in Federal Transportation Projects." Jessica Granell and David Grachen, *Transportation Research Record 1931*, 2005.
- FHWA Tribal Transportation website (http://www.fhwa.dot.gov/hep/tribetrans/ttpcs/index.htm): Case Studies of State, MPO, and Tribal Coordination in Transportation Planning.

The research proposed by this statement would focus on transportation facilities operated and maintained by non-tribal agencies on or near tribal lands. The research would provide transportation professionals with an identification of the problems—from multiple perspectives—that have occurred as state and county agencies have worked to involve the members of tribal communities in the process of planning, designing, and constructing facilities. An important aspect of the research would be the objective definition of the root causes of these problems. The project would culminate in the development of an array of practical strategies for successful communication, cooperation, and coordination that are designed to meet the needs of both transportation agencies and tribal communities. Intrinsic to the development of recommendations for "successful" strategies would be working definitions of success for both transportation agencies and tribal communities. The recommendations would also identify elements common to public involvement that, in light of these definitions, are deemed successful by both parties.

Research tasks may include interviews, surveys, and focus group discussions with representatives of Native American tribal governments, state departments of transportation, and local transportation agencies. Information obtained may include an overview of policies and procedures from various regions of the country; case studies reflecting varying levels of success regarding actual plans, studies, and projects; an investigation into the role of multi-leveled bureaucracies that exist on all sides of the issue; and insight from tribal members. Throughout the research process, the role of general public involvement should be distinguished from the prescribed consultation process.

♦ **Project 08-66**
Trip-Generation Rates for Infill Land Use Developments in Metropolitan Areas

Research Field: Transportation Planning
Source: California
Allocation: $300,000
NCHRP Staff: Crawford F. Jencks

New development and redevelopment projects located near, or surrounded by, existing land uses, are often termed urban or suburban "infill." This proposed research is important and beneficial because it will provide data that would help overcome existing transportation-related barriers to implementing cost-effective and infrastructure-efficient infill land use projects within existing urban and suburban areas. Appropriate development and redevelopment in such areas is an important strategy for revitalizing the nation's aging cities and suburban cores, increasing the efficient and cost-effective use of existing infrastructure (streets, transit, utilities, etc.), and expanding opportunities for housing, recreation, and economic vitality in such areas.

During local land use review and development permitting processes, public agencies (and/or transportation engineering consultants) commonly estimate vehicle travel impacts associated with proposed land use projects, assess their potential contribution to traffic congestion, and identify appropriate mitigation strategies (often fees and/or specific facilities improvements). In developing such estimates, transportation professionals often rely on the Institute of Traffic Engineers' (ITE) published trip generation rates for various types of land uses.

However, it may not be accurate to use currently available trip generation rates to analyze traffic impacts associated with proposed infill land use projects because such data typically does not take into account variations in the locations of land uses, the availability and/or proximity of transit service, and/or the existence of pedestrian and/or bicycle facilities. ITE's suggested methodology for developing trip generation rates data currently recommends studying existing land uses that are located in isolated suburban areas with little or no existing transit service and that have a low level of pedestrian or bicycle facilities. Therefore, applying such trip generation rates data to urban or suburban infill land use projects that do have high-quality transit service and/or good pedestrian access can overpredict their traffic impacts. This can make infill land use projects more costly and difficult to implement, thereby reducing the efficiency, housing, mobility, environmental, and economic benefits that can result from the more efficient use of existing urban and suburban areas.

The California Department of Transportation (Caltrans) is currently funding a pilot study to develop a methodology for developing vehicle trip generation rates for several land use categories in selected urban and suburban infill areas in California. In close coordination with ITE and a knowledgeable technical advisory group, this study is expected to take the first steps toward defining and gaining acceptance for a methodology for collecting and providing specific infill trip generation rates data. Although the data produced should be useful to practitioners within California, applying its results outside of California will be problematic. This proposed NCHRP study is needed to develop vehicle trip generation rates data outside of California that can be used to assess infill land use projects in urban and suburban areas in other states. This national-scale study would also provide an opportunity to review the methodology and data developed during California's pilot study and to determine whether it is useful for collection and dissemination of infill trip generation rates data in the U.S.

A related study is NCHRP Project 08-51, "Enhancing Internal Trip Capture Estimation for Mixed-Use Developments," currently being conducted by the Texas Transportation Institute. The objective of this study is to assess internal travel "capture" rates of mixed land uses (e.g., trips that have destinations within a specified mixed-use area). Project 08-51 differs significantly from this study because the mixed-use projects being evaluated in Project 08-51 are not necessarily located in urban or suburban infill areas, and may have little or no transit or walk/bike facilities. In contrast, this proposed study focuses solely on land uses within existing urban and suburban infill areas (which are often mixed-use in character, but not necessarily so). Therefore, these two studies will provide much needed, though different, types of data for assessing proposed land use projects.

The primary objective of this study is to establish, document, and disseminate a methodology for producing and applying vehicle trip generation rates data for infill land use projects located within existing urban and suburban areas throughout the United States. Another major objective is to collect, analyze, and report on vehicle trip generation rates data for several types of land uses in a sample of existing urban and suburban infill locations in a selection of U.S. metropolitan areas. This study will be conducted in close coordination with the NCHRP study advisory committee and ITE. (ITE staff has expressed support for submitting this study proposal.)

Using existing trip generation rates data to estimate traffic generation associated with infill land use projects potentially over-estimates such impacts. The consequences often include excessive traffic mitigation fees and facilities, neighborhood opposition (and sometimes costly and time-consuming lawsuits), and the provision of more parking spaces than actually may be needed. These effects, in turn, often result in higher development costs, the delay and even cancellation of otherwise beneficial infill projects, and related impacts that can stall economic development, housing, and job growth within existing urban and suburban areas. By making it more costly and difficult to implement urban and suburban infill land uses, such effects also reduce the efficiency of transit service and other infrastructure and services and contribute to "sprawl."

The results are expected to be implemented via the publication of the methodology and data developed during the study (potentially by ITE and/or other professional organizations).

♦ Project 08-67
Integrating Individual Transportation System-Level Performance Programs to Determine Network Performance

Research Field:	Transportation Planning
Source:	Minnesota, AASHTO Standing Committee on Planning
Allocation:	$300,000
NCHRP Staff:	Crawford F. Jencks

Governmental entities at all levels are currently involved in the process of developing and reporting results of programs aimed at measuring transportation system performance. To date, research in this arena has primarily focused on establishing general frameworks and guidelines to serve as a basis from which system-level performance programs may be established and expanded. Such research provides examples of the tools and institutional frameworks that are necessary for the construction of performance measurement programs designed to measure the performance of individual transportation systems. What is missing from the literature is an understanding of the performance of transportation networks (a combination of transportation systems representing multiple modes and jurisdictional ownership) that function across political and institutional boundaries. Whether individual systems are owned, operated, and maintained by state, regional or local governments, specially designated authorities, or the private sector, it is expected that users will be able to navigate among the systems with relatively little knowledge of the controlling entity. This is at the heart of creating a "seamless" transportation network that, in one form or another, is a primary goal of most, if not all, transportation providers throughout the United States. Performance evaluation of individual systems alone is not sufficient to determine multi-modal and multi-jurisdictional network performance. What is needed is in-depth analysis of the potential for integration of performance measurement programs that have been created to gauge the performance of individual systems, to measure the performance of multi-modal and multi-jurisdictional transportation networks. Once an understanding of network performance is gained, results can be used to inform and improve decisions related to not only the process by which projects are selected and implemented by transportation professionals and other decision makers, but also to the usefulness of the transportation network to all users. Such research will build on existing research, providing necessary insight into implementation by not only identifying system-related performance measurement program commonalities and dissimilarities, but also by identifying ways in which existing multi-modal and multi-jurisdictional performance programs may be integrated to provide estimates of transportation network performance to improve decisions and

thereby improve the flow of people and goods along the network.

The objective of this proposal is to assist transportation professionals as they strive to implement performance management programs by investigating how individual, multi-modal, multi-jurisdictional, system-level performance measurement programs can be integrated to provide estimates of transportation network performance.

The final product should outline the process of integrating multi-modal and multi-jurisdictional performance programs using information from a representative sample of state, regional, and local programs. Information considered for analysis should include an understanding of individual system priorities, goals and associated data sources, and methods of analysis and procedures for implementing program results at both the system and network levels to improve network-related decisions.

The majority of research for developing transportation system performance management programs highlights the tools, frameworks, guidelines, etc., necessary for performance program creation and implementation. No investigation exists of the potential for integration of system-level performance measurement programs to measure the performance of multi-modal and multi-jurisdictional transportation networks.

Scarce transportation resources and the need for improved decision support tools are two main justifications for the development of performance management programs. The main justification for this research is that, although many jurisdictions have begun the process of creating performance measurement programs, few, if any, have attempted the comprehensive, multi-jurisdictional implementation of performance management programs required for the strategic planning of transportation networks. While many are knowledgeable concerning individual, system-level performance programs—their creation and implementation—many have yet to attempt multi-jurisdictional, network-level performance program creation or implementation.

Implementation and integration of transportation system performance management programs is essential if public transportation providers are to make the transition to more business-like operations. Without the comprehensive, multi-jurisdictional integration of performance measurement program monitoring efforts and results, the network impacts of system-level decisions will remain unclear and largely unpredictable. Thus the ultimate impact of decisions made will be imprecise, resulting in varying chances of success or failure. It is impossible to make decisions among multiple investments without an overall understanding of possible options and outcomes. The knowledge gained through this in-depth research project will result in network-level performance measurement providing such understanding by carefully laying out the multitude of factors and their effect on the provision of a seamless transportation service that all providers of multi-modal, multi-jurisdictional transportation systems strive to provide for their customers.

♦ Project 08-68
An AASHTO Citizen, Stakeholder and Interdisciplinary Guide for CSS in Transportation

Research Field:	Transportation Planning
Source:	Rhode Island
Allocation:	$400,000
NCHRP Staff:	Crawford F. Jencks

Since 1998, FHWA, AASHTO, and state DOTs have been striving to improve the quality of transportation decision-making and project development processes through implementation of the philosophy and principles of Context-Sensitive Solutions (CSS). The CSS approach not only advocates timely and effective involvement of stakeholders and the public in these processes but also the project-specific tailoring and integration of multidisciplinary experts and interdisciplinary teams in these processes. CSS considers the total context within which a transportation project or system exists and seeks to balance, preserve, and enhance transportation safety and mobility along with environmental and community values and assets. Although FHWA, AASHTO, and many state DOTs have made considerable progress in advancing CSS in transportation practice, barriers still remain in the way of mainstreaming full and effective implementation of the principles of CSS.

Findings from a recent AASHTO Survey of State DOTs on CSS and a national

AASHTO/FHWA CSS Peer Exchange indicate that, in many states, CSS misperceptions and resistance to change exist and DOT leadership, staff, stakeholders, and the public do not have a clear understanding of what defines and constitutes CSS; therefore, (1) state DOTs want to improve their CSS implementation processes, and (2) state DOTs desire more effective educational and training tools and guidelines. These concerns and needs are also consistent with findings and research priorities that have been identified through recent workshops and activities conducted by the TRB joint committee Task Force on Context Sensitive Design & Solutions.

The objective of this research is to advance the mainstreaming of CSS nationwide through development of a comprehensive and online "Citizen, Stakeholder, and Interdisciplinary Guide for CSS in Transportation" that will clearly articulate and visually illustrate the following:

- What does (and what does not) define and constitute CSS;
- Principles, attributes and best practices of CSS;
- Guidance that enables citizens, stakeholders, and interdisciplinary professionals to become more effectively and successfully engaged and integrated to help inform context-sensitive decision-making and project development processes;
- A broad and diverse range of project case studies that represent exemplary CSS process, outcomes and benefits; and
- Tools and resources for citizens, stakeholders, and interdisciplinary professionals.

This project should build on and implement joint recommendations to be provided or agreed on through an NCHRP oversight panel that includes the AASHTO CSS Task Force, FHWA, TRB CSD&S Task Force, State DOT, citizen, stakeholder, and interdisciplinary representation. The researcher will be required (but not limited) to

- Review the existing literature to identify and document efforts made toward informing and guiding citizens, stakeholders, and interdisciplinary professionals in how they can become integrated in CSS decision-making and project development processes;
- Address gaps in current understanding, knowledge and applied practice and conduct research in these areas as advised by the oversight panel;
- Work with AASHTO, FHWA, TRB, state DOT, transportation stakeholder, citizen, and other research and industry representatives in developing information and guidance and in identifying best practices and project case studies for incorporation and illustration in the online guidance publication; and
- Compile and synthesize the research (along with exhibits, illustrations, color photos and computer simulations of the supporting examples, best practices, and case studies) and integrate narrative text and supporting visuals into a comprehensive, interactive, and intuitive online AASHTO Citizen, Stakeholder, and Interdisciplinary Guide for CSS in Transportation.

The urgency and payoff potential are both high in terms of the contribution an online and "state of the art/science" publication could make toward advancing and mainstreaming more successful implementation of CSS nationwide in transportation decision-making, project development processes, and outcomes. As mentioned before, findings from a recent AASHTO CSS Survey of State DOTs, a national AASHTO/FHWA CSS Peer Exchange, and the activities of the AASHTO CSS Task Force and the TRB CSD&S Task Force all support the urgency and payoff potential for this research project and the fuller and more successful implementation of CSS that would be further enabled by an AASHTO Citizen, Stakeholder, and Interdisciplinary Guide for CSS in Transportation.

Further urgency is evidenced by the heightened expectations and recent incorporation of the 15 CSS principles (by reference) in SAFETEA-LU as an amendment to Section 109(c)(2) of Title 23, U.S.C. and the fact that this project would also support FHWA Objective #1 (Implementing Context Sensitive Solutions) under Environmental Stewardship and Streamlining as one of their three national "Vital Few Goals."

♦ **Project 08-69A**

Update of the AASHTO Transportation Asset Management Guide: Transportation Asset Management Guide, Volume 2—A Focus on Implementation

Research Field:	Transportation Planning
Source:	AASHTO Standing Committee on Planning
Allocation:	$175,000 (Additional $125,000 from Federal Highway Administration)
NCHRP Staff:	Andrew C. Lemer

Asset management is an important focus of efforts by AASHTO, FHWA, and many state departments of transportation (DOTs) to improve agency management practices and improve the performance of transportation system investments. AASHTO's *Transportation Asset Management Guide*, developed under NCHRP Project 20-24(11) and released in 2002, provided agencies with a basis for understanding of the benefits to be gained by adopting asset management principles and guidance for how to use these principles to enhance accountability, reduce fragmentation of decision-making, and make more effective use of information and analytic tools to manage their transportation system assets. Since the Guide's release, many DOTs have begun to incorporate asset management in their day-to-day activities. Agencies have begun not only to understand the concepts of asset management, but also to implement its techniques, including performance-based planning and innovative program delivery, with particular emphasis on system performance measurement and monitoring.

The objective of this research is to extend the Guide's content by developing a second volume focusing on implementation of transportation asset management (TAM) programs in state DOTs. The new volume will promote further implementation of asset management tools, analysis methods, data collection, and application of management system information. The extended guide will include tools for economic evaluation and tradeoff analysis and strategies for enhancing communication and information sharing among policy and technical decision makers as well as elected officials throughout the project development process—a process that extends from initial goal setting, through planning and programming, to operations, asset preservation, and maintenance. The research will also update the initial 2002 guide to the extent needed to reflect significant changes in legislation, regulation, or industry practice that have occurred since the Guide's development.

The two-volume guide developed in this project should address at least the following topics:

- Definition or explanation of TAM as a set of management principles and practices,
- TAM framework and organization structures for implementation,
- Performance measures,
- Organization self-assessment of asset-management performance,
- Condition assessment and assessment tools,
- Demand forecasting,
- Cost estimation,
- Risk analysis,
- Optimized decision making,
- Economic analysis,
- Tradeoff analysis,
- Financial management,
- Data needs,
- Asset preservation strategies,
- Relationships of TAM and long- and short-term planning,
- Integrated management systems,
- Communication of asset-management information, and
- Development of TAM plans.

Case studies and practical examples should be documented in this project to demonstrate how TAM may be used to enhance transportation system performance.

Note: The AASHTO Standing Committee on Research suggested that this project and Project 08-69B should be assigned to a single panel.

♦ **Project 08-69B**
Implementing Enterprise-Wide Asset Management Decision-Making Tools and Linkage to Other Management Systems

Research Field: Transportation Planning
Source: AASHTO Planning Subcommittee on Asset Management
Allocation: $300,000
NCHRP Staff: Andrew C. Lemer

The principles and practices of Transportation Asset Management (TAM) have gained adherents in many state departments of transportation (DOTs), but developing databases and software systems to support TAM within the context of an agency's other management systems has proven to be a significant challenge. Many DOTs are reluctant to change management software tools developed over the years that for the most part these have served the agencies well. On the other hand, improving data-processing hardware and software systems have spurred DOTs to adopt integrated Enterprise Resource Planning (ERP) systems that attempt to integrate all of an organization's data and management processes, often requiring substantial changes in the ways that organizational units within the agency collect, maintain, and gain access to data.

While there are substantial variations among agencies in how they conduct their business, such core functions as financial management, project management, roadway maintenance, and others are common to all agencies. Recognition of these commonalities underlies AASHTO's support for development of the Transport Suite of software products. The objective of this research is to determine how TAM may most effectively be integrated with other elements of ERP systems and to identify a strategy for AASHTO to motivate enterprise-wide adoption of TAM software systems.

The project should entail a survey of ERP systems being used by DOTs, either developed by the agencies themselves or commercial packages adapted to the agency's needs, for such purposes as financial management, payroll processing, procurement and contracting, maintenance work order processing, and project management, and the degree to which TAM is supported by agency ERP systems. The survey should determine if and how these software systems interface with one another and how DOT management uses these software systems in decision making. The research should identify effective DOT practices for integrating TAM tools with enterprise-wide software solutions and primary impediments to such integration.

The project should review AASHTO's role in providing management software and DOTs' use of AASHTO-supported software. This review should include consideration of whether AASHTO does and should contribute to standardizing DOT software solutions. Based on this review and the survey of current practices, the research should develop a strategy for AASHTO to motivate enterprise-wide adoption of TAM software systems.

Note: The AASHTO Standing Committee on Research suggested that this project and Project 08-69A should be assigned to a single panel.

♦ **Project 08-69C**
Quantification of the Benefits of Utilizing Asset Management for Resource Allocation

Research Field: Transportation Planning
Source: AASHTO Planning Subcommittee on Asset Management
Allocation: $150,000
NCHRP Staff: Andrew C. Lemer

State DOTs, local agencies, and the Federal government have invested significant resources, estimated to total more than $2 trillion, in building our nation's highway system. The physical assets that comprise that system—pavements, bridges, traffic signals, safety appurtenances, drainage pipes, signs, lights, and more—must be adequately maintained, rehabilitated, or ultimately replaced if the system is to provide effective service and support the economic vitality. The concepts of transportation asset management (TAM) have in recent years been developed and adopted by increasing numbers of agencies responsible for managing these assets. Nevertheless, some agencies remain reluctant to make changes in long-standing policies and procedures that may be needed to implement TAM fully in their programs. A quantitative evaluation of the net benefits gained by

agencies adopting TAM practices and by the community of road users and taxpayers who are the assets owners and service consumers will encourage broader TAM adoption.

The objective of this research is to identify the specific net benefits of using a TAM decision-making process in a DOT and how those benefits may subsequently be communicated most effectively to the agency's stakeholders. The research will use theory and observations of field experience to consider whether overall transportation system condition and performance are improved through the use of TAM practices and whether an agency's cost to maintain and preserve their transportation assets is reduced compared to management practices prior to adoption of TAM. The research will also consider the agency's costs to adopt and use TAM practices compared to prior practices. Finally, the research will consider how customer satisfaction and perception of transportation system performance are related to TAM adoption and will consider other measurable benefits that may be attributed to TAM, such as enhanced road safety and reduced traffic delay. The research will give particular attention to the challenges agencies face in allocating limited financial resources across multiple asset classes and how agencies may use TAM across a broad portfolio of highway asset categories. The project should include consideration of the likely sensitivity of the realized net benefits to organization structure and other characteristics of a specific agency.

Note: The AASHTO Standing Committee on Research suggested that this project should be incorporated with Project 08-69A.

♦ Project 08-70A
Setting Effective Performance Targets for Transportation Programs, Plans, and Policy

Research Field:	Transportation Planning
Source:	Federal Highway Administration, Minnesota, AASHTO Standing Committee on Planning
Allocation:	$375,000
NCHRP Staff:	Andrew C. Lemer

Transportation agencies at all levels of government are embracing performance measurement to guide operations, asset management, capital investments, and policy development. While an extensive and growing literature exists on defining and applying performance measures, little attention is given to methods for setting performance targets. Most agencies appear to base performance targets on arbitrary standards or marginal adjustments to trends. If performance targets are set without a sound and defensible basis, the effectiveness of performance measurement as a management tool to improve efficiency and accountability can be compromised. In addition, setting targets often creates political implications that need to be weighed carefully and balanced with a data-based approach.

NCHRP Report 551: Performance Measures and Targets for Transportation Asset Management outlines basic steps for setting targets, but the methods described for setting performance targets are limited primarily to asset preservation. Development of a wider ranging and more rigorous set of methods to establish performance targets is required to support effective management and accountability for all aspects of transportation, from planning and policy development to project implementation and operations. While extensive literature exists on definition and use of performance measures, treatment of methods for setting performance targets is very limited.

The objective of this research is to develop a comprehensive, rigorous set of methods for establishing performance targets to support effective management and accountability for all aspects of transportation. Candidate methods should be drawn from within and beyond the transportation sector. Candidates may be based on benefit-cost analyses, peer comparisons, industry standards, and other means. A successful research project will develop products that can be used by public agencies and private organizations, such as the following examples.

- State-of-the-practice review of methods used by federal, state, and local agencies, non-profit groups, and related organizations in the United States and other countries for setting performance targets in transportation policy, planning, program development and implementation, project development and implementation, and op-

erations.

- State-of-the-practice review of methods used by carriers, shippers, private investors in transportation, and other transportation and transportation-related businesses for setting performance targets, and an assessment of applicability of the methods to transportation agencies.
- State-of-the-art review of methods for setting performance targets in areas outside of transportation (such as social services and manufacturing), and an assessment of applicability of the methods to transportation agencies.
- Examination of factors likely to influence the setting of performance targets, such as the role of forecasting methodology, consideration of causal factors versus symptoms, and outputs versus outcomes in setting performance targets; influence of data precision; application of benefit-cost analysis principles; and public expectations and perceptions.
- Examination of the effects of different approaches used to set targets and of not setting targets on organization performance.
- Proposed set of methods and associated data requirements for setting performance targets for transportation policy, planning, program development and implementation, project development and implementation, and operations, with analyses of the application areas for which the target-setting methods are appropriate.
- Case studies of applications of the proposed methods for setting performance targets, for example, in safety and capital project delivery.

This research will produce a guidebook for setting effective performance targets for transportation policy, plans, programs, projects, and operations. The guidebook should be supplemented by additional training materials that agencies can use to implement performance measurement and management based on performance targets.

Note: The AASHTO Standing Committee on Research suggested that this project and Project 08-70B should be assigned to a single panel.

♦ **Project 08-70B**

Developing Performance-Based Investment Programs and Data Systems

Research Field:	Transportation Planning
Source:	Minnesota, AASHTO Standing Committee on Planning
Allocation:	$325,000
NCHRP Staff:	Andrew C. Lemer

Transportation agencies are coming to recognize that performance-based management systems would be useful throughout planning, programming and other stages of their investment decision-making processes. A variety of issues must be resolved in development and wider application of such systems, including data availability and quality; systems integration; and availability of tools to retrieve data, analyze it, develop predictive models, conduct tradeoff analysis, and report results in useful formats. *NCHRP Report 551: Performance Measures and Targets for Transportation Asset Management* provides a good description of these issues, but notes that examples of performance-based management programs successfully applied in practice are limited to a few specialized application areas such as pavement and bridges.

The objective of this research is to develop guidance for institutionalizing performance-based investment decision-making and supporting data systems for uses throughout a transportation agency. The project will identify successful approaches using an organizational and systems development perspective, addressing such questions as the following:

- What are the key elements of a performance-based investment process and what are the tools and systems needed to support these elements, considering that decisions must be made among competing investment opportunities and across partnering organizations?
- How are performance-based systems used in practice, for example, to make decisions, to track trends, to share with the public, or to satisfy legislative mandates?
- What are the key technical considerations to guide data collection and data system develop-

ment to enable performance-based investment decision making?

- What are the characteristics of agency organization, and allocations of roles and responsibilities—relating, for example, to developing data and data systems and to relationships among information technology and operating units within an agency—that facilitate performance-based investment processes?
- What are the specific steps and relationships among steps for collecting, organizing, and processing data to yield useful information for performance-based investment decision making?
- Will uniformity of performance measures and data across state and local agencies provide significant benefits to warrant development and adoption of uniform data standards?

The research will produce guidance for agencies on development and implementation of data-collection plans; data documentation, storage, analysis, and reporting; and implementation of information systems to support performance-based investment decision making. This guidance will include examples of analysis reports to illustrate alternative methods for presentation of information, with explanations of how each report may be used.

Note: The AASHTO Standing Committee on Research suggested that this project and Project 08-70A should be assigned to a single panel.

♦ Project 09-46
Mix Design and Evaluation Procedure for High Reclaimed Asphalt Pavement Content in Hot Mix Asphalt

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$400,000
NCHRP Staff:	Edward T. Harrigan

As paving materials become more expensive, pressure is increasing to make the best use of available resources. Reclaimed Asphalt Pavement (RAP) is a resource and has been used for several decades in Hot Mix Asphalt (HMA). Based on current AASHTO guidelines, recycled HMA generally contains 10-25% RAP which, in most parts of the country, does not consume the entire amount of RAP being generated. As a result, RAP is accumulating and is being used in low value non-bituminous applications or being wasted.

RAP processing equipment and procedures have advanced since the Superpave RAP recommendations were made. RAP is typically processed into smaller pieces than in the past. Hot mix plants are better able to handle higher amounts of reclaimed pavement without detrimental effects. As a result, it is now possible to produce quality hot mix asphalt containing 35% to 50% RAP. High RAP mixtures have the potential to significantly reduce the cost of HMA paving while conserving energy.

Current AASHTO specifications cannot be used for high RAP mixtures or fractionated RAP mixtures. Following the recommendations for evaluating binder properties leads to erroneous decisions producing mixtures that suffer early rutting or, for fractionated RAP, could underestimate the mix stiffness leading to increased cracking problems. A minor adjustment to the current specifications is not sufficient to assure agencies that good performing mixtures will result.

RAP fractionating means that the ratio of old-to-new asphalt binder and old-to-new aggregate will no longer be approximately equal. The asphalt binder content of screened RAP is higher than RAP used in the past and a recycle ratio of old-to-new asphalt binder can reach 50% while producing HMA that meets all Superpave specifications.

The objective of this research is to develop a mix design method and specification for HMA containing up to 50% RAP. The mix design method should include a system of materials evaluation and measurement of key properties for cracking and rutting performance. This should include a mix analysis approach and may also include a method for evaluating the binder. The analysis should include a method to determine if binders and additives can be handled and mixed with the HMA in accordance with environmental standards. In addition to establishing the limits for the key properties, the specification should consider material quality control and processing

requirements for high recycle ratio mixtures such as with RAP fractionating.

The following tasks are anticipated to accomplish this objective: (1) develop a mix design method to include greater percentages of RAP than currently used and that addresses binder, aggregate and mixture properties, either directly or indirectly; (2) develop a test method that directly measures the properties of the composite binder in the RAP–HMA mix in lieu of projected values based on the extracted and recovered binder alone; (3) develop a specification for RAP quality and processing in the field such that the RAP stockpile will be acceptable to produce HMA that has a high content of RAP; (4) evaluate mixtures designed with fractionated RAP that produce high percentage (50%) recycle ratio of old-to-new asphalt binder; (5) develop a method and/or test procedures to determine that the binders, RAP, and RAP-HMA mixture will meet current environmental requirements during production; and (6) develop a specification for surface, binder, and base course mixes which will ensure that the high RAP content mix will be of equal or better quality than a comparable virgin mix and meet all the current environmental requirements during production.

♦ Project 09-47
Evaluation of the Environmental and Performance Properties of Warm Mix Asphalt Technologies

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Materials
Allocation:	$1,200,000
NCHRP Staff:	Edward T. Harrigan

Traditionally, hot mix asphalt (HMA) is produced in either batch or drum plants at a discharge temperature of between 280° and 320°F. These temperatures are needed to dry the aggregate, coat it with the asphalt binder, and achieve the desired workability. Mix production temperatures are set according to local practice or AASHTO Test Procedure T 316. Higher temperatures are often associated with the use of polymer modified binders.

The HMA industry is embarking on a program to substantially reduce mix production temperatures. Reduced mix production and paving temperatures would (1) decrease the energy required to make HMA; (2) reduce emissions and odors from plants, and (3) improve the working conditions at the plant and paving site.

The term *warm mix asphalt* (WMA) refers to technologies, including various proprietary products and processes, that allow substantially reduced HMA mix production temperatures. Because these technologies were often originally intended to enhance compaction, they may also have positive impacts on HMA performance. Such technologies should make in-place density easier to achieve because they improve the workability of the mix. The majority of aging in an asphalt mixture takes place during mix production when it is exposed to elevated temperatures. By reducing mix production temperature, less oxidative hardening will take place, which should reduce the asphalt mixture's susceptibility to cracking. Reduced hardening during WMA production can increase its susceptibility to permanent deformation, but strategies such as the use of higher asphalt binder performance grades and stone matrix mixes can address this issue.

While the current state of the practice for producing HMA has been shown to meet existing environmental, health and safety standards, the reduced temperatures used in WMA production and placement offer several potential benefits, including reduced emissions, fumes, and odors, and a cooler work environment.

The lower temperatures used with WMA may also improve its construction and long-term performance. Workability improvements may lead to higher in-place density. This decrease, in turn, will reduce the permeability of the WMA, the in-service hardening of the asphalt binder, and the moisture susceptibility of the WMA. Lower in-place air voids should improve the resistance of the pavement to fatigue and thermal cracking and may also improve rutting resistance.

However, WMA technology may present potential engineering challenges. Since the asphalt binders may not harden as much at the lower production temperatures, WMA pavements may contain softer binders when opened to traffic, with a greater potential for rutting. In addition, traffic may not be allowed on the pavement at the conclusion of the compaction process until the mixture cools beyond what is normally required for conventional

HMA. Since binders may be softer, and since some of the WMA technologies use water as a workability aid, the WMA could be more susceptible to moisture damage. Correlation of WMA engineering properties with their field performance needs to be established for widespread implementation of this technology to occur.

The objectives of this project are to: (1) evaluate the type and level of emissions from WMA during production and placement compared with those from HMA; (2) correlate the engineering properties of WMA technologies with their performance in field pavement sections and full-scale test tracks; and (3) compare the initial field performance of pavements constructed with WMA with that of conventional HMA. It is anticipated that a minimum of four WMA technologies will be investigated.

The following tasks are anticipated to accomplish these objectives: (1) determine availability of existing and proposed field trials; data available on existing field trials; available WMA technologies; and studies to correlate WMA engineering properties measured in the laboratory with rutting, fatigue cracking, thermal cracking, aging and water sensitivity in the field; (2) develop and conduct a laboratory test program to measure the type and level of emissions from WMA at production and placement temperatures and compare them to those from HMA; (3) develop a sampling and testing plan for measuring WMA emissions and field performance during pre-construction, construction and post-construction; (4) identify and select both new and existing field pavement and test-track sections for emission and performance testing; (5) conduct the sampling and testing plan developed in Tasks 3 and 4 and analyze the results to answer the project objectives; and (6) prepare a final report including a plan for long-term monitoring of the performance of field pavement sections.

Note: The AASHTO Standing Committee on Research directed that the scope of Problem Statement No. 2008-D-19 be included.

♦ Project 10-74
Development of Rational Loading, Analysis, and Inspection Criteria for Highmast Lighting Towers

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$750,000
NCHRP Staff:	David B. Beal

Recent failures of high-mast lighting towers in several states have raised questions about the robustness and safety of the existing inventory of similar structures. Failure of these structures is very critical as they are typically located adjacent to Interstates or other high-speed highways. The potential exists for these fracture-critical, non-redundant structures to fall across multiple traffic lanes or adjacent property.

Forensic studies have revealed that fatigue is the cause of most of the failures, either at the base plate-to-column weld, the handhole detail, or anchor rods. Several of the failed towers had been in service for less than 5 years at the time of the failure, indicating that they had accumulated a large number of damaging stress-range cycles in a short period of time.

The loading that produces cyclic stresses is a combination of natural wind gusts and vortex shedding. Vortex shedding effects are not adequately addressed in the current specifications. This is a phenomenon that can produce a significant number of large stress-range cycles in a short amount of time under relatively low wind speed. Though it is not clear if natural wind or vortex shedding controls the fatigue life of these structures, measurements of a few towers in Iowa have indicated that natural wind gusting causes the highest fatigue-damage-causing cycles, and vortex shedding (though it occurs) causes significantly lower stress ranges. This field testing study has also indicated that damping ratios can be significantly lower than those suggested by the current AASHTO Specifications. The damping ratio is a parameter critical to the prediction of vortex shedding response. The calculations required to predict vortex shedding are very complex and rely on a variety of assumptions, resulting in questionable predictions.

The consequence of observed low damping ratios is that once excited, the tower will continue to vibrate (i.e., accumulate stress range cycles) for a longer period of time, which would increase the amount of fatigue damage caused by a single event

(such as a wind gust in this case). Because the tower will vibrate longer after subjected to a wind gust, the potential exists for the effects of subsequent gusts to be superimposed on the effects of the first gust and could result in higher stress ranges. This is also critical for vortex shedding as the stress range scales by the inverse of the damping ratio.

Regardless of the loading and fatigue performance, it is critical that rational minimum inspection intervals and detailed inspection procedures be established, similar to those in use for highway bridges. These are fracture critical structures and they should be treated as such for inspection. (However, the criteria for fracture critical bridges will not likely apply to these structures).

The objective of this research is to develop rational loading and analysis criteria for the fatigue limit states for high mast lighting towers. In addition, rational and detailed inspection criteria will also be developed to ensure longevity of the structures and enhanced safety.

♦ Project 10-75
Evaluation of Pavement Type Selection Processes Including Alternate Design/Alternate Bidding

Research Field: Materials and Construction
Source: Georgia
Allocation: $400,000
NCHRP Staff: Amir N. Hanna

State DOTs use a variety of methods to select pavement types for roadway construction projects. Every DOT routinely determines the appropriate and most cost-effective pavement type for a specific project. However, the pavement design and type selection process is a very contentious issue. Almost every DOT is dealing with this issue in some form, and there are no easy answers. Concerns have arisen within and external to DOTs regarding the effectiveness and equity of pavement type selection processes. Current processes need improvements and streamlining to enhance and accelerate selections and ensure that designs are not selected by default. Life-cycle cost analysis (LCCA) data has been perceived as having a possible bias toward one pavement type or the other.

Some DOTs have begun developing processes that provide for selection of pavement type or other highway materials through the bid process. For pavement type selection, the process traditionally uses LCCA concepts to model the cost of pavement alternatives during a performance period. The selection process is then accomplished through the alternate design/alternate bidding (ADAB) procedure that provides for the lowest bidder to participate in selection of which pavement type will be constructed. For other highway materials, the selection process is accomplished through the alternate bidding process alone. While this process seems to be working well in cases, it is also recognized that the process is dynamic and will change as more data is gathered and more lessons are learned. Numerous questions about the value and mechanics of the processes remain unanswered for DOTs and require investigation. Also, industry and political interest in the equity of the process is growing, and the value to stakeholders, if any, from ADAB needs to be more clearly defined.

An exploration of the value, risks, key policy elements, and role of ADAB is critically needed at this time, since numerous questions about the process remain unanswered. Industry and political interest in the equity of the process is growing, and the following milestones also provide impetus for the investigation:

1. States are beginning to use the *Mechanistic-Empirical Pavement Design Guide*, which provides a platform for examining multiple pavement types in the design process.
2. Oil prices may continue to rise and/or portland cement shortages may reoccur, making alternate pavement designs more necessary to ensure selection of the most cost effective pavement types.
3. With the 50th anniversary of the Interstate System, design lives of pavements around the country are expiring, and judicious selection of replacement pavement types is critical at this time.

The overall project objectives are to (1) identify and evaluate various pavement type selection processes, including alternate design/alternate bidding; (2) identify risks associated with pavement type selection

procedures/ADAB; (3) determine key policy elements of pavement type selection procedures; and (4) document how ADAB is integrated into pavement type selection procedures.

The research will focus on analyzing information obtained from state DOTs to provide states with quantitative and qualitative measures of the value of pavement type selection procedures, including ADAB, and will include the following specific tasks:

1. Literature Review
2. Survey of State DOTs – Pavement Type Selection Processes
3. Classification and Evaluation of Types of Pavement Type Selection Processes (including site visits to state DOTs)
4. Summary of Project Findings

The final report will be a compendium of this information, including a survey of the various types of pavement type selection procedures currently used and of ADAB activities since the inception of this practice.

Note: The AASHTO Standing Committee on Research recommended that the scope of the project should incorporate issues relevant to bid alternates using life-cycle determinations (Problem Number 2008-D-03).

♦ **Project 10-76**
Initial Cost Benefits of Quieter Pavements Compared with Other Forms of Noise Mitigation

Research Field: Materials and Construction
Source: Washington
Allocation: $500,000
NCHRP Staff: Amir N. Hanna

Noise barriers, once designed and constructed, are meant to maintain their design noise reduction in perpetuity and benefit outdoor use areas. There is a high capital cost for noise barriers while maintenance costs are usually minimal (except for high graffiti and crash zones). Noise barriers reduce noise at the path, thus protection is limited to receptors within several hundred feet of the roadway. Noise barriers are considered when noise impacts are identified and where the noise abatement is constructible, provides a meaningful noise reduction, is cost-effective to build, is desired by the public and the barrier is designed to protect. Often times, noise barriers cannot be constructed, and noise impacts cannot be mitigated. Conversely, sometimes standard noise mitigation will work, but residents choose not to have it in order to avoid visual blockage of scenic viewpoints. The cost reasonable determination is a calculation based on cost per benefited receptor (and sometimes also by decibel noise reduction).

With the growth of quieter pavement studies, test sections, and pavement choices, additional verification is needed that quieter pavement maintains a certain noise reduction for the durable life of the pavement or at least the initial number of years that it has been applied. Pavement life varies from 10 to 50 years or more, depending on the pavement type. Quieter pavement capital and maintenance costs can vary. There may be increased maintenance costs for de-icing materials or for cleaning of porous concrete or asphalt. Quieter pavement reduces noise at the source, thus it may benefit more receptors than standard noise barriers.

A reasonableness calculation process considering social, economic, and environmental factors will be needed in the future as quieter pavement technology advances. For example, the calculation method might include a quieter pavements cost per benefited receptor per decibel would be beneficial to compare to the noise barrier cost per benefited receptor per decibel in order to assist in decision-making (the analysis should identify pertinent factors and consider costs in future year dollars).

The objectives of the project are to (1) identify and recommend an evaluation model/calculation method, hopefully using existing data available, appropriate for comparing the benefits of different types of transportation related noise mitigation that can be used as a level playing field when new mitigation types come along, and if data is not available, then identify what data would be needed for future evaluations by states; and (2) identify initial/interim results of quieter pavements noise levels compared with standard noise mitigation like walls or berms (perhaps in the form of case studies). With this evaluation, estimate the number

of benefited receivers that could be achieved with the different noise mitigation techniques.

Quieter pavements (concrete and asphalt) have been constructed and are under research in several states in recent years. Per federal requirements they are currently not allowed as a noise abatement measure nor are they considered in noise level prediction at this time. This research is designed to accomplish several things to advance the understanding and set the stage of quieter pavement compared to other types of more standard noise mitigation once more research and testing is completed by states and universities.

♦ Project 12-78
Evaluation of Load Rating by Load and Resistance Factor Rating

Research Field:	Design
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$500,000
NCHRP Staff:	David B. Beal

The draft Manual for the Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges was developed under NCHRP project 12-46. The manual, and in particular the section on load rating, has been extensively reviewed by Technical Committee T-18, Bridge Management, Evaluation and Rehabilitation of the AASHTO Highway Subcommittee on Bridges and Structures. As a result of this review, several changes were made to Section 6, Load and Resistance Factor Rating. The revised version was adopted as a guide manual at the May 2002 Meeting of the AASHTO Subcommittee on Bridges and Structures (SCOBS).

Before the guide manual could be endorsed by the committee members to become a full manual, some additional research was requested to explain differences between the new LRFR specifications and the established load factor (LFD) specifications. NCHRP 20-07/Task 122 was initiated in 2003 and presented to committee members prior to the 2005 SCOBS meeting. That project provided explicit comparisons between ratings produced by the LRFR methods of the Guide Manual and the load factor ratings from the latest edition of the *AASHTO Manual for Condition Evaluation of Bridges*. Both rating methods are contained in Section 6 of the soon to be published *AASHTO Manual for Bridge Evaluation*, which was adopted by the AASHTO Subcommittee on Bridges and Structures in June, 2005. Nevertheless, the Task 122 scope was limited to flexural ratings and the number of structures rated was small. Because of those limitations the committee wanted to see more bridges rated and a LRFR/LFR comparison using design loads, AASHTO legal loads, and permit vehicles to evaluate bridges with consideration given to force effects from both moment and shear. There is concern that the choice of load rating method could have a significant affect on the transportation of goods and services over the nation's highways by restricting routes that were previously unrestricted. The conclusions reached in the previous study, especially those related to the posting of bridges and the issuance of permits for overweight vehicles based on the evaluations using LRFR must be clarified.

The objective of this project is to extend the research done under 20-07/Task 122, to provide explicit comparisons between ratings produced by the LRFR methods of the Guide Manual and the load factor ratings from the latest edition of the *AASHTO Manual for Condition Evaluation of Bridges.* The load rating comparison should be used to review the LRFR calibration to verify that the results reflect an appropriate level of conservatism and correlate to the observed effects on conditions of the national bridge inventory.

♦ Project 12-79
Guidelines for Analysis and Construction Engineering of Curved and Skewed Steel Girder Bridges

Research Field:	Design
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$600,000
NCHRP Staff:	David B. Beal

Curved and skewed steel girder bridges can experience significant three-dimensional deflections and rotations. These deflections and rotations affect the final position and alignment (lateral position and

vertical plumbness) of the girders after the concrete deck has been cast. In addition, they can affect the detailing of the cross-frames and the fit-up of cross frames during erection.

Once the girders are all in place and the bridge is complete, depending on the direction provided on the plans, the fabrication assumptions and method, and the given behavior of the structure, the webs may be out of plumb. This may or may not pose an issue in terms of increased stresses. Also, as indicated in Article C6.7.2 of the AASHTO LRFD 3rd Edition, the potential for problematic locked-in stresses in girder flanges, cross-frames or diaphragms (due to fabricated lack-of-fit intended to achieve certain web-plumb geometries) should be considered at some extent of long spans, tight radii, sharp skews, and stiff and/or slender flanges in the lateral direction. These problems can be quite complex to address in cases of more severe curvature and/or more severe web out-of-plumbness. Depending on the severity of the conditions, a simple analysis solution may be adequate, or a more refined analysis may be required.

Curved and skewed steel girder bridges also are inherently at risk to stability problems prior to the complete assembly of all girders and cross frames, and the installation of the composite concrete deck. The prediction of the behavior of these structures at various stages of construction can be quite complex. Depending on the specific configuration of the structure (span lengths, degree of curvature, degree of skew, size and spacing of girders and cross frames, etc.) different levels of analysis techniques may be required to adequately assess the stability of the structure and the possible need for temporary shoring, bracing, or other means to ensure stability during erection.

Longer spans, more severe curvature, and more severe skew exacerbate the magnitude of the above effects (stability effects, and girder deflection and rotation effects). Larger deflections and rotations, combined with larger weights and stiffnesses of the bridge components, lead to increases in the forces required to handle the structure during erection. Longer, more slender girders are more susceptible to stability issues, which may lead to structural failures during construction.

Various methods and techniques are available for the analysis of curved and skewed steel girder bridges. In brief, the most common methods used in design offices can be characterized as either approximate methods, 2D methods, or 3D methods. Approximate methods can often be performed by hand calculations and are simple and easy to understand. Nevertheless, they are not always refined enough to assess complex stability and deformation effects in more complex structures. 2D methods are more refined than approximate methods, and are simpler and faster than 3D methods, but involve significant simplifying assumptions that can affect the accuracy of the results. 3D methods are the most rigorous and are theoretically the most accurate, but require more effort and time and are more complicated and therefore potentially more prone to inadvertent errors.

Steel girder bridges, particularly when they are curved and/or skewed, require a certain level of erection engineering analysis and a certain level of erection plan detail. Recent unfortunate construction problems, claims, and accidents have suggested that as modern bridges involve longer spans, more severe curvature, more severe skew, and more “optimized” designs, greater attention must be paid to erection engineering analysis, preparation of erection plans, and review of erection plans. Conversely, for cases where the above attributes are milder, simplified methods should be acceptable.

The research objectives are: 1) to quantify when 3D analysis methods are more necessary, 2) to provide guidelines on when out-of-plumbness and/or locked-in stresses must be considered in the analysis, and 3) to provide guidelines on the erection engineering analysis, erection plan detail, review of erection plans, and the associated minimum erection engineering analysis techniques.

Note: The AASHTO Standing Committee on Research requests that this project consider related work done by the Texas DOT.

♦ **Project 12-80**
Reliability Based Design of Concrete Bridge Superstructures Against Sudden Failure

Research Field:	Materials and Construction
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$200,000
NCHRP Staff:	David B. Beal

Current North American codes prescribe minimum reinforcement in flexural members to safeguard against brittle failure following flexural cracking. In the 2005 Interim revision to the LRFD Bridge Design Specifications the modulus of rupture, f_r, is 50% higher than the previously specified value. There are indications that the current provisions for minimum reinforcement, even before the increase in f_r, may cause designers to use excessive amounts of flexural steel. This leads to compression-controlled sections, i.e. brittle behavior of bridge superstructures. This is primarily because in prestressed concrete the cracking moment increases with increasing levels of prestress. If this condition cannot be satisfied, the minimum reinforcement limits must provide a flexural strength not less than $1.33M_u$. Thus, the required flexural reinforcement increases with the increase in prestress. An anomaly exists, in some spliced girder and segmental box girder applications where the minimum reinforcement based on $1.2M_r$ is higher than the maximum reinforcement required for flexural strength.

The American Segmental Bridge Institute (ASBI) has recently reported difficulty in satisfying either of the current limits on minimum reinforcement, sometimes resulting in use of thicker bottom box girder flanges or higher concrete strength. On the other hand, the states of Washington and Nebraska have reported a desire to increase the limits for prestressed concrete members in order to produce equal margins of safety for both prestressed and reinforced concrete cross sections. That position is based on the fact that sections reinforced with Grade 60 mild steel are normally designed with steel strength equal to the 60 ksi yield strength, not the breaking strength, which could be as high as 90 to 100 ksi. On the other hand, prestressed concrete is designed to take advantage of the full 270 ksi strand strength.

There is a need to evaluate the reliability of a limit state to guard against sudden failure after cracking. A limit-state function must be determined for this condition including the choice of a target reliability index. AASHTO LRFD has recently introduced the "variable ϕ," which has been a significant improvement over previous editions of the Specifications. However, the resistance factor ϕ of 1.0 to 0.75 in the transition zone between tension controlled and compression controlled design as well as the resistance factor of 0.75 in compression controlled sections would need to be reassessed and load factors chosen to achieve uniformity reliability.

The issue needs to be addressed in the context of a total superstructure system. In a continuous span bridge, for example, if the negative moment section does not meet minimum reinforcement requirements, would the system allow for redistribution of the moments between positive and negative moment sections? How much redistribution and how reliable is the estimate of redistribution? In a total superstructure system, if one stringer "fails," would the other girder lines be adequate to prevent sudden failure?

♦ **Project 12-81**
Evaluation of Fatigue on the Serviceability of Highway Bridges

Research Field:	Design
Source:	California
Allocation:	$500,000
NCHRP Staff:	David B. Beal

In the United States, there are about 600,000 highway bridges in operation and about 37% of these are steel bridges. Most of them have been in service for more than 50 years and are close to or have surpassed their expected fatigue life. The proper evaluation of these structures to determine their remaining life is of great importance. AASHTO Guide Specifications for Fatigue Evaluation of Existing Steel Bridges (1989) was published about 15 years ago. There is urgent need to update and revise the 1989 AASHTO Guide Specifications to incorporate the state-of-the-art research performed in the last 15 years, and to look

at reported work and accumulated information in new light.

In recent years, more information on steel bridges has been developed world wide that provides a foundation upon which to develop this research, such as the following: variable-amplitude fatigue behavior; high-cycles and long-life behavior; weigh-in-motion; super-load effects; actual traffic loading; inspection, risk and reliability assessment of material properties and structural conditions; and fracture mechanics-based approaches. New information together with extensive experience accumulated in the U.S. make the development of the new guidelines possible with the assistance of this research.

The objective of the proposed research is to develop the new guidelines for the evaluation of the remaining life of existing steel highway bridges. The guidelines shall provide practical procedures and examples to assess the remaining life of steel bridges for purposes of inspection, maintenance and replacement to ensure public safety, mobility and reliability of U.S. aging steel bridges.

Note: The AASHTO Standing Committee on Research recommends that this project be titled "Evaluation of Fatigue on the Serviceability of Highway Bridges."

♦ Project 14-18
Determining Actual Cost of Performing Routine and Preventive Maintenance Operations on Highway Systems

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

Maintaining and upgrading the highway system is costly, and deferring the timely maintenance of the infrastructure usually results in proportionately greater rehabilitation costs at a later date, while contributing to congestion and accident rates. Alternative means of financing, increased contracting for highway maintenance services, and more public-private partnerships will place increased competition on funding issues. Magnifying these difficulties is disagreement among agencies as to what factors should be included when calculating the true cost of highway maintenance. Further, authority at all levels of highway agencies (federal, state and local) is being decentralized with a resultant lack of responsibility, which makes leadership towards a national policy even more difficult.

Due to the overall influence of the highway system on almost every aspect of our daily lives, determining the true cost of performing highway maintenance by the various entities is needed; it shall be the focus in this research. The purpose of this research is to enable highway maintenance agencies to identify the actual cost of performing work as though they were a private firm trying to prepare a bid for performing the work. For this to happen, agencies must develop a strategy to identify all costs involved in providing the routine and preventive maintenance of each agency's highway and bridge system. Routine and preventive maintenance may be defined as "A program to keep pavements, structures, drainage, safety facilities, and traffic control devices in good condition by repairing defects as they occur and taking measures to mitigate further deterioration," and does not include activities designed to expand existing features (i.e. new lanes, additional bridges, etc.) or to rebuild existing failed major components due to age, neglect, accidents or natural disasters. Cost elements to be considered should include, but not be limited to:

- *Salaries* – All costs used to compensate agency employees for performing routine maintenance work on the agency highway and bridge system and appurtenances thereto.
- *Matching Agency Contributions* – All costs paid by the agency as matching contributions and/or perquisites. These shall include social security, employee and/or family insurance, union dues, 401K savings programs, etc.
- *Mobile Equipment* – All costs for the purchase, rental, operation, insurance, fueling, servicing, storing, garaging, etc. of mobile equipment used for performing routine maintenance activities.
- *Materials* – All costs for materials and supplies, including warehousing, storage, inventorying and issuing materials being used or in support of agency routine maintenance operations.

- *Incidental Related Costs* – All direct or indirect costs for those activities done in support of agency routine maintenance functions. These items would usually come from other agency budget offices, but are used to directly support routine maintenance operations. These may include direct or indirect costs for agency offices such as management, clerical, personnel, fiscal, legal, training, warehousing equipment, etc.
- *Contributions by Others* – All costs for support and/or donations received from agencies outside of the agency doing the routine maintenance work. Some of these could be from prison inmates, handicapped groups and etc. that may be performing routine maintenance work on the agency highway and bridge system, and are not budgeted for by the agency.

The objectives of this research are to determine the actual costs of routine and preventive maintenance operations with regard to each of the cited costs and to develop cost guidance for decision makers in determining whether to outsource maintenance operations or maintain in-house maintenance operations.

This research effort would involve obtaining the annual budgets and cost records of at least 15 state highway agencies that are responsible for the routine and preventive maintenance of the state highway system, and conducting a comprehensive cost analysis of each. It will also involve the development of a "Cost Analysis Manual" or framework for decision makers to determine the true cost involved in their state. The specific tasks of the research include the following:

1. Obtain the annual budgets and cost records of at least 15 state highway agencies and compile the actual costs of routine and preventive maintenance operations addressing all the cost elements cited above.
2. Interview each of these agencies and determine how their routine highway and bridge maintenance work is being conducted and if specific funds/services are being performed and/or contributed by others outside the agency.
3. Prepare a matrix of how much routine and preventive maintenance work is being done within the agency budget, versus what percentage is being done by other agencies.
4. Based on the investigation of the operating practices of all the agencies studied, prepare guidance for decision makers and an instructional "Cost Analysis Manual." This manual should identify a recommended method for use by any agency responsible for routine and preventive highway maintenance in calculating its true cost for performing routine and preventive maintenance services.

♦ Project 14-19
Culvert Rehabilitation to Maximize Service Life While Minimizing Direct Costs and Traffic Disruption

Research Field:	Maintenance
Source:	Virginia
Allocation:	$750,000
NCHRP Staff:	David A. Reynaud

Highway infrastructure across North America is characterized by a huge inventory of damaged and decaying culverts. The cost of culvert replacement is high, and disruption to highway traffic makes conventional trench excavation and use of "new culvert" design and construction methods undesirable. Furthermore, in many cases the existing structure and the soil around it are maintaining the waterway and provide access whereby other more efficient repair options can be considered. Culvert repair without trench excavation also avoids problems experienced by pavements reconstructed over consolidating trench backfill. Research is needed to investigate techniques of local and continuous culvert repair, and to develop design procedures and specifications for cost effective rehabilitation techniques that extend service life while avoiding disruption to traffic.

Many pipe relining techniques have been developed to restore the hydraulic and/or structural integrity of gravity flow culvert structures, and the use of these methods has increased significantly in recent years. Either the liner is cast in place, or a pre-formed liner is pulled into place through the culvert and grout is pumped behind the preformed liner. Methods have also been developed to undertake local repairs using patches. Entrepreneurs in

the construction industry are now developing techniques to restore the integrity of the backfill behind the culvert, repairing voids caused by soil erosion.

While use of this technology is increasing, the development of rational design methods and specifications for these repairs has not kept pace. Repair methodologies are largely driven by specialist contractors, and engineers representing infrastructure owners (structural and geotechnical consultants) generally have limited experience with these systems. Others have questions regarding the extent to which earth loads and vehicle loads reach the patch or continuous liner. Questions also remain regarding the effect of ground loss behind repaired culverts, and circumstances requiring repair of soil voids rather than focusing repair efforts on the culvert structure alone. Field monitoring of typical projects is needed to examine the performance of existing and proposed design procedures for these repair systems.

Research in the United States, Canada, and the United Kingdom has established the mechanism of buckling instability for liners responding to external groundwater pressure. First, semi-empirical calculations of buckling strength were developed in the UK for cast-in-place liner systems. Researchers at the Trenchless Technology Center at Louisiana Tech and at Tulane University measured the buckling strength of different liner systems and established that buckling pressures vary substantially. Researchers at Queen's University in Canada used finite element analysis to modify the nonlinear buckling solution of Glock so it accounts for the geometry of the liner and the old culvert. Design methods developed at Queen's and in Germany account for the liner material, the culvert geometry, and geometrical imperfections that are characteristic of the liner installation procedure.

These Canadian and German investigators have also examined the effect of earth loads on liners. The interaction of the liner, the damaged culvert, and the surrounding soil has been examined and finite element analyses have been used to determine how elastic soil-pipe interaction solutions can be used to estimate deformations. Local strains on the inner and outer surfaces of the liner at crown and invert have been identified as a performance limit that controls the maximum liner thickness. Work is needed, however, to establish how vehicle live loads reach liners placed within shallow culvert structures.

Recent studies at Cambridge University in the United Kingdom and at Queen's University in Canada have examined how erosion voids in the soil surrounding the culvert influence the deformations that occur under vehicle live loads or increases in earth loads. While there are no known research studies focusing on patches used to repair culvert damage, findings from the studies of continuous liner systems can be extended to understand the implications of patch size and stiffness, and design choices influencing these elements. Research is also needed on (a) the influence of soil voids in the backfill surrounding the culvert when they need to be filled and (b)the quantity of the loads that reach patches and continuous liners as a result of earth and live (vehicle) loads. This research will help us understand the interaction of the original culvert and the liner or patch, in addition to the influence of the geometry and extent of the culvert damage on the performance of the liner. Both of these things will be helpful to review case studies involving successful and unsuccessful use of these technologies, to establish the circumstances where erosion voids in the backfill soil need to be repaired, to develop design guidelines for cast-in-place liners and slip-liners as well as patches used to restore structural integrity, and to synthesize existing research on both the effects of open-cut technologies on the surrounding environment and the total costs of trenchless versus open-cut rehabilitation.

The need for infrastructure renewal is growing steadily, and road authorities urgently need guidance on methods to select, design, and undertake repairs to culvert structures. Potential savings in direct and indirect costs from avoiding the use of "cut and cover" replacement are huge, as is the potential for gaining greater efficiency from the existing highway networks.

The development of standards and specifications will have enormous impact on the industry, filling key gaps where current practice lacks clear guidance. Once such documents are available, implementation of the research findings is expected to be rapid and effective.

Results will be drafted in the form of recommended design specifications for consideration by either AASHTO or ASTM design and materials standards, and recommended construction specifica-

tions and codes of practice. FHWA, AASHTO, NHTSA, local Department of Public Works, utilities (gas, water, sewer, electric, telephone), contractors and consulting engineers will all benefit.

♦ Project 17-41
Human Factors Guidelines for Road Systems—Phase III

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$400,000
NCHRP Staff:	Charles W. Niessner

The TRB Joint Subcommittee Meeting on "International Human Factors Guideline for Road Systems," AND10(2), was created to help plan the development of a human factors guideline for road systems that highway designers and traffic engineers could readily use in their work. NCHRP Project 17-18(8), "Comprehensive Human Factors Guidelines for Road Systems," was initiated in 2001 with a contract with Westat. This study provided the framework for the guideline and two chapters. The project was completed on January 31, 2005.

NCHRP Project 17-31 was awarded to Battelle on August 1, 2005, to develop three more chapters and integrate them with the work completed by Westat. Battelle has developed a style guide for the guideline, refined Chapters 1, 3 and 5 from NCHRP Project 17-8(8), and prepared an annotated outline for three new chapters, signalized intersections, unsignalized intersections, and work zones. A workshop is planned for January 20, 2007, so highway designers and traffic engineers can apply the draft-6 chapter guideline to example problems and provide user comments to Battelle and NCHRP Panel 17-31. Completion of Project 17-31 is planned for April 30, 2007.

The Human Factors Guide (HFG) is intended to be a resource document for highway designers, traffic engineers, and other practitioners. The purpose of the HFG is to provide the best factual information and insight on road users' characteristics, in a useful format, to facilitate safe roadway design and operational decisions. The impetus behind this effort was the recognition that current design references have limitations in providing the practitioner with adequate guidance for incorporating road user needs and capabilities when dealing with design and operational issues.

The work of this Joint Subcommittee is being coordinated with the development of the highway safety manual being overseen by the TRB Task Force to Develop a Highway Safety Manual (HSM). The first edition of the HSM is expected to be produced after the completion of NCHRP Project 17-36 in June 2008. While the HSM includes one section of a chapter on human factors, it will provide only a broad scope and not include any guidelines.

The objective of this project is to develop three additional draft chapters of the human factors guideline and prepare the first ten chapters for publication (2 from NCHRP Project 17-8(8), 2 from the Joint Subcommittee, 3 from NCHRP Project 17-31, and 3 from this project). A full media version of all ten chapters that will be suitable for a CD or uploading on a website will also be developed. The chapters to be developed will be in accordance with the plan recommended by the NCHRP 17-8(8) and 17-31 studies.

♦ Project 17-42
Development of Information and Data to Support Improved Safety Management and Communication of Safety Needs

Research Field:	Traffic
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$350,000
NCHRP Staff:	Charles W. Niessner

The AASHTO Standing Committee on Highway Traffic Safety during their 2006 meeting endorsed formation of the Subcommittee on Safety Management. The Subcommittee formed six task forces, each focused on specific highway safety issues: Technical Information and Resources; At Risk Roadway Users; Strategic Highway Safety Plan; Safety Data Systems and Analysis; Safety Information Packages; and Research. At the task force meeting specific goals were identified and action steps created to achieve those goals.

The research proposed in this problem statement will develop the information and data needed to facilitate reaching their stated goals.

Research objectives for each of the six task groups are discussed separately:

Group 1. Technical Information and Resources

- Perform an initial scoping study to develop a process for summarizing safety best practices as evaluation results from state pooled fund/FHWA/NCHRP projects become available. Develop a dissemination technique through enhancements to the AASHTO website, www.transportationsafety.org. A specific objective of this study will be to ensure a very user-friendly format that can be used by all stakeholders in implementing the strategic highway safety plans (SHSPs).
- Develop a marketing plan to assist in the dissemination of SHSP implementation efforts to all stakeholders.
- Develop a template for states to add to their SHSPs for specific safety areas. The template should contain suggested marketing strategies to be implemented in the states to reach all stakeholders, i.e., local governments, law enforcement, safety education, and EMS providers.
  (This would be analagous to the effort made in the "Tools for Life" marketing of AASHTO's SHSP and the implementation guidebooks, but should be more extensive and focus on all stakeholders.)

Group 2. At Risk Roadway Users

- Conduct a survey of states on Safe Routes to School implementation and initial results and promising best practices. From the survey identify additional data needs of the states and local agencies and research gaps. Also from the survey identify current laws that would be models for states to use and legal/policy issues arising from implementation of safe routes to school programs.
- Conduct a multi-part survey of states regarding pedestrian, bicycle, and motorcycle issues. This survey will encompass each state-identifying problems and successes regarding demographic groups, data, laws, rules, penalties, adjudication processes, and research. From the survey, identify specific states where additional information through a second survey could be garnered to further identify best practices and laws/policies that would be models for other states to use. Compile a list and description of the best practices and laws/policies for state and local use. Disseminate through the enhanced AASHTO website (see Task Group 1 research idea).

Group 3. Strategic Highway Safety Plan

- Review the 22 objectives of the AASHTO Strategic Highway Safety Plan using current crash data. Update the objectives and their strategies as needed.
- Conduct a survey of states on status (successes and impediments) of SHSP implementation.

Group 4. Safety Data Systems and Analysis

- Explore state and local crash data system needs and gaps to identify tools that would enhance existing systems and processes. Survey the states to identify safety data improvements for state and local agencies.
- Explore the need and techniques to provide a single source for safety countermeasure evaluation results.

Group 5. Safety Information Packages

- Develop a template for leadership safety information that can be customized by each state for use with their leadership (agency, legislative, local).
- Complement and enhance the above template plan and outline a primer on highway safety for state executive level management in state agencies.
- Plan and outline a toolbox on current safety issues, high interest areas and emerging trends. This would be for use by state, district, MPO and local agencies.

Group 6. Research

- Identify research gaps through review of safety literature, specifically products of NCHRP Projects 17-18(3) and 17-27.
- Develop methods to systematically disseminate and market immediately useable research results. This would cover the broader safety research arena, not just evaluation studies, and would complement (not duplicate) the evaluation summaries from Task Group 1.

This project provides research support essential to successful implementation of State Strategic Highway Safety Plans and, ultimately, achieving national goals for reductions in fatalities and serious injuries.

♦ Project 17-43
Long-Term Roadside Crash Data Collection Program

Research Field:	Traffic
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$1,000,000
NCHRP Staff:	Charles W. Niessner

Roadside crashes account for 35 percent of the fatalities on the nation's highways. Safety professionals have strived to address this problem and have had some success. Continued improvement in roadside safety will depend on improved understanding of the conditions that lead to injuries and fatalities during ran-off-road crashes. There is a fundamental need to collect better and more detailed information about crashes into roadside objects and the conditions under which they occurred.

Data related to roadside crashes are primarily obtained from police accident reports, but these reports lack the details needed for analyses of ran-off-road crashes, such angle of impact, impact speed, vehicle damage, type of object struck, roadway geometry, roadside features, driver behavior, and occupant injuries. Where fatalities occur, additional data are gathered to make an entry into the Fatal Accident Reporting System (FARS), but this reporting also falls short in level of detail needed. The Highway Safety Information System (HSIS) developed by the FHWA provides additional data for roadside crashes by linking crash, roadway inventory, and traffic data. This system only includes data from eight states and it is limited to the data that is gathered by the individual states, thus making comparison of data across several states difficult. In-service evaluations and research studies provide some additional data about roadside crashes, but the number of cases is very small.

The National Automotive Sampling System (NASS) Crashworthiness Data Subsystem (CDS) collects detailed information on vehicles and occupants for a strategically selected sample of crashes across the country. This data collection system was designed to provide information regarding vehicle safety performance during real-world crashes and it has proven to be very valuable for developing vehicle countermeasures to reduce the risk of injury and fatality in multi-vehicle crashes. However, the NASS CDS program collects very little data on the roadway, roadside, and safety features at the site of ran-off-road crashes. Some recent research studies have supplemented the NASS data for selected roadside crashes to gather more of the needed data, but the sample sizes have been small, which consequently limits the potential for analyses.

One recent study is NCHRP Project 17-22, the objective of which is "to identify distributions of impact conditions, including speed, angle, and vehicle orientation, of serious injury and fatal ran-off-road crashes." The study gathered supplemental roadway and roadside data on 388 NASS CDS cases from years 2000 and 2001 and the crashes were reconstructed to estimate the impact conditions. While the study is still ongoing, preliminary results provided critical information on impact conditions that helped in the formulation of the test conditions in the update of *NCHRP Report 350* crash testing guidelines. The data has also provided further insight into encroachment conditions and appropriate guardrail runout lengths. Based in large part on the additional support provided by the 17-22 data, AASHTO's Technical Committee on Roadside Safety is expected to soon adopt new guardrail length guidelines that will reduce the total costs of ran-off-road crashes and guardrail construction costs.

Project 17-22 has also begun to identify the nature of longitudinal barrier crashes that lead to serious injury and fatality. Although still based upon anecdotal data, findings indicate that most fatal barrier crashes involve either vehicle rollover or high-angle redirections that lead to secondary crashes. If sufficient data become available, the identification of impact conditions that lead to this undesirable barrier performance will be possible and developers will be able to design new barriers that can significantly reduce the annual toll of approximately 1500 fatal crashes where striking a longitudinal barrier is the first harmful event. Similar studies can be undertaken for other types of roadside safety hardware and geometric features.

Project 17-22 has also undertaken efforts to incorporate the data gathered in NCHRP Project 17-11 and the FHWA rollover study to increase the size of the database. It may be possible to incorporate other datasets, particularly those from new research efforts. Over time, the database will grow to several thousand crash cases that will reflect the changing fleet, road design, roadside hardware features, and traffic conditions. These data will permit identification of potential incompatibilities between vehicles and hardware that may warrant discouraging the use of some types of hardware, the need to design modifications, changes to the crashworthiness criteria, and so on. While the database from NCHRP Project 17-22 will be helpful in answering some questions, many other questions and issues remain to be addressed. For example, the data could be used to establish some of the following distributions and relationships:

- Identify the safety performance of all common roadside safety features to provide highway designers with more objective criteria for safety hardware selection.
- Develop a link between occupant compartment deformation and occupant risk in ran-off-road crashes.
- Quantify the occupant risk associated with partial rollovers by vehicle class.
- Establish a link between impact conditions and probability of injury for common safety features and roadside hazards.
- Identify distribution of vehicle trajectories and the effects of roadside slopes on vehicle trajectories.
- Identify the relationship between impact angle and crash severity for longitudinal barriers.
- Identify the effects of curbs, ditches, and other terrain irregularities placed in front of safety hardware on the probability of injury during a crash.
- Identify distributions of impact conditions, including speed, angle, and vehicle orientation, as a function of highway type or functional class.

Identifying the impact conditions associated with injury and fatality for roadside features will provide hardware developers with critical information necessary for designing safer appurtenances. Further, when armed with the knowledge of the safety performance of common roadside features, highway designers will be able to select hardware systems that provide optimum safety for any given roadside situation. Many of the relationships described above would provide inputs to the development of future crash testing guidelines and to the improvement of the cost-effectiveness analysis codes, such as the Roadside Safety Analysis Program (RSAP). The improved cost-effectiveness codes would then be used to provide better assessment of issues such as guardrail runout length, flare rate, hardware performance-level selection guidelines, etc.

This list of questions and issues is by no means exhaustive, but it serves to illustrate the many unanswered questions that can be addressed with in-depth crash data. The database created from the current study may provide hints to the answers for some of these questions, but the sample size and the level of detail would limit its applications. A need remains for a long-term effort to collect in-depth data on single-vehicle, ran-off-road crashes in a continuous and systematic manner.

A plan for a long-term crash data collection program was also developed under NCHRP Project 17-22. The recommended approach for the long-term data collection effort is a prospective study (i.e., the cases will be sampled from new crashes) under the NASS CDS program. A subset of the cases already selected for inclusion in the NASS CDS program would be subjected to a more detailed investigation. By incorporating the data collection system in the existing NASS program, the costs of obtaining the required information is greatly reduced.

Recognizing the need for such a program, the Project 17-22 panel directed the researchers to develop an implementation plan for a long-term data collection effort. The implementation plan for the long-term crash data collection program has sufficient detail such that the data collection effort could proceed without additional work once funding is approved and becomes available. In other words, the implementation plan includes data collection protocols that have been reviewed and approved by the NCHRP 17-22 panel and the staff of the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA).

The objective of this research project is to (1) continue the long-term crash data collection program via the NASS CDS to gather detailed data on roadside crashes for 3 additional years; (2) implement a scheme for merging this crash data with other legacy databases; and (3) continue demonstrating the nature of monitoring and analyses that would be possible with a detailed sample of roadside crashes. It is not intended that NCHRP will support this data compilation effort over the long term, but rather will provide solid evidence about the value of having a long-term, detailed roadside crash database. It will also aid efforts to translate sample statistics to populations and to enhance the usefulness of the data via links to other data. The ultimate goal is to institute a long-term data collection program through NASS or another U.S.DOT agency that can provide an in-depth, continually growing data resource applicable to solving roadside safety problems.

Note: The AASHTO Standing Committee on Research added Problem No. 2008-C-07, Improved Procedures for Determining Longitudinal Barrier Length of Need, to this study and increased the funding request from $750,000 to $1,000,000.

♦ **Project 20-68 (Continuation)**
Continuation and Increase of Funding for NCHRP Project 20-68, U.S. Domestic Scan Program

Research Field:	Special Projects
Source:	AASHTO Highway Subcommittee on Maintenance
Allocation:	$500,000
NCHRP Staff:	Andrew C. Lemer

The exchange of information among state DOTs is mutually beneficial to their respective programs, but currently occurs mainly through informal meetings at conferences or ad-hoc encounters of personnel from individual states, and these encounters only benefit the agencies involved. The Domestic Scan Pilot Program is proving to be an effective and useful means of information and technology sharing among all states through the professional coordination of activities and the documentation and implementation of findings. With current demand for scans greatly exceeding current capacity, and with the potential for benefiting from alternative forms of information exchange, an expanded program would provide tremendous benefit to the DOTs.

The value of efforts to share new and innovative ways of doing business among transportation agencies has been demonstrated by the first two "pilot" domestic scans that were conducted in 2006: one on best practices in right-of-way acquisition and utility relocation to expedite project delivery and the other on best practices in transportation asset management. These scans are now complete. NCHRP staff had anticipated extension of the Domestic Scan Program at a level of effort similar to that envisioned when the pilot program was initiated, i.e., two to four scans to be conducted per year. However, based on the experience and success of the two pilot scans and the tremendous demand from the states to conduct additional domestic scans and share innovative practices with each other (in FY 2007, 48 topics for scans were proposed, adding to the list of 18 topics that were deferred during the topic selection for pilot program), it is proposed that the program be expanded to include additional scans, provide additional flexibility in the program, and ensure that implementation activities are appropriately addressed. An expanded Domestic Scan Program could accommodate three to six formal domestic scans per year, each potentially involving 8 to 12 participants. As in the pilot program, individual scans would take place over a 1- to 2-week period, but could also be modified to fit the situation or need. In addition to the "formal" scans that currently represent the core of the program, "mini-scans" could be conducted, such as regional topic-oriented meetings, demonstrations of new technologies, or time-critical educational visits such as after catastrophic weather events.

Note: The AASHTO Standing Committee on Research agreed that the Domestic Scan Program should be continued, reoriented to emphasize implementation activities, and possibly expanded to include the broader range of tour types envisioned in this statement, but asserted that the scale of spending for the program should not be expanded

beyond the average $500,000 annual expenditure of NCHRP funds anticipated in previous allocations.

♦ **Project 20-74A**
Development of National Level of Service Criteria for the Interstate Highway System

Research Field:	Special Projects
Source:	AASHTO Highway Subcommittee on Maintenance
Allocation:	$400,000
NCHRP Staff:	Andrew C. Lemer

Booming trade from the North American Free Trade Agreement (NAFTA) and other factors are driving large percentage increases in traffic of heavy trucks on many of the nation's highways. This traffic growth has accelerated rates of pavement and other roadway deterioration, particularly on the Interstate Highway System. At the same time, demands for on-time delivery of goods, personal mobility, and a safe, reliable, and environmentally responsible highway system have raised the costs and increased public dissatisfaction with deteriorating performance and traffic disruptions associated with highway repair and reconstruction. Competition for limited funds nevertheless makes it difficult for many agencies to ensure adequate funding to maintain their highways in a manner likely to meet these growing demands for service. The development of national service-level criteria for the Interstate Highway System would provide benchmarks that state agencies can use to assess their Interstate maintenance needs, taking into consideration the high costs that an underperforming highway system imposes on the nation.

The objective of this research will be to develop national service-level criteria for pavements and other critical components of the Interstate Highway System, considering factors such as the following examples:

- Safety – visible signs and pavement markings; safe and secure rest area facilities; pavement skid resistance; guardrail condition
- Operations – incident response time; traffic free flow
- Energy – smooth pavements; traffic control systems that allow continuous movement
- System investment preservation – functional drainage features (culverts, inlets, rutted pavement lanes that pond water, ditches, etc.); pavement condition and remaining service life; bridge condition
- Customer Service – travel delays; weather effects

The research would include review of service-level measures now used by state agencies, identification of a short list of key measures that can be recommended for application by all agencies, determination of suggested minimum levels of service that an agency might adopt and the bases for this determination, and development of a generic "report card" that can be used to show the actual level of service with respect to each measure that a state's system is providing. The work could also include development of estimates of national average service levels.

♦ **Project 20-79**
Expansion of the Transportation Research Thesaurus

Research Field:	Special Projects
Source:	District of Columbia
Allocation:	$90,000
NCHRP Staff:	Christopher J. Hedges

In 2001 TRB published *NCHRP Report 450: Transportation Research Thesaurus and User's Guide*. The primary purpose of the Transportation Research Thesaurus (TRT) is to provide a common vocabulary for producers and users of TRB's Transportation Research Information Services (TRIS) database. Indexers can describe documents in a consistent way, and TRIS users can successfully retrieve TRIS records in their areas of interest by searching the thesaurus terms.

In FY2006 NCHRP Project 20-70 funded the development of web access to the TRT on the TRB website as well as improvements to the technology that supports use of the TRT by TRIS indexers. Both tasks were successfully completed and implemented.

Although the technical improvements have been significant, many users would benefit from the addition of new content, specifically term definitions. Thesauri, in the limited sense, do not include definitions, just scope notes to allow the user to distinguish between terms that have more than one definition, for example cranes (birds) and cranes (equipment). Providing more information to those indexing or defining their reports and resources would allow for more consistent use of vocabulary across repositories and thus improve access to like information. Definitions would support the user who is working outside his/her specialization and would allow the user of the TRT on the web to improve his/her search strategy. Anecdotally, members of the TRB Committee on Library and Information Science for Transportation have heard many times that users of the TRT are surprised to find that definitions are not included.

A source of definitions to add to the TRT already exists in AASHTO's draft multi-modal glossary, which was developed under NCHRP Project 20-7/Task 153. The proposed project would leverage that material to improve and enhance the TRT.

The objective of the research is to expand the TRT to include definitions of terms that exist in both the TRT and the AASHTO glossary. The process would involve approval of the terms and definitions by the appropriate AASHTO body. The details of the process would be determined jointly by the project panel and AASHTO. The contractor or contractors would facilitate the work. It is assumed that AASHTO may still want to publish the glossary as a separate document. The general tasks are as follows:

1. Appropriate AASHTO groups review and approve some (or all) of the terms/definitions in the draft AASHTO glossary and submit them to the contractor.
2. Contractor 1 maintains the list of terms and definitions in a format that will facilitate import and identifies which of the terms exist in the TRT. Terms not in the TRT may become candidate terms eligible for addition to the TRT through standard processes.
3. Contractor 2 adds the field or fields necessary to accommodate the definitions to the TRIS production database and to the web TRT.
4. Contractor 1 exports the data in a suitable format to TRB.
5. Contractor 2 adds the definitions to the database.

♦ Project 22-25
Design Layout and Placement Guidance for Cable Barrier Systems

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$400,000
NCHRP Staff:	Charles W. Niessner

In recent years cable barrier systems have gained in popularity and are rapidly being deployed along the roadside and in the medians of our roads and highways. As the use of these products has grown, so has the knowledge about critical placement issues. Experience with these systems has revealed that placement of the system has a significant influence on system performance. As the number of installations escalates around the country, there is a need to collect and share what has been learned about cable barrier placement.

Within the variety of generic and proprietary systems available across the country, there are performance differences and commonalities. Research is needed to identify those commonalities and provide guidance that will optimize performance of these systems. Optimizing system performance is dependant on attention to several placement issues. Maintenance of the cable barrier system and other roadside features may also be impacted by placement choice. Systems are often placed in the field assuming that performance will be consistent with crash test conditions. A better understanding of the link between placement and performance of these systems is needed to ensure that they will meet expectations.

This research is expected to produce a report outlining critical placement guidance for cable barrier systems. Finite element modeling should be considered in evaluating some of the placement variables.

This report will include the following components:

- Address the range of slopes where cable barrier is and is not appropriate.
- Address positioning in proximity to slope changes that may impact system performance.
- Address positioning in proximity to drainage structures, raised curbs, fixed objects, and other barrier systems in proximity to cable systems.
- Address interconnection with other barrier systems (particularly existing beam guardrail, including terminals, bull-nose end treatments, bridge approach guardrail, and cable anchor locations).
- Provide guidance on how placement can reduce repair crew exposure to traffic.
- Identify maintenance activities that may potentially be affected by the presence of cable.
- Provide guidance on preferred treatment at median turnarounds.
- Provide guidance on how to transition from one side of the median to the other, to accommodate placement around fixed objects or on the high side of curves.
- Address placement of cable systems on vertical and horizontal curvatures and its impact on performance issues such as deflection, post spacing, and vehicle under-ride tendencies.
- Explore the differences between high-tension cable barrier systems and low-tension systems. Evaluate standard cable and pre-stretched cable systems. Address cost, performance, and maintenance issues.
- Explore options for post foundations, addressing direct driven posts, sleeved soil plate designs, and concrete sleeves (cast in place and pre-cast). Examine cost of installation, repair times, and performance in different soil or pavement conditions, climates, and placement on slopes and shoulders. (Consider developing a life-cycle model.)
- Explore cable anchor designs and placement and their influence on cost, performance and maintenance. Consider crashworthy *NCHRP Report 350*–compliant designs and non-crashworthy designs with shielding. Identify tradeoffs with protecting the anchors from impact such as reduced potential for long sections of the system being out of service after impact versus likelihood of more severe injury from striking the shielding used to protect the anchor. Address anchor spacing and its influence on installation costs, maintenance, and system performance.
- Identify variables (such as spacing between anchors) that may produce in-service performance characteristics (such as cable deflection) that differ from the crash test results. Evaluate probabilities that field conditions will produce results that differ from crash test results and identify critical installation details.
- Recommend any additional crash test criteria unique to cable barrier systems such as system length, performance on slopes, impact point, maximum height of bottom cable, etc.

The following specific tasks are needed to develop the report:

1. Conduct a literature search for previous studies relating to placement issues. This effort should focus on studies that reveal a link between placement, length of the installation, and the effect on performance.
2. Conduct a survey of state and local agencies, and abroad for unpublished studies, for a list of specific placement issues where system performance has been a concern.
3. Summarize survey and prepare interim report of findings.
4. Identify gaps in knowledge where additional data/testing is needed
5. Develop work plan detailing scope of the study and data requirements.
6. Obtain approval of the work plan from the panel.
7. Undertake the efforts detailed in the work plan. Periodic progress reports to the project panel will be required.
8. Prepare a draft guidelines document, detailing the entire range of typical installations for cable barrier systems in median and roadside applications.
9. Formulate and execute a plan to solicit feedback on the draft guidelines, incorporating review by state agencies and industry representatives.
10. Prepare final report that fully documents the research efforts and includes placement guidelines as an appendix. The final report should document limitations on analysis and

sources of the material presented, and cite needs for future research.

♦ **Project 24-33**
Development of Design Methods for In-stream Flow Control Structures

Research Field: Soils and Geology
Source: AASHTO Technical Committee on Hydrology & Hydraulics, Alaska, Utah
Allocation: $600,000
NCHRP Staff: David A. Reynaud

Natural resource agencies have encouraged many state DOTs to use natural stream stability and restoration measures in lieu of traditional engineering responses to stabilize river and stream beds against erosion and scour. These measures include the construction of shallow, in-stream flow control structures, including those referred to as Rosgen structures, across all or part of a stream channel. These measures have gained wide acceptance with national and state regulatory agencies responsible for protecting natural habitats, because the structures often enhance stream habitat. Structure types include cross vanes, j-hooks, w-weirs, constructed riffles, and stream barbs usually constructed of rock riprap. Proponents of these structures have claimed and evidence sometimes suggests that these structures can be durable and cost effective and provide scour stability, but the necessary case studies have not been documented to verify these claims. Furthermore, comprehensive engineering and quantifiable financial, design, and analytical criteria do not exist for designing, installing, and maintaining these structures.

Optimization of parameters such as life-cycle cost, size, spacing, foundation depth and their influence on scour depth, sediment transport, and long-term structure and channel stability will support the development of authoritative engineering design, installation, and maintenance criteria necessary for hydraulic engineers to design economic in-stream flow control structures with confidence.

The object of this project is to develop authoritative engineering guidelines and/or criteria for in-stream flow control structures that include quantitative engineering criteria and/or specifications for long-term performance in terms of structure stability, cost effectiveness, fisheries habitat sustainability, erosion protection, channel stability, sediment transport, and scour stability under design flow conditions using recommended installation and maintenance practices. The guidelines/criteria should include a list of conditions under which in-stream flow control structures, including Rosgen-type structures, are either successful or not recommended in performing habitat restoration functions and effectively providing protection against erosion and scour.

In-stream flow control structures sometimes require less rock than traditional streambank stabilization practices therefore promising greater economy, especially where material sources are scarce. Natural resource agencies generally believe that these structures pose less environmental impact and may enhance fish habitat. The state of the art in design and installation does not include proven engineering design criteria, which results in frequent instances of failure and associated costs for repair. Validated engineering criteria promise reduced risk of failure and increased cost effectiveness of installations. Implementation potential is high because of the large numbers of structures that have been, and continue to be, designed and installed. All that is necessary is validation, refinement, and optimization of assumptions and engineering protocols to reduce risk.

♦ **Project 25-31**
Hydraulic Modifications to Existing Drainage Infrastructure in Ultra-Urban Areas to Achieve Watershed Total Maximum Daily Loads

Research Field: Transportation Planning
Source: AASHTO Standing Committee on the Environment
Allocation: $475,000
NCHRP Staff: Christopher J. Hedges

The transportation community is faced with a need to mitigate pollutant loadings from existing facilities to achieve watershed Total Maximum Daily Loads (TMDLs) and/or meet the requirements of federal stormwater programs. Mitigation is more

difficult to achieve in urbanized areas where land use around transportation facilities competes for a finite amount of allowable pollutant load. In these so-called "ultra-urban" areas available right-of-way is significantly limited. However, existing transportation infrastructure includes extensive hydraulic facilities that may be suitable for retrofit to provide such water quality benefits. Examples would include catch basin/inlet modifications, detention pond retrofit to embankments and/or outlet works, riser structures added to culvert/embankment systems, and the fostering of pipe storage in storm drains.

Transportation administrators are under pressure to address water quality concerns, some of which are driven by TMDL litigation. Reactive solutions can be expensive and unwarranted even though they can relieve short-term pressure. There are no coordinated programs or guidance to address how the existing infrastructure can be most effectively modified to benefit water quality. This problem is critical as the TMDL process moves forward and agencies are spending money for TMDL implementation but do not have focused direction with respect to exploiting existing infrastructure or meaningful partnering. The mitigation of the adverse water quality of highway runoff is a modern need. Existing infrastructure addresses getting rid of water and minimizing the spread of water in the gutters. This infrastructure offers several possibilities for retrofits to enable water quality mitigation. Focusing on what can be done with what we have can address TMDL implementation in a cost-effective manner.

The literature on retrofitting of storm drainage systems to increase effluent water quality is divided into two broad areas. The first assumes the availability of land or right-of-way sufficient to place new or off-line Best Management Practices (BMPs) for treatment; the second is usually referred to as "ultra-urban," meaning that the right-of-way is limited and that the addition of stormwater quality measures must take place within the existing limited space. The latter condition is to be the focus of this work.

Numerous proprietary devices on the market are aimed at treating stormwater in limited-space conditions and a variety of studies document their stormwater treatment performance. A great preponderance of these studies have been developed and published by the manufacturers of the devices. In 2001 a test facility was developed by the Washington State Department of Transportation that was intended to test the efficiency of several stormwater treatment devices. After the first testing effort the program was scaled back and apparently little additional testing has been done.

Two significant independent retrofit studies include independently collected field performance data. The first, developed by FHWA in 2002, is titled *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring.* This document is still one of the most comprehensive studies of available stormwater treatment technology for limited-space conditions. Its first sections describe a broad palette of stormwater treatment options that can be located in limited right-of-way conditions and its last section presents case studies with monitoring data to document performance of selected BMPs. The second is a study by Taylor and Barrett (2004), "Retrofit of Storm Water Treatment Controls in a Highway Environment," done for Caltrans. This study looked at 12 retrofit practices over 40 different sites. The conclusion of this study suggested the rejection of four of the tested BMPs based on poor performance, complexity, and installation and maintenance costs.

The Texas Department of Transportation is currently evaluating an extended detention device that uses off-the-shelf precast concrete channel sections intended as an online retrofit for limited-space conditions. Preliminary data from this device are very promising and work will continue in 2007 to further document and improve the performance.

While all of these efforts provide information on potentials for retrofit of the existing drainage infrastructure, the focus of the work has been primarily on BMP performance. In addition, although Taylor and Barrett did provide some insight on cost and maintenance, more work is required to provide needed design guidance. For a viable palette of stormwater quality retrofit tools to be achieved, research is needed to assemble the existing data into a single source with guidance on selection and design. In order to accomplish this some additional testing of actual retrofit installations may be required to better document the mean performance that can be expected. This part of the work will be critical if the information is to be used for nego-

tiating and meeting the requirements of specific TMDLs.

The objectives of this research are to verify and quantify the performance of viable stormwater retrofit BMPs that can be used to meet TMDL requirements. The research will build on previously conducted research efforts that have generated well-documented performance data for specific retrofit BMPs in highway environments. Based on a careful assessment of previous work, identification of any gaps in previous research, and any additional testing that may be needed, a guidance document will be prepared which provides selection criteria and ranges of anticipated water quality performance that can be expected for meeting TMDL requirements.

The proposed research will involve careful literature review, collection of existing data sets from published sources and transportation agencies, analysis of available data, and, if needed, the development of a testing and data collection design. If it is determined that a testing phase is needed and the testing and data collection plan are approved, work will continue with collection of the water quality performance data, data analysis, and development of the guidance document for structural retrofits for meeting TMDL requirements. Because of the nature of the work, the project should be completed in two phases. The research would include the following specific tasks:

1. Review the existing literature on devices for stormwater treatment and their performance, with a specific emphasis on in-line structural modifications to existing systems. The research will identify all of the elements of existing hydraulic facilities that may be modified or enhanced to provide water quality benefits. These existing elements may include such things as preserving and/or improving vegetated swales, extended residence times in drainage structures using baffles and other devices, or adding detention to existing drain inlet structures.
2. Review current operation and design practices related to existing stormwater management infrastructure and recommend changes in design and management practices that will result in cost-effective modifications to the existing infrastructure that will meet TMDL requirements.
3. Based on the literature and contacts with transportation agencies, identify and evaluate existing stormwater system retrofits. Collect and evaluate any existing monitoring data that can be used for documenting performance.
4. Based on the findings of the literature review and the examination of retrofit sites and studies, develop a list of retrofit prototypes and a plan for deployment and monitoring.
5. Upon approval of the selected prototypes, deployment and monitoring plan, proceed with the install of prototypes for evaluation.
6. Collect and analyze data, prepare technical memo report of performance findings.
7. Generate implementation guidance for the retrofit of hydraulic facilities, including recommendations for partners for cost sharing, design performance ranges, and maintenance cycles to maintain performance.
8. Prepare a final report.