National Cooperative Highway Research Program

Fiscal Year 2009 April 2008

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 2009 is expected to include 21 continuations, 31 new projects, 2 projects contingent on joint funding from other TRB-managed cooperative research programs, and 9 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 2008.

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.

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IMPORTANT NOTICE

Potential proposers should understand clearly that the research program described herein is tentative. The final program will depend on the level of funding available from the Federal-aid apportionments for FY 2009. 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 2008; proposals will be due in October and November 2008, and agency selections will be made in November and December 2008. 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 2009 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 01-47
Sensitivity Analysis of MEPDG

Research Field: Design
Source: AASHTO Joint Technical Committee on Pavements
Allocation: $250,000
NCHRP Staff: Amir N. Hanna

With the completion of the Mechanistic-Empirical Pavement Design Guide (MEPDG) that was developed under NCHRP Project 1-37A, and its planned adoption as an AASHTO document, there is a great need to determine the sensitivity of the analysis outcomes to the numerous input variables.

To date, several studies have investigated the input variables to assess their impact on results (e.g., rutting due to changing binder type) or to ensure that the outcome makes sense. However, a comprehensive analysis of each variable and its interaction with other inputs remains to be fully investigated. The MEDPG is capable of analyzing both hot mix asphalt and portland cement concrete pavements, and each of these pavement types has hundreds of input variables. Because it can not be expected that a state department of transportation (DOT) will dedicate staff time and resources for investigating each and every input variable, it is essential to determine which of these variables have a significant impact on the analysis outcome so that agencies can allocate the staff and resources needed to accurately estimate the most important input variables. Thus, developing a list of the most critical input variables is desperately needed to facilitate and expedite the nationwide (and worldwide) implementation of the MEPDG.

The research will analyze the importance of each input variable and its interaction with other input variables (including but not limited to climatic variables) on the MEPDG outcomes. It will also develop a list of critical input variables on which state DOTs should concentrate staff time and resources to ease the implementation of the MEPDG.

With the adoption of the MEPDG Manual of Practice and the planned issuance of an AASHTO-Ware version in 2009-2010, understanding the impacts and relationships of the hundreds of input variables contained in the MEPDG is essential for successful implementation by state DOTs. This understanding not only will help speed the implementation process but it will also allow focusing efforts and resources on collecting and analyzing the more important input variables (i.e., those that greatly impact the analysis outputs).

♦ Project 03-94
Development of an AASHTO Guide for Systems Operations and Management

Research Field: Traffic
Source: AASHTO Highway Subcommittee on Systems Operations and Management
Allocation: $450,000
NCHRP Staff: B. Ray Derr

Systems operations and management is becoming recognized as a discipline focused on maximizing the efficiency and safety of the transportation network. It requires attention from and coordination of many functions in a state's department of transportation (DOT), including traffic engineering, maintenance, ITS, safety, planning, design, operations, construction, and sustainability. The AASHTO Highway Subcommittee on Systems Operations and Management has defined systems operations and management as "an integrated program designed to make the best use of existing highway infrastructure through provision of systems and services that preserve and improve performance." Some activities that are typically included within this definition are routine traffic operations, planned and unplanned event management (e.g., traffic incidents, special events, weather-related incidents, natural disasters, terrorism), network and facility management, construction and maintenance work zone operations, regulatory and enforcement streamlining, multimodal traveler and freight information, and cooperation and coordination with other modes and jurisdictions.

Transportation professionals today are responsible for the construction, operation, management, and maintenance of a transportation system that is safe and reliable for customers. Improved

operation of the highway network is the most effective approach to confronting the transportation challenges of the 21st century. Technology improvements, such as intelligent transportation systems (ITS), provide us with new and better tools to make the most of the available roads and their capacity. Achieving an image for a 21st century transportation system involves applying practical and hands-on management techniques in a variety of application areas, and changing our institutional arrangements to better serve the users of the system.

NCHRP Project 20-7/Task 238 explored the need for an AASHTO Guide to Systems Operation and Management. Twenty-four representatives of state DOTs were interviewed and all but two of the interviewees responded that they would use an AASHTO Guide for Systems Operations and Management. General comments were that the guide would be used as a reference to establish best practices and performance measures. Also mentioned was that the guide would be helpful in developing standard procedures and practices in implementing management and operations strategies nationwide. A draft table of contents for the proposed guide was developed in the course of the work.

The objective of this project is to develop a practical guide that assists state and large local transportation agencies to provide a better level of service through improved systems operations and management. The ultimate goal of this guide is to encourage and promote the safe and efficient management and operations of integrated, intermodal surface transportation systems to serve the mobility needs of people and support economic growth and development.

The following tasks are anticipated to accomplish this objective:

1. Review existing information, including but not limited to the following: (AASHTO Guides, National Transportation Operations Coalition (NTOC) activities, Emergency Transportation Operations (ETO) reports, Activities of the TRB Committees on Freeway Operations and Regional Transportation Systems Management and Operations, ITE's Guidelines for the Management and Operations of ITS, Existing state DOT operations manuals, Summary of interviews of state DOT operations managers performed at the July 2007 meeting of the AASHTO Highways Subcommittee on System Operation and Management in Madison, Wisconsin)
2. Formulate an annotated outline from the draft table of contents developed in NCHRP Project 20-7/Task 238. Submit for review to the NCHRP project panel.
3. Develop recommendations on the purpose, objectives, target users, and target usage for the SO&M Guide. These recommendations should address multimodal analysis needs.
4. Submit an interim report, within 4 months, presenting the results of Tasks 1 through 3. NCHRP review and approval of the interim report will be required before proceeding with work on the remaining tasks. The contractor should anticipate meeting with the NCHRP project panel to discuss the interim report.
5. Research and develop case studies, best practices, and performance measures for the implementation of systems operations and management in state and large local DOTs.
6. Prepare draft SO&M guide chapters based on the annotated outline and present them to the NCHRP project panel. The chapters should be submitted in the format of the most current version of the Microsoft Office Suite that is in widespread use in the user community. Revise the draft chapters based on comments from the NCHRP project panel.
7. Explore alternative methods of delivering, maintaining, and updating the SO&M Guide that address the needs of users and those of the AASHTO Highways Subcommittee on System Operation and Management (SSOM). In any case, an executive summary should be provided as a paper copy.
8. Submit the final draft SO&M guide with text and graphics. Present the final draft SO&M guide to the NCHRP project panel for approval. If necessary, revise the final draft SO&M guide based on the panel's comments and resubmit it. The guide should be submitted as a stand-alone document. It should be clear and concise for use by practitioners and students.
9. Submit a brief final report that documents the entire research effort.
10. Assist AASHTO staff during the editing and production of the SO&M guide.

♦ **Project 03-95**

Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections

Research Field:	Traffic
Source:	Federal Highway Administration, AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$300,000
NCHRP Staff:	David A. Reynaud

Red-light running is one of the most common causes of intersection crashes. Research shows that yellow interval duration is a significant factor affecting the frequency of red-light running, and increasing yellow time to meet the needs of traffic can dramatically reduce red-light running. However, it is not known if the reductions in red-light running translate into reductions in crashes and injuries. Longer yellow times may increase the zone in which drivers have the option of safely stopping or going and thus increase the potential for conflicts and risk of rear-end crashes. Furthermore, there is no consensus on how the yellow and all-intervals should be timed. The assumed reaction time and deceleration rates for timing yellow lights are based on limited research of car drivers that is a quarter century old. The effects of heavy vehicles are ignored although trucks require longer distances to stop especially at higher speeds.

Given the aging of the population, research is needed to determine normal reaction times and deceleration rates for use in timing yellow change intervals. This should be done for intersection approaches covering a range of speeds, grades, vehicle types, surface condition (wet/dry), and turning movements. The end product would be improved guidelines for timing change intervals.

Most studies on driver behavior during yellow change intervals were conducted more than 25 years ago and the observations were limited to a few hours at a few sites. The research indicates that if the deceleration required to stop is less than 8 ft/sec^2 most drivers will stop and if it is more than 12 ft/sec^2 most drivers will continue through the intersection. None of the research appears to investigate behavior or needs of truck drivers or assess whether these values apply for all approach speeds. Most studies on the effects of all-red intervals report accident reductions; however, these studies were limited to a 1-year-after period. Long-term evaluations in Indiana and Minnesota found accidents increase after the first year resulting in no net reduction.

Bonneson and Son (2003) and Zador et al. (1985) found that longer yellow interval durations consistent with the ITE Proposed Recommended Practice(1985) using 85th percentile approach speeds are associated with fewer red-light violations, all other factors being equal. Bonneson and Zimmerman (2004) found that increasing yellow time in accordance with the ITE guideline or longer reduced red light violations more than 50 percent. Van Der Host found that red light violations were reduced by 50 percent 1 year after yellow intervals were increased by 1 second. Retting et al. (2007) found increasing yellow time in accordance with the guideline reduced red-light violations on average 36 percent with higher reductions.

This project will develop guidelines for timing yellow and all-red intervals to meet the needs of traffic and assess the long-term effectiveness of increasing yellow time on red-light running and crash risk.

Observational field studies should be carried out to determine reaction times during onset of the yellow light and develop updated functions for probability of cars stopping versus deceleration required to stop and new functions for trucks. Before-and-after crash studies should be done at intersection where yellow times have been altered. The research task should address questions such as: Do reductions in red-light running associated with increased yellow time translate in to crash reductions? Should yellow timing be based on prevailing speed or posted speed. If prevailing speed is used, should it be 85th percentile, 95th percentile, or some other measure? Does acceptable level of deceleration vary with approach speed and vehicle type? What reaction time is normal? Does reaction time differ by area type or driver age? Should there be an upper limit on length of the yellow? What amount of side street start-up delay if any should be subtracted from the clearance time to determine the amount of all-red? What is a fair and reasonable tolerance for RLC violations?

There are approximately 1,000 fatalities and 90,000 injuries each year attributed to red-light running. Deficient yellow times entrap drivers into running red lights or stopping abruptly and risk being

rear-ended. Red light cameras are being implemented with little or no grace period. Such practice fails to recognize that current practice for timing yellow lights reflect an average driver and unfairly penalizes a large number of motorists behaving reasonably. Over time, this practice could lead to a backlash against red-light cameras and prohibition of a potentially useful tool in improving highway safety.

Data collected at several red-light camera (RLC) sites in northern Virginia where the yellow was increased has yielded impressive results and suggests that increasing the yellow interval can be more effective in reducing red-light running than RLCs. The dramatic reductions in red-light running from increasing the yellow have been sustained up to 3 years after the yellow was increased, and there is no evidence that motorists take advantage of the increased yellow over time. Further, it is very simple and inexpensive to implement. This needs to be evaluated on a wider scale and the results widely disseminated.

The final report should include recommended changes to the *Manual on Uniform Traffic Control Devices* and a recommended practice for consideration by the Institute of Transportation Engineers.

♦ Project 03-96
Analysis of Oversaturated Traffic Flow Conditions and Managed Lanes on Freeway Facilities

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

The HCM2000 contains procedures for the analysis of both oversaturated and under-saturated conditions on freeway facilities. This is the first edition of the HCM to analyze oversaturated freeway segments over multiple time intervals. Although this was a significant improvement over previous manuals, there are some major areas and gaps that need to be addressed in the current procedures.

The speed-flow curves that were developed for basic freeway sections were based on field data collected in the 1990s. While a significant amount of data representing oversaturated flow was collected, definition of a relationship in this regime was not possible due to the high variability in the data. Therefore, the speed-flow curves in the HCM2000 only include the under-saturated flow regime.

This was a significant issue during the development of the freeway facilities procedures. To address the issue, a simple linear flow-density relationship was assumed to model the associated speed-flow relationship representing the oversaturated regime. This assumed relationship has not been extensively validated with field data. Initial results were promising (Hall et al., TRR 1710, 2000), but far from comprehensive. A better understanding of the speed-flow-density relationship in the oversaturated regime will result in greater accuracy in estimating freeway operations under congested flow, in particular, how far back will queues extend upstream of bottlenecks or incidents. Since many freeways in metropolitan areas now operate in this oversaturated regime for part of the day, a better understanding of these operations is critical for accurate analysis.

In addition to better definition of the oversaturated speed-flow-density relationship, additional research is needed on the apparent loss of capacity once oversaturated conditions occur. Previous research has shown that the queue discharge rate appears to be 5 to 10 percent less than the capacity that can be achieved in under-saturated flow. The HCM2000 does not take this reduction into account. The loss of only 5 percent of the capacity at a bottleneck can have a large impact on queue formation and dissipation, and facility throughput.

Also, the HCM2000 procedure is currently limited to a single bottleneck or multiple, non-interacting bottlenecks. A better understanding of traffic flow within multiple, interacting bottlenecks is needed so that the HCM2000 model can be modified to provide a more realistic estimate of oversaturated flow. Multiple, interacting bottlenecks are common, so incorporation of these into the existing model would greatly increase the usefulness of the HCM2000 procedures.

In addition to the need to address oversaturated conditions, the interface of the freeway facility operation with the surface street should be improved. Most notably, the current HCM procedure does not account for the effect of capacity restrictions at off-ramps, which may cause queuing and back-ups onto the freeway mainline (e.g. due to a

downstream signal). Furthermore, queues that may occur at the on-ramps are modeled "vertically," and therefore do not realistically model the effect of such queues on surface street operations.

Another significant need for the freeway facilities analysis procedure is the ability to analyze managed lanes (i.e., non-general purpose lanes). For the purposes of this project, managed lanes may include high occupancy vehicle (HOV) lanes, high-occupancy toll (HOT) lanes, and lanes which are restricted to a specific class of vehicle (passenger cars, buses, commercial vehicles, etc.). These lanes are becoming much more prevalent in freeway environments, particularly in urban settings.

With simplifying assumptions, the HCM2000 can be used to analyze independent managed lanes. However, most managed lanes have frequent or constant interactions with general purpose lanes. The HCM2000 does not include any tools for understanding the impacts of managed lanes on the overall segment or facility. Since the inclusion of managed lanes on a freeway facility can significantly alter weaving patterns and even affect the per-lane capacity of the general purpose lanes, HCM2000 tools are a high priority. A better understanding of the impacts of these types of lanes on overall freeway operations is greatly needed. Including such a capability in the freeway facilities analysis procedure would greatly enhance its usefulness to engineers, designers, planners, and decision makers.

It is envisioned that the results from this project will make significant contributions to the capabilities of the HCM, as well as provide additional tools for the forthcoming "toolbox" that is being developed by FHWA in support of their congestion initiative on Localized Bottleneck Reduction (LBR).

The research objectives are to 1) improve and enhance the HCM2000 methodology for the operational analysis of freeway facilities in oversaturated conditions and 2) develop methods to allow for the analysis of freeway facilities that include managed lanes.

The following potential tasks should be considered:

<u>Analysis of Oversaturated Conditions</u>

1. Catalogue the current deficiencies and gaps in the current freeway facility methodology in modeling oversaturated conditions. Identify the level of effort needed to improve the computational procedures, and data needs for procedure calibration. Prioritize improvements.
2. Identify existing data sources that could be used for model calibration and validation in the oversaturated regime (e.g., NGSIM, NCHRP 3-45). If appropriate data are unavailable, develop a field data collection plan for characterizing the speed-flow-density relationships in the congested flow regime.
3. Develop an improved procedure for oversaturated freeway facilities for inclusion in a post HCM2010 version manual.
4. Validate the procedure against field data identified in Task 2. Supplement the analysis with simulation results as needed.
5. Provide a computational engine of the revised procedure for use by the Freeway and Multilane Highways Subcommittee of the HCQS.

<u>Managed Lanes</u>

1. Determine the different types of managed lane designs (e.g., barrier-separated, buffer-separated, non-separated, etc.).
2. Identify a limited sample of sites for field data collection and supplement with simulation data.
3. Develop a procedure for assigning managed-lane vehicles to managed and unmanaged lanes at various decision points along a freeway corridor.
4. Quantify the influence of adjacent managed and general purpose lanes upon each other. This influence should focus on the physical points of contact between the two types of lanes, as well as other potential influence areas (e.g., weaving, HOV bypass lanes, impacts to ramp junction operations).
5. Develop a procedure for analyzing the operations of a freeway facility that contains both managed and unmanaged lanes.
6. Provide a computational engine of the revised procedure for use by the Freeway and Multilane Highways Subcommittee of the HCQS.

Note: The AASHTO Standing Committee on Research approved phased funding for this project. The panel is expected to develop a plan for accomplishing an improvement to the HCM (either in managed lanes or oversaturation) and may request additional funds if justified.

♦ Project 03-97
Modifications to HCM Signal Analysis to Support Reliability Assessment and Maintenance of Signal Timing

Research Field: Traffic
Source: Florida
Allocation: $850,000
NCHRP Staff: B. Ray Derr

The signalized intersection analysis methodology described in the Highway Capacity Manual (HCM) is one of the most widely used tools for evaluating the operation of signalized intersections. It has traditionally been used to quantify the delay and level of service associated with an existing intersection and with any proposed changes to the intersection's geometry, timing, or traffic demands. Recently, two new emphasis areas have been identified as national priorities: providing motorists with reliable travel times and maintaining signal timing. The HCM signal analysis methodology will be an important tool for engineers to use in achieving the goals associated with these two priority areas.

The SHRP 2 Reliability research program has the goal of providing highway users with reliable travel times by preventing and reducing the impact of non-recurring incidents. The SHRP research program will develop analytic procedures for estimating reliability metrics. It will also develop a methodology for the HCM for predicting the impacts of random events (e.g., rain, crashes, breakdowns) on speed and delay. SHRP 2 Project L03 is concerned with *travel time* reliability, that is, the travel time over an extended highway segment. On signalized highways, a segment will include multiple signals. The L03 Research Plan states that it will use existing procedures for characterizing signal capacity so that predictive models of reliability can be constructed (i.e., *reliability = f{signal capacity, demand, event characteristics}*). As such, the scope of Project L03 is fairly macroscopic, since the primary measurements are travel times over an extended segment. The intent is not to study the operation of individual signals. Given the changes in signal control technology and innovative treatments, existing estimation procedures are probably limited in what they can provide. Therefore, research is needed to learn how these factors influence signal capacity and operation, and further, how these relate to travel time reliability over an extended segment.

Estimation of travel time reliability on signalized highways is currently a daunting task. Reliability measurement demands a long history of *continuously collected travel times* (minimum of 6 months, ideally a year) be available. Such data are extremely rare right now and limited to where agencies have deployed either toll tag readers or electronic license plate readers. In the future, we will probably see more of these technologies deployed on signalized highways. Further, there is potential for privately collected travel time data (e.g., cell phone tracking and GPS-based travel times from instrumented vehicles) to provide travel times on signalized highways. However, these private technologies are still in their infancy, so the research will face data collection as a major issue.

In response to the aforementioned research need, the HCM signal analysis procedure needs to be enhanced so that agencies can use it to evaluate the effect of the full range of traffic conditions on travel time reliability. This research would complement and leverage the SHRP investment by combining with it to produce a comprehensive methodology for evaluating urban street operation, level of service, and reliability.

It is estimated that there are about 300,000 signalized intersections in the United States. These signals account for about 300 million vehicle-hours of delay each year. A recent evaluation of the Nation's signals by the National Transportation Operation Coalition (NTOC) indicated an immediate need for improvements to the timing of the nation's signals. These improvements have the potential to reduce travel time by 25% and save almost 17 billion gallons of motor fuel each year. The biggest obstacle to achieving these benefits through retiming is limited agency resources. Agencies have both limited staff-hours and limited funds to adjust timing plans and update equipment. Identifying and im-

plementing efficient signal timings is one of the most time-consuming elements of signal maintenance.

The HCM signal analysis methodology is a key element in the NTOC plan to achieve improved signal operation. However, research is needed to update the HCM signal analysis methodology to make it more efficient to use (e.g., less data intensive) and more consistent with the operation of today's traffic signal controller. The desired improvements in the timing of the Nation's signals will only be realized if the HCM signal analysis methodology is updated to accurately reflect current driver behavior and traffic conditions.

The objective of this research is to update and modify the HCM signal analysis procedure to support reliability assessment and maintenance of signal timing. The final product of this research will be a comprehensive methodology for efficiently evaluating signal timing, identifying effective timing plans, and quantifying the effect of signal timing and traffic demand on reliability. This methodology will be documented in the form of draft text for a forthcoming edition of the HCM.

The following tasks are expected:

1. Define appropriate reliability metrics for urban streets as applicable to, or influenced by, signalized intersection operation. Review the findings and recommendations of the completed (or nearly completed) SHRP Reliability Project L03—Analytic Procedures for Determining the Impacts of Reliability. To the extent possible, incorporate these findings and recommendations in this research.
2. Evaluate the procedure for estimating saturation flow rate. Review saturation flow models in use around the world and compare their theoretical framework and adjustment factors with those of the HCM. Identify factors that may be appropriate for inclusion in the HCM procedure and modifications to the existing procedure that will make it more applicable to today's drivers and traffic conditions. As a minimum, the procedure should be updated to account for the effects of queue spill back from a downstream intersection.
3. Identify strategies for improving reliability that include changes to the signal timing or operation. Such strategies may include the use of: (1) actuated, responsive, or adaptive signal control; (2) dynamic lane assignment; or (3) spill back detection and response. Alternative or innovative sensing technology that provides more reliable, informative, or accurate information than existing loop or video detection should be considered. The objective of this task is to insure that the methodology developed in this research can utilize state-of-the-art sensor information to model a range of strategies for improving reliability.
4. Identify and evaluate alternative methodological frameworks for evaluating the performance of a pretimed or an actuated intersection that may, or may not, be part of a coordinated signal system. The objective of this task is to recommend a framework for updating the existing HCM signal analysis methodology so that it is more efficient to use and more accurately models the operation of today's traffic signal controller. Criteria used to evaluate the alternative frameworks should be identified at the start of this task. They should recognize a preference for a framework that minimizes resource requirements (e.g., minimize the amount of time required to collect input data, develop efficient timing plans, convert output to controller inputs, etc.). As a minimum, the framework should support the analysis of actuated controller operation, a variety of sensor inputs (including pedestrian detection), individual traffic lanes, queue spillback from turn bays, queue spillback from downstream intersections, and supplemental lanes (i.e., lane drops/adds). It should support the optimization of pretimed and coordinated signal timing plans. The recommended framework should include a procedure for estimating reliability during periods of recurring congestion and uncongested conditions.
5. Based on guidance from the panel, develop the methodology associated with the framework recommended in the previous task. This development should be coordinated with SHRP 2 Project L08—Incorporation of Non-Recurrent Congestion Factors into the Highway Capacity Manual Methods. The SHRP project is planned to start in FY 2008 and will be producing a procedure for predicting the probability and duration of *non*-recurring congestion as well as procedures for estimating the impact of this

congestion on freeway and urban street operations. The product of this task and of project L08 will be combined to propose a comprehensive methodology for evaluating urban street operation, level of service, and reliability.

6. Develop a data collection plan that will guide the collection of the data needed to update the saturation flow rate procedure developed in Task 2 and the data needed to calibrate the signal analysis methodology developed in Task 5. The plan should focus on the collection of delay and queue length data for model calibration purposes. A portion of the data should be used to validate the delay and queue length estimation procedures for a wide range of volume, geometry, and signalization conditions. The data collected should also be used to calibrate and validate the procedure developed in Task 5 for estimating reliability.
7. One product of this research should be draft text for the HCM. This text should describe the proposed methodology developed in Task 5 and calibrated in Task 6. It should focus on updating the methodology currently in Chapter 16—Signalized Intersections in the HCM. Impacts to other HCM chapters will also need to be identified, and draft text may need to be prepared for these chapters as well. A second product of this research should be a computational engine that automates the proposed methodology. This engine should be developed in a manner similar to other engines that the committee currently uses to automate the HCM chapters.

Note: This project should be coordinated with relevant SHRP2 projects, particularly L03 and L08.

♦ **Project 03-98**

Assessment of Auxiliary Through Lanes at Signalized Intersections

Research Field:	Traffic
Source:	Maryland
Allocation:	$400,000
NCHRP Staff:	Nanda Srinivasan

Auxiliary through lanes beyond signalized intersections are recognized as an approach to increase the intersection capacity through their efficient utilization. The benefits from the use of auxiliary through lanes at signalized intersections can be realized in the presence of equally distributed traffic over the lanes prior to the intersection.

Utilization of auxiliary through lanes beyond a signalized intersection has been seen throughout the United States. Prior studies suggest that the length of the auxiliary lane beyond the intersection is a significant factor affecting the upstream lane usage, therefore, the intersection capacity. However, the conditions for their effective use and their impact on safety, operation, and the environment have yet to be documented. Thus, research is needed to provide technical assessment of their use, document their impact on safety and operations, and develop guidelines including design criteria and placement. This study will assist traffic engineers in adopting criteria for the effective and safe use of intersection auxiliary through lanes.

TRIS and RIP literature searches yielded few documents. Another literature search found that non-uniform formulas in practices have been used in determining the length of auxiliary through lanes downstream of an intersection. 12 * Green interval time in seconds (Public Roads Vol. 34, Nos. 9 and 10, August 1967 and October 1967, FHWA) and 10 * Minimum green time G in seconds (Roadway Design Manual, Section 6, New Jersey Department of Transportation) are examples.

The objectives of the research are the following: (a) provide a comprehensive literature and state-of-practice review on intersection auxiliary through lanes, (b) assess the operational effectiveness and impact on safety and capacity, and (c) develop guidelines for their use.

These objectives will be accomplished through the following tasks:

1. Literature Search – A thorough literature search should be conducted to study issues related to conditions for use, design criteria, placement, operation, intersection capacity, and safety of intersection auxiliary through lanes.
2. Current Practices – State transportation officials and federal agencies will be contacted to determine current practices and experience with auxiliary through lanes at signalized intersections. A list of well-documented case of the auxiliary through lanes will be developed. Sites that rep-

resent a wide range of common field conditions will be selected for possible investigation.

3. Interim Report – A white paper with findings and conclusions from the literature and state-of-practice review should be forwarded to the review panel. Recommendations for proceeding with the next steps will be formulated.
4. Data Processing – Data for selected sites will be obtained from state highway agencies to assist in the evaluation of the auxiliary through lane operation at a signalized intersection and develop guidelines for implementation. Requested data will focus on capacity changes, lane usage changes, as well as changes in intersection operational measures, and application conditions.
5. Data Analysis – Analysis of data will quantify the impact of the length of downstream auxiliary through lanes at a signalized intersection on the upstream lane usage and the intersection capacity, driver perceptions, traffic safety, quality of intersection operations, and the environment. Simulation methods will be employed to develop a chart of minimum length of auxiliary through lanes vs. effectiveness of the lane usages.
6. Final Report – The final report will document the findings from the previous tasks. Moreover, it will provide guidelines for selection, design, and operation of intersection auxiliary through lanes to be used as a recommended practice in the future.

The Findings from this study should greatly aid engineers in properly implementing auxiliary through lane treatments in response to intersection capacity issues. Potential payoffs include: (a) operation effectiveness and safety at signalized intersections, (b) decreased intersection delay costs, (c) increase traveler satisfaction, and (d) environmental benefits.

The anticipated product from this research will include recommended specification language for inclusion in the AASHTO materials specifications governing the use of auxiliary through lanes at signalized intersections.

♦ Project 03-99
Development and Application of Access Management Guidelines

Research Field:	Traffic
Source:	AASHTO Highway Subcommittee on Traffic Engineering
Allocation:	$400,000
NCHRP Staff:	Christopher J. Hedges

Many states and local governments are considering, or in the process of, revising their access management standards and guidelines. These standards or guidelines commonly include key elements such as: a) an access management classification system and access management categories; b) signalized access spacing; c) medians and median opening spacing and design; d) unsignalized access spacing; e) driveway design; f) internal and interparcel circulation; and g) alternative access.

These standards and guidelines are often based on a continuation of historical practices or from the practices of other jurisdictions. As a result, the access management criteria often vary widely and questions remain as to the appropriate access spacing and design criteria for different types of roadways and roadside environments.

However, at this time, there is no consolidated source giving a rationale for the application of various access management techniques and their designs. Research is needed to provide information for state DOTs and local governments to rationally evaluate their current access management standards or guidelines; document the safety and operational logic for adoption and administration of access management techniques; provide guidance for the adoption of criteria and procedures for deviation from access management standards while maintaining consistency in the permitting process; and to help address institutional, political, and economic barriers to the adoption of rationale access management standards.

The research will examine and compare the roadway design manuals, access management standards and guidelines, driveway designs and other relevant manuals adopted by the various state DOTs as well as selected local governments. Agencies will be contacted to ascertain: a) why the agency adopted guidelines rather than standards; b) the rationale for the standards/guidelines for signal spacing, unsignalized access spacing, the use of medians, median opening spacing and design, driveway geometrics, warrants for and design of

auxiliary lanes, etc.; c) criteria and procedures for deviations from adopted standards; d) how applications vary for different roadside environments (rural, suburban and urban) or roadway functional design types; and e) issues in administration of the standards/guidelines such as consistency in application of the standards/guidelines and institutional, political, and economic barriers to implementation.

A major objective of the research will be to develop a rationale or basis (criteria) for such access management elements as, but not limited to, the following: a) roadway classification and access management categories; b) signal spacing; c) unsignalized access spacing for different access management categories; d) driveway design; e) warrants for auxiliary lanes; f) design of auxiliary lanes; g) median opening spacing and design; h) u-turns, including u-turns by large vehicles; i) access connections on opposite sides of undivided roadways; j) warrants for and design of isolated left-turn lanes and shoulder by-pass lanes; k) application of a continuous two-way, left-turn lane (TWLTL); and l) replacing a TWLTL with a nontraversable median. The research will also identify variations, where appropriate, in the desired application of the access management elements.

This research would culminate in model access categories and model sets of access management and design guidelines and procedures for various roadway functional classifications and design types. It would also address how these criteria might vary in the context of different roadside environments. The resulting models would be accompanied by detailed rationale on their benefits and application so they may be readily adapted and applied by state transportation agencies and local governments or MPOs, through their transportation planning and design processes.

♦ Project 04-36

Characterization of Cementitiously Stabilized Layers for the Mechanistic-Empirical Pavement Design Guide (MEPDG)

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

The Mechanistic-Empirical Pavement Design Guide (MEPDG) developed under NCHRP 1-37A considers cementitiously stabilized materials to include lean concrete, cement treated aggregate, open-graded cement stabilized aggregate, soil cement, lime-cement-fly ash, lime-fly ash, and fly ash and lime-stabilized base and subbase layers. The engineering properties of these materials vary over a wide range in which lime-stabilized sub-grade soils represent the low end and lean concrete represents the high end. These properties influence the distribution of traffic loads through the pavement structure such that pavement behavior could range from rigid to flexible. Furthermore, some agencies do not consider lime stabilization of soil subgrade material as a permanent treatment and do not include it in the structural design process. Therefore, research is needed to explore these issues and develop recommendations for measuring parameters and analytical methods that should be used to characterize stabilized base and subbase layers. Currently the parameters used to characterize stabilized base and subbase materials are elastic modulus (E) or resilient modulus (M_r) and flexural strength (MR). The MEPDG provides for three levels of inputs (designated Levels 1, 2, and 3 with Level 1 inputs providing the highest level of accuracy and Level 3 inputs providing the lowest level of accuracy). At present, there are no standard protocols for testing the majority of these material prpoerties at Level 1 accuracy. The protocols included in the MEPDG are a combination of adaptations of various concrete testing methods and a limited number of procedures for cementitiously stabilized materials. The MEPDG provides various relationships with unconfined compressive strength (UCS) for obtaining Level 2 inputs, and Level 3 inputs are based on “typical” values available in literature.

One issue that needs to be considered is the characterization of stabilizers other than cement. While cement-treated materials reach their equilibrium strength values fairly quickly, lime and lime-fly ash materials have long term pozzolanic strength gains that could last up to 2 years. Therefore, there is a need to explore and recommend laboratory molding and curing procedures for predicting long-term equilibrium strengths of pozzolanic materials.

Many state highway agencies utilize cementitiously stabilized materials in pavement construc-

tion and are considering the use of the MEPDG. Furthermore, because pavement thickness design is very sensitive to both E and M_r inputs, there is an urgent need for developing standard testing protocols for obtaining these properties for cementitiously stabilized materials, and for evaluating the accuracy of the unconfined compressive strength correlations provided for Level 2 inputs.

This research should include the evaluation of standard and new destructive testing procedures (compressive strength, flexural strength, indirect tensile strength, and other relevant procedures) and consider the potential of utilizing non-destructive-testing (NDT) techniques, such as pulse velocity, resonant frequency, impulse-echo, SASW (Spectral Analysis of Surface Waves), the Clegg Hammer, etc. Non-destructive test procedures are particularly well adapted for characterizing the effect of curing (temperature/time) effects. The research should also consider recommending laboratory test protocols that could be performed in no more than 1 week (tests that require a long period are not practical for most pavement design applications).

A fundamental understanding of how traffic loads are distributed throughout a pavement structure that consists of hot-mix asphalt (HMA) layers over either a cementitiously stabilized base or subbase layer (i.e., a semi rigid pavement structure) is needed. Also, recommendations need to be made regarding the laboratory test parameters that should be used in the MEPDG to reflect the pavement's semi-rigid behavior.

The research should include a comprehensive laboratory testing program on a variety of cementitiously stabilized materials to recommend a set of consistent and appropriate procedures (in AASHTO format) for characterizing the semi-rigid behavior of cementitiously stabilized materials for use as MEPDG inputs. The research should also provide recommendations on how to incorporate these layers into the MEPDG, provide guidance on how to characterize these materials in the laboratory, and identify the conditions for considering these materials in the thickness design process.

The research shall include at least the following tasks:

1. Modeling the semi-rigid behavior in pavements and determining the parameters that best predict load distribution characteristics of semi-rigid pavements incorporating stabilized layers with a wide range in strengths.
2. A sensitivity analysis for each cementitiously stabilized material using the typical ranges of minimum and maximum values of the parameters identified in Task l to establish the parameter and material with the greatest impact on pavement thickness design and help in setting priorities for the laboratory testing program.
3. Review of pertinent literature (both national and international) with an emphasis on the utility of the identified test procedures and summarizing the best demonstrated technology [Arellano, David, and M. R. Thompson. *Stabilized Base Properties (Strength, Modulus, Fatigue) for Mechanistic-Based Airport Pavement Design*. Final Report, COE Report No. 4, FAA Center of Excellence for Airport Pavement Research, University of Illinois at Urbana-Champaign, February, 1998, can serve as a starting point].
4. Recommend a comprehensive laboratory testing program utilizing the most promising procedures/techniques identified in Task 3, and submit for NCHRP review and approval.
5. Execute the approved laboratory testing and analytical program.
6. Prepare a final report documenting the entire research effort, including draft versions of recommended AASHTO test procedures for characterizing the modulus and strength properties of cementitiously stabilized materials.

♦ **Project 04-37**

Long-Term Performance of Epoxy Adhesive Anchors

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

In July 2006, a section of a suspended concrete ceiling failed and collapsed in the D Street Portal of the Interstate 90 connecter tunnel (part of the "Big Dig") in Boston, Massachusetts. This was a rapid and catastrophic failure that resulted in the loss of life. In July 2007, the National Transportation Safety Board (NTSB) issued a report tracing the cause of this collapse to the failure of

epoxy bonded anchors that held the suspended ceiling in place (SB-07-36). NTSB cited a poor creep resistance of the epoxy resin and a general lack of understanding and knowledge about creep in adhesive anchoring systems.

Epoxy bonding systems have widespread use throughout the world. These systems are used to anchor both threaded rods and reinforcing bar into hardened concrete. Common transportation applications for epoxy bonded anchors include bridge widening, concrete repair and rehabilitation, barrier retrofitting, utility installation on existing structures, and tunneling. Despite widespread use, the suppliers of these systems provide little guidance on how the adhesives perform under sustained, long-term loading. The long-term behavior needs further investigation to prevent failures like the one in Boston.

Finally, the AASHTO LRFD Bridge Design Specification doesn't adequately address the use of epoxy adhesive anchors. The results of this research will be crucial in the development of appropriate guidelines for AASHTO.

The objectives of this project are the following: (1) through testing and numerical modeling, if needed, document the long-term characteristics of epoxy adhesives currently in use, with emphasis on identifying what levels of sustained loading pose a risk to anchor performance; (2) develop standards and protocols for the testing and use of adhesive anchors in sustained loading applications; (3) provide guidance for future use of adhesive anchors, including (a) identifying the creep performance requirements that are necessary for acceptance of an adhesive anchor system, and (b) developing acceptance criteria that are a function of application, with epoxy anchors not subjected to sustained loading having different acceptance criteria than anchors that will have sustained loading; (4) provide recommendations for agencies for the use of adhesive anchors in sustained loading applications, including (a) how to identify which applications pose a potential risk to the public, (b) inspection and monitoring for anchors posing a potential risk, and (c) retrofit/repair suggestions for anchors posing a potential risk; and (5) provide draft language for addressing the use of epoxy adhesive anchors in the AASTHO LRFD Bridge Design Specification.

♦ Project 04-38
Developing a Laboratory Test for Determining the Initial Retro-Reflectivity Level of Glass Beads in Pavement Markings

Research Field: Materials and Construction
Source: Iowa
Allocation: $350,000
NCHRP Staff: Edward T. Harrigan

The initial retro-reflectivity level of pavement markings is greatly dependent on the quality of glass beads applied on top of the marking material. Agency experience has shown that glass beads meeting the same specifications for gradation and roundness and applied by the same paint crew with identical equipment can exhibit a difference of 200 mcd/lx/sq m from one batch of glass beads to another.

In Iowa, an increase of 100 to 200 mcd/lux/sq m in initial retro-reflectivity levels can lead to an additional year of useful life from a pavement marking. A quick, reproducible, and standardized laboratory test method is needed to predict the initial level of retro-reflectivity a particular batch of glass beads can provide. Such a test can be used by purchasing agencies to screen glass beads before they are applied to the road.

The objective of this project is to develop a laboratory test to predict the initial retro-reflectivity of glass beads applied on top of liquid pavement markings. Actual field applications will need to be compared to laboratory tests to determine a method for accurately predicting how various batches of glass beads will perform in providing initial retro-reflectivity. The test should be rapid (less than 24 hours) and able to be conducted in a typical state DOT materials testing laboratory.

♦ Project 08-71
Optimum Life-Cycle Analysis of Maintainable Assets

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

As highway agencies' funding continues to be squeezed, the agencies' decision makers are faced with the difficult task of choosing between capital projects that expand the system to meet growing demands or maintenance and preservation activities that will sustain the highway assets over the long term. One of the key components of Asset Management is the maintenance of a highway agency's assets at their lowest life-cycle cost. In order to do that, an agency must know the life expectancy of each major asset along with the type of maintenance treatments and the frequency that is necessary to maintain that asset at its optimum condition. There may be some assets where the maintenance can be deferred without creating a liability for the agency (either financial or legal), but there are other assets (such as bridges and pavements) that cannot be ignored without serious legal or financial implications.

There is a need to define the optimum life expectancy of major asset types for maintenance management under certain conditions and maintenance programs. Often, the agency's designers use a prescribed asset life expectancy in their life-cycle cost analysis for major asset types like pavements and bridges. However, experience has shown that the serviceable life of an asset is often determined by the frequency of recurring or periodic maintenance (or lack thereof) and can be enhanced by the use of superior material types or higher design criteria. The deterioration of the highway network begins as soon as the "ribbon is cut;" therefore, maintenance and preservation programs require the knowledge of the design life expectancy for maintenance planning and program execution in order to comply with the agency's expectancies. This research would be explicit in defining the expected life of critical maintainable assets for at least three potential cases of the current state of the practice: 1) when the maintenance activities are performed as assumed by the designer in the lifecycle cost analysis; 2) when no or very little maintenance is accomplished over the life of the asset; and 3) when superior materials or designs that require no or very little maintenance are used. A strong consideration for research would GASB 34 Modified Statement, with regard to depreciation of assets.

The objective is to provide agencies with a methodology to perform an in-depth analysis on the most cost-effective way to deliver a highway product by asset type that will perform adequately over its life and at the lowest cost. The research will investigate the current methodology highway agencies use to determine life expectancy for major asset types such as pavements and bridges and expand it to include other major asset types such as culverts, signs, pavement markings and guardrail. The research will also investigate the benefits or drawbacks to performing various maintenance activities to the asset at the prescribed frequencies estimated by the designers and report on the cost effectiveness of that alternative versus a do-nothing alternative as well as a do-nothing alternative using superior materials or design criteria. Another research objective is to provide a framework of future activities for maintenance, and preservation treatments that should be programmed into future year's maintenance plans and budgets in order to optimize the value of the asset to realize the lowest cost of the asset over its life expectancy.

♦ Project 08-72
Case Studies of Best Practices, Model Initiatives, and Mitigation Strategies that Incorporate the Principles of Title VI and Environmental Justice in Transportation Decisions

Research Field:	Transportation Planning
Source:	AASHTO Standing Committee on the Environment
Allocation:	$400,000
NCHRP Staff:	Lori L. Sundstrom

The evolution of the transportation planning process has meant that both Title VI and environmental justice are receiving greater emphasis and more attention today than ever before. Effective, efficient, and inclusive transportation decision making depends and relies upon recognizing, responding to, and properly addressing the unique needs, cultural perspectives, and financial limitations of different socioeconomic groups in order to achieve a more comprehensive approach to not only engage the public, but also to understand their value systems and view points. Instrumental in the continued expansion of this social and economic awareness has been the federal requirement for providing meaningful access to transportation decision mak-

ing for all affected and interested people, especially those with limited English proficiency. More often than not, it is environmental justice populations who also are low literate or have limited English proficiency.

Both the Environmental Justice Executive Order (12898) and Limited English Proficiency Executive Order (13166) have their basis in Title VI of the Civil Rights Act of 1964. Together these legal instruments seek to prohibit discrimination based on race, color, national origin, income, and limited English proficiency. These conditions severely limit that person's ability to participate in the decision-making process through traditional public engagement techniques. To effectively engage these populations will require adjustments in notification procedures; timing and location of public meetings; the presentation of project information; and the methods of capturing public comments.

In response to a growing awareness that the demographics of this country's population have dramatically changed since the early 1950s when public involvement was first required on federal projects, FHWA recently published a guidebook for transportation planning professionals on how to identify these populations within a community affected by a transportation planning effort and how to effectively engage them in the planning and design processes (*How to Engage Low-Literacy and Limited-English-Proficiency Populations in Transportation Decisionmaking*, March 2006). The guidance benefited from collecting experiences of individuals across the nation involved in outreach to those members of a community who are limited in their English proficiency. This publication reported "best practices" in the identification of individuals who have limited English proficiency within a study area and also in the adjustments made in the outreach process to engage these individuals effectively.

The response to this publication inside the planning profession has been very favorable, and the interest in a "sequel" has arisen. Such a sequel would further collect from practitioners their "best practices" in the field with these populations, and would also investigate specific issues in dealing not only with the language, literacy, race/ethnicity, cultural, and income barriers but also any insights which have proven important in tailoring public participation plans. Even small towns, rural areas, and other locations that are not traditionally considered as having mixed minority populations are experiencing growth in specific "pockets" of minority communities that have common linguistic, literacy, income, race/ethnicity and cultural backgrounds.

Understanding the ramifications of the timing and location of meetings, oral and written notification procedures/formats, appropriate gatekeepers and social hierarchy, gender, and public relations are important to breaking down the barriers and allowing public participants in the planning process to have a meaningful level of dialogue on complex issues. The provision of a convenient guide on the major differences that may influence the success of a public engagement campaign would be of value to a large number of transportation planning organizations. Especially valuable would be a number of case studies explaining why a particular engagement technique was selected, how well it worked, how it could have worked better, and what the level of effort and outputs were for each case studied.

The process of examining communities, neighborhoods, and people in published format in the post Environmental Justice Executive Order era can be traced to *Community Impact Assessment* (1996), an early primer which showed how to conduct a community impact assessment to address the impacts of proposed transportation actions on communities, neighborhoods, and people. This was followed by *Community Impact Mitigation: Case Studies* (1998), a complimentary volume that used five case studies to provide examples of how transportation projects had been planned, designed, and constructed across the country to be neighborhood friendly; avoid, minimize, and mitigate impacts; and, where appropriate, enhance the livability of communities and neighborhoods.

Transportation & *Environmental Justice Case Studies* (2000) illuminated effective practices on how to better promote environmental justice principles. The 10 case studies profiled how various transportation agencies had integrated environmental justice considerations in their activities to improve transportation decision making. It was followed by *Transportation & Environmental Justice Effective Practices* (2002), a compendium of tools and techniques that could be utilized in planning, public involvement, project development, right of way, construction, and operations and maintenance.

In 2006, *How to Engage Low-Literacy and Limited-English-Proficiency Populations in Transportation Decisionmaking* sought to spotlight the underlying effects that low literacy and limited English proficiency had on populations and their abilities and constraints to participate fully in the public involvement process. It provided a host of tools and techniques that could be used to engage these populations, as well as other populations.

This proposed research would build on these past efforts and seek to progress the state-of-the-art by presenting case studies of best practices, model initiatives, and mitigation strategies that incorporate the principles of Title VI and environmental justice in transportation decisions. It will seek to show how an awareness of and sensitivity to the often overlooked or misunderstood underlying nuances in different cultures and income levels affect the ways in which communities, neighborhoods, and people should be approached. This is crucial to understanding how an impact can be viewed very differently depending upon one's culture and income level, and what mitigation and/or enhancement may be appropriate given a culture and income level.

The main objectives of this research include 1) developing a practitioner's handbook that describes how to engage specific cultural groups, low-English-proficiency populations, and low-literacy populations; 2) advancement of best practices, available supplemental resources (printed material and training opportunities), and practical techniques for engaging various cultural groups, low-income, low-literate, and limited-English-proficiency populations; 2) the development and conduct of research that evaluates the effectiveness of various engagement options, their cost, and their results in case study format; and 4) identification of effective mitigation and enhancement strategies. The format and content of the document should be accessible so that the material for specific populations can be readily accessed by transportation professionals with general backgrounds in project-level and systems-level planning.

With an increasing emphasis on engaging a diverse public in the development of transportation solutions, state departments of transportation and local transportation providers need guidance in public engagement to complete NEPA/SEPA actions; conduct corridor and sub-area planning studies; and to obtain feedback on design and maintenance options. The increased emphasis on context sensitive solutions (CSS) requires that the public be engaged earlier and to a greater degree in the systems planning, project planning, and design processes. The increasing numbers of U.S. residents for whom English is a second language has further underlined the need for additional research and guidance in many areas of the country. The immediate payoff will come in the form of more cost-effective outreach; superior design products; and potentially shorter turn-around times on transportation projects. The longer-term payoff will come in a better appreciation of state DOTs and other transportation providers by typically underserved populations.

NOTE: The AASHTO Standing Committee on Research added Problem No. 2009-B-12, "How to Engage Low-Literacy and Low-English-Proficiency Populations in Transportation Decisionmaking, Volume 2," to this study and recommended that the final project scope be broad enough to encompass all cultural groups.

♦ Project 08-73
Road Pricing: Educating and Informing Stakeholders and the Public

Research Field:	Transportation Planning
Source:	Federal Highway Administration
Allocation:	$100,000
NCHRP Staff:	Nanda Srinivasan

The current system of funding our roads and highways does not provide sufficient capacity or quality of service for all who want to use them, and traffic congestion has grown to such an extent that building new roads by itself will not solve the problem. Direct charging for road use in major metropolitan areas (where prices vary by level of demand) has been proven to enable traffic flows at posted speed limits and could maintain transportation funding at current levels.

Recent research has shown that the public and key transportation stakeholders do not have a sense of the comparative costs and benefits of various solutions to traffic congestion, particularly road pricing. Recent research into public opinion of tolling and road pricing indicates that supportive atti-

tudes increase when more information is made available.

To affect stakeholders' and the public's attitudes and behavior regarding road pricing, a commitment would have to be made to implement a long-term national public education initiative. This research effort would build upon past research to provide the underpinnings for such an initiative.

Public officials, technical experts, and advocates on either side of the tolling and road pricing issue would use the information gleaned from this research to develop improved messages and techniques for communicating about road pricing with their constituents. These entities include:

- State DOTs
- Professional Organizations (e.g., IBTTA, ITE, APA)
- TRB
- MPOs and Regional Agencies (e.g., OCTA, SANDAG, HGAC/QuickRide, PSRC)
- Toll Facility Operators
- Interagency Groups (e.g., Team Texas, Team Florida, CTOC)
- Industry Associations (e.g., AASHTO, ARTBA, IBTTA)
- Private Consulting Firms
- Advertising and Public Relations Firms
- Private Transportation Investment Interests

The final research report would provide a framework for implementation of a public education initiative on road pricing, a detailed management plan, and an implementation schedule. Specific tasks include:

- Assessing the sponsors' priorities and expectations.
- Using message parameters provided by the sponsors, conduct a facilitated discussion with committee members to clarify the goal and expectations of the initiative and, if possible, come to consensus on the basic messages it would like to convey.
- Assessing what the public thinks about road pricing and testing a variety of communication strategies and message concepts in at least two major metropolitan areas.
- Identifying key target audiences and their preferred ways of receiving information.
- Developing a panoply of messages that resonate with the target audiences and that would be acceptable to stakeholders on both sides of the issue.
- Developing a media plan and communications tools, based on available funds.
- Providing an implementation schedule.

This research is an essential element in the foundation of a comprehensive national public education initiative on road pricing and, on its own in the short-term, will enable policymakers and practitioners to communicate the value of transportation in enhancing communities, quality of life, and the economy, which is Goal 2 of AASHTO's Strategic Plan.

♦ Project 08-74
Sustainable Transportation Performance Measures for State DOTs

Research Field:	Transportation Planning
Source:	Texas
Allocation:	$500,000
NCHRP Staff:	Lori L. Sundstrom

Transportation Research Board (TRB) committees were tasked to identify key research needs to be posted on the TRB website. TRB's Committee on Performance Measurement (ABC30) has done extensive work over the past three years to identify research needs. The committee prioritized these needs and identified five key needs to be posted on the website. Two of these are directly related to the issue of using performance measurement to address sustainable transportation. This proposed research project has been developed to address these two needs.

The objective of sustainable development is to ensure that the economic, social, and environmental needs of current and future generations are effectively addressed. Sustainable transportation can be viewed as an expression of sustainable development in the transportation sector and requires the provision of safe, effective, and efficient access and mobility into the future while considering economic, social, and environmental

needs. The reality, however, is that these principles are rarely implemented in an integrated way.

For sustainable transportation to be successfully implemented, it is essential that the concepts are adequately understood, quantified and applied. Similarly, for state departments of transportation (DOTs) to move closer to achieving the goals of sustainable transportation, it is essential that the underlying sustainability-related goals and objectives be quantified and applied. To facilitate this process there is a need for a practical and easy-to-use tool or methodology.

All DOTs have strategic goals that they seek to achieve. These goals typically cover a broad range of topics and can be consolidated into categories that specifically address the dimensions of sustainability—economic development, social equity, and environmental stewardship. Therefore, achieving these consolidated goals will enhance the sustainability of the specific DOT's transportation system. Examples of state DOT goals related to sustainable transportation include improved safety, reduced congestion, enhanced economic opportunity, improved air quality, reliable mobility, system preservation, accelerated project delivery, economic vitality, and increased value of transportation assets.

Performance measurement has, over the decades, evolved as an effective methodology for quantifying goals and objectives. Working with performance measures, however, can be a daunting task due to the large number of possible measures, extensive data that might be required, and computational complexity that is often introduced—hence the need for identifying "good" and easy-to-use performance measures.

This project will develop a tool or methodology that will put state DOTs in a position to measure the relative sustainability of their transportation corridors and networks over space and time. The methodology will clearly describe the underlying principles of sustainable transportation, possible goals that can be used to address these principles, and performance measures that can be used to address these goals. In developing the measures, all the attributes of a "good" performance measure will be considered, including aspects such as data availability, sensitivity, and relevance. The methodology will be in the form of a "toolbox" from which the states can select their most appropriate sustainability goals and associated performance measures. The toolbox will also describe computation methods for these measures and possible data sources. Finally, the toolbox will comprise a decision-making method that can be used to develop decisions based on the quantified measures.

The overall goal of this project is to develop a methodology or tool that would allow state DOTs to use performance measurement to assess the relative sustainability of their transportation networks and corridors over space and time. This goal will be achieved by addressing the following objectives:

- Performing a comprehensive assessment of sustainable transportation as it relates to state DOTs.
- Identifying appropriate goals that can address the concepts of sustainable transportation.
- Developing performance measures to address these goals. In the development of the performance measures, consider data that is available to states or easily obtainable.
- Developing quantification techniques for the various performance measures.
- Developing a decision-making framework that can be used to make decisions based on the quantified performance measures.

TRB's Committee on Performance Measurement (ABC30) has identified performance measurement for sustainable transportation as one of its key research focus areas. The reason for this is the new emphasis at all levels of government on environmental, social, and economic issues as they relate to transportation. Sustainable transportation provides an integrated way of addressing these issues simultaneously. However, due to the relative newness and complexity of sustainable transportation, related performance measures have not been well developed and applications are few and far between. This project will provide state DOTs with the necessary tools to assess the relative sustainability of their transportation systems so that appropriate remedial actions can be taken that will help to preserve a sustainable transportation system for current and future generations.

♦ **Project 08-75**
Performance Measurement and Evaluation of Tolling and Congestion Pricing Project Benefits and System Impacts

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

Highway traffic congestion will likely become worse in the future as demand for highway facilities increases and supply (or capacity) remains stagnant. Peak time spreading, loss of productivity during congested periods, and underutilization of existing capacity during off peak periods are some of the current system management challenges. Transportation authorities and organizations around the country and abroad have explored and applied capacity improvement strategies as well as several Transportation Demand Management and Transportation System Management methods in an effort to mitigate the negative consequences of current and future congestion levels. What has been realized in many areas is that significant capacity expansion opportunities are limited due to environmental, right of way, and financial constraints; thus, maximizing existing and underused capacity has become paramount.

One of the lesser-used tools in the congestion management toolbox is tolling and congestion pricing of existing and new infrastructure. However, there is a growing national momentum within government transportation entities to explore that option and evaluate its performance. A number of states are considering and/or implementing tolling and congestion pricing projects such as HOT lanes. In addition, USDOT issued a set of national strategies to reduce congestion that includes pricing concepts. A key element of this strategy is the development of Urban Partnership Agreements which includes tolling, transit, telecommuting and technology, and operations components. Following a competitive process, USDOT recently announced the selection of five metropolitan areas as the first communities to receive Urban Partnership grants (i.e., Miami, Minneapolis, New York, San Francisco, and Seattle). Implementation of these agreements and tolling projects will require focused data tracking and analysis of the effectiveness and impact of pricing. Performance measurement will be critical in this process.

In addition, the last highway authorization legislation, SAFETEA-LU, made provisions that provide state departments of transportation with flexibility to use congestion pricing programs in their congestion mitigation programs (Sec. 1604), providing over $50 million during this authorization period for pilot programs to use congestion pricing to mitigate congestion and air pollution, as well as improve fuel efficiency.

Tolling and pricing options also face considerable political and public pressures. Effective performance assessment and analysis of existing and planned pricing projects is central to gaining public acceptance and use, along with encouraging broader application. Currently, there is lack of knowledge and benchmarking of best practices on how to develop appropriate performance measurements and related data tracking and analysis methods and communicating the results to the public.

Transportation organizations need assistance in developing and tracking measurements for assessing the benefits and impacts of tolling and congestion pricing strategies.

Congestion pricing may be a critical and efficient method of managing congestion and enhance system efficiency. The current national momentum is growing and aids in the implementation of trial projects. Many states are closely watching the deployment and performance of existing projects. Setting up the appropriate framework and data tracking for measurement, evaluation, and communication will not only affect that specific state or MPO, but its success has potential impacts on many others.

The research objective is to create a guide that provides Departments of Transportation (DOTs) and MPOs with specific information to develop appropriate performance measures, track data, and evaluate and effectively communicate the results of pricing projects based on various goals, but especially in terms of efficiency, system management, and maximizing throughput and available capacity.

Specific measures that should be considered during the course of this research include system efficiency; system management; maximization of throughput and capacity; efficiency related to collection methods and tools; measures related to user benefit (such as decreased travel time and increased

travel reliability); and measures related to efficiency and equity in toll revenue allocations.

♦ Project 08-76
Strengthening and Integrating Safety in the State and Regional Planning Processes: Best Practices and Recommended Procedures

Research Field:	Design
Source:	AASHTO Standing Committee on Highway Traffic Safety
Allocation:	$400,000
NCHRP Staff:	Lori L. Sundstrom

In TEA-21, safety was made a required decision factor in the transportation planning process. In SAFETEA-LU, the preparation of Strategic Highway Safety Plans (SHSPs) was mandated. Each requirement is unique and separate, but they complement each other. Implementing these two requirements and facilitating the integration and reinforcement of each others goals must be ensured if these efforts are to meet their intended goals.

What the states and regional planning agencies are doing to implement the safety planning factor in their planning processes, as required by SAFETEA-LU, is unknown. What effect has this had on institutional changes, cooperation, and communication been planning and safety offices and other partners? What are the technical and/or policy benefits from any changes?

An additional question that should be answered is how well the states have coordinated the SHSP and planning factor (referred to as safety conscious planning or SCP in SAFETEA-LU) processes to complement and improve those respective processes. Another question relates to what the states and regional planning agencies believe they need in order to better accomplish this coordination. For example, do safety and planning professionals understand the benefits of collaborating and sharing—both in meeting the legislative mandates and for the larger goal of improving highway safety? Do decisionmakers have a similar understanding, and what is the best way to communicate this to them?

Finally, once the state of practice is known, what steps and tools are needed in the short and long term to improve and institutionalize these processes so that safety and planning coordination and collaboration become integrated into standard operating processes and thinking at state and regional planning agency levels?

The objectives of this project are to:

1. assess the state of the practice, at state and regional levels;
2. develop techniques and methods to more efficiently and effectively accomplish the federal mandates, potentially including:
   a. documenting best practices;
   b. developing and recommending procedures, performance measures, and policies for meaningfully integrating safety into the capital improvement programming process;
   c. initiating an outreach program to educate and train state and regional planning agency staff in using tools and techniques to more effectively incorporate safety into long-range planning and bringing planning into the SHSP process;
   d. developing case studies that illustrate the effective use of safety as a planning decision factor and showing the benefits of planning input to the SHSP process; and
   e. developing outreach methods such as websites and newsletters to highlight tools and techniques.
3. develop recommendations for implementation of the techniques and products developed, e.g., support or work with professional organizations for state and regional planning agencies in the short term and develop a strategic/action plan for longer term implementation.

The SHSP and safety conscious planning processes are in relatively formative stages. Quick action is required to ensure that these processes mature and become institutionalized so that they can assist safety, planning and policy/decisionmakers. State-of-the practice research can also inform the reauthorization discussion but must be accomplished now to be timely.

Transportation planners, especially at the state and regional level, safety staffs, and decisionmakers across the country would have use for this information developed by this project. Groups such as the Transportation Safety Planning Working Group, AASHTO, FMCSA, AMPO/NARC/NADO, and GHSA would use this information and these

techniques to train, educate, stimulate, and motivate their respective constituencies.

Materials and techniques developed through this project would be used by professional associations, specialty groups, state DOTs and their partners in the SHSP, and regional and local agencies and governments to examine their processes, adopt techniques/strategies from this project, and train staff and decisionmakers. Initially, implementation could be expedited working with the Transportation Safety Planning Working Group which includes the relevant federal, state, safety, and planning organizations.

NOTE: The AASHTO Standing Committee on Research added Problem No. 2009-G-37, "Highway Safety as an Asset: Incorporating Safety Performance Metrics in State Level Planning and Programming," to this study.

♦ Project 09-44A
Validating an Endurance Limit for HMA Pavements

Research Field:	Materials and Construction
Source:	NCHRP Project Panel D09-44
Allocation:	$500,000
NCHRP Staff:	Edward T. Harrigan

Implementation of a fully characterized endurance limit in the mechanistic-empirical pavement design guide (MEPDG) software will enhance the ability to prepare long-life HMA pavement designs that achieve a balance between practical layer thickness and satisfactory fatigue performance.

NCHRP Project 9-44 prepared a multi-part work plan to (1) validate, through an analysis of laboratory and field data, the existence of an endurance limit for HMA pavements characterized in NCHRP Project 9-38; (2) determine, insofar as possible, the shift factor between the endurance limits for HMA mixes measured in the laboratory and the field; and (3) identify and recommend methodologies for incorporating an endurance limit in the MEPDG and other approaches to HMA mechanistic-empirical pavement design.

Based on the results of a workshop with the participation of U.S. and international experts in HMA fatigue cracking, the 9-44 contractor has proposed the incorporation of a variable endurance limit that is likely a function of mixture composition, binder properties, temperature, aging, and duration of rest periods in HMA pavement analysis through the modification of current fatigue relationships in the MEPDG. Thus, the work plan includes a laboratory experiment to quantify the effect of these variables on the rate of damage and damage recovery.

The work plan further proposes to use accelerated pavement testing to validate certain effects in the high-strain region of the fatigue curve; however, the overall validation and calibration effort will include both accelerated pavement tests and the evaluation of in-service pavement sections. The latter analysis requires the sections' detailed composition and construction history, which will require the need to make and document assumptions where firm data do not exist. This situation argues for an in-depth analysis of a small number of well-documented pavements.

The objectives of this project are to carry out the work plan developed in Project 9-44 to (1) validate the existence of an endurance limit for HMA pavements and (2) recommend changes to the MEPDG necessary to incorporate a fully capable endurance limit.

♦ Project 09-48
Field versus Laboratory Volumetrics and Mechanical Properties

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

Most federal and state DOTs and many local agencies have adopted Quality Assurance (QA) programs for use on hot mix asphalt (HMA) pavement projects. The QA approach requires the contractor and the agency to share testing responsibilities. Typically, the contractor conducts the majority of the testing for quality control and acceptance purposes and the agency conducts fewer tests to verify the contractor's test results.

Many specifications require the measurement of volumetric properties by both the contractor and agency as part of the QA program. Typically, the volumetric properties that are measured include air voids, voids in mineral aggregate (VMA), and percent voids filled with asphalt (VFA). Volumetric testing is performed on compacted samples of HMA material.

Many projects also require testing of mechanical properties of the produced HMA, such as moisture susceptibility tests, rutting tests, and stability tests. These mechanical tests too are conducted on compacted specimens of HMA. The same sampling and compaction equipment and procedures that are used to generate the compacted specimens for volumetric testing are generally used to produce specimens for mechanical testing.

As with other QA test results, the results of the volumetric testing conducted by the contractor and agency are compared statistically to verify the accuracy of the contractor's test results. This comparison helps the agency make a judgment about whether its QA test results are from the same population as the contractor's test results. However, because different operators using different testing equipment are performing the tests, variability of the test results is inevitable. Therefore, it is essential that the variability of the test results arising from sampling, splitting, equipment, and operator bias be kept to a minimum.

Another potential source of variability occurs if the location and makeup of the samples are not the same (laboratory produced versus field produced), the location of compaction is not the same (laboratory compacted versus field compacted), or both. Unfortunately, many specifications require the comparison of volumetric mixture properties from different locations and with different compaction methods. A major barrier to conducting a legitimate, defensible QA program is quantifying the variability expected when comparing volumetric properties for different materials produced in different circumstances (laboratory blended/mixed versus plant blended/mixed), compacted in different locations, compacted with different equipment, and with potentially different test procedures.

Specifically, the three possible scenarios for production of specimens for HMA QA testing of volumetric and mechanical properties are: (1) laboratory mixed-laboratory compacted specimens, (2) field mixed-laboratory compacted and (3) field mixed-field compacted. It is essential to fully understand and quantify the variability between the expected results from each of these scenarios. Further, it is important to understand the causes of the differences in volumetric or mechanical results. A research project is needed to identify the differences and causes of the differences between volumetric and mechanical properties obtained on samples from each of the three scenarios discussed.

The objectives of this project are to (1) define the causes of differences in volumetric and mechanical property test results among three QA specimen types: (a) laboratory mixed and laboratory compacted, (b) field mixed and laboratory compacted, and (c) field mixed and field compacted; and (2) develop a recommended practice for QA programs that identifies and helps minimize sources of variability arising from mixing and compaction in the testing of compacted HMA specimens.

The following tasks are anticipated to accomplish these objectives: (1) review the state-of-the-practice of QA testing programs that include volumetric or mechanical testing of compacted HMA specimens and identify previous, current, or proposed studies that address this issue; (2) based on the results of Task 1, conduct an experiment (including both lab and field mixing and compacting) on actual field projects using different HMA types to determine the variability and its causes for volumetric and mechanical property test results obtained from specimens prepared by the three mixing and compaction scenarios; (3) analyze the data from the Task 2 experiment and report preliminary findings, including a draft recommended practice for comparison of volumetric and mechanical properties, including variability, to be used in statistical comparison software; (4) validate the preliminary results from Task 2 in a separate series of field projects with respect to degree and cause of variability between volumetric and mechanical test results among the three mixing and compaction scenarios; and (5) prepare a final report that summarizes the findings of the project, identifies the variability and causes of variability among the three mixing and compaction scenarios, and presents a recommended practice for development of a QA specification where volumetric and mechanical properties are included.

♦ **Project 10-77**
Developing Guidelines for GPS (Geographical Positioning System) Controlled Construction Machine Guidance and Required CADD Software

Research Field: Materials and Construction
Source: Utah
Allocation: $500,000
NCHRP Staff: David A. Reynaud

Increasingly, the highway construction industry is using GPS controlled construction machinery to build highway improvements. Some Departments of Transportation (DOT) have been hesitant to accept the technology and provide digital files to aid the contractor building the highway. Some possible reasons for the hesitations are: possible manipulation of data, incompatibility of CADD programs, and unknown precision and quality control. The GPS construction automated technology has been used successfully by the private sector for some time, and the public sector is being pressured increasingly to use it. This technology has the potential of saving time and money when used properly. The DOTs need guidelines to help them understand and use the technology, without affecting quality and budget negatively.

Evaluate current GPS controlled construction machine technology to verify accuracy and efficacy. Develop policies and guidelines for implementing GPS controlled construction machinery to aid DOTs in the use of the technology. The guidelines should include a list of available related technologies, CADD/GPS interface, and quality control of completed work. The research should also evaluate the potential errors and liability.

This is very urgent research; the technology is currently being used by many construction companies across the country. The policy can be used to guide DOTs in automated construction.

♦ **Project 10-78**
Analysis of Nighttime Construction Activities and Impacts to Safety, Quality, and Productivity

Research Field: Materials and Construction
Source: AASHTO Highway Subcommittee on Construction
Allocation: $250,000
NCHRP Staff: David A. Reynaud

The aging of state and local roads and highways and the availability of funding by the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) have increased the number of major highway maintenance, rehabilitation, and reconstruction (MRR) projects. Large highway MRR projects can cause significant disruptions to travel patterns and economic activity. MRR activities could be expedited by closing the facility, but in many situations, the remaining transportation network is not able to accommodate the redirected traffic volumes. A method to reduce the impact on the traveling public and area businesses during highway MRR projects is to schedule nighttime work. The advantage in performing MRR activities during off-peak hours is the reduced impact on the traveling public due to decreased traffic volumes. Construction activities during periods of lower traffic volumes minimize inconveniences to highway users and impacts on local businesses. However, nighttime construction introduces other issues to consider including increased safety hazards due to fatigue and poor visibility conditions, impacts on quality of the constructed product, and construction productivity.

Research should address the following questions:

a. According to literature and past studies, work-zone construction illumination impacts safety, quality, and productivity. Lack of proper illumination or improper uses of lighting equipment are causes of construction-related accidents. What are the most effective construction illumination methods? What are the gaps between nighttime construction illumination research and current practices?
b. What is the impact of nighttime MRR activities on productivity? Which construction activities are more/less productive when performed during nighttime periods? How do the availability and delivery of materials effect nighttime efficiency? How does the use of multiple shifts influence productivity?

c. How does nighttime construction affect the safety of the traveling public? How is the safety of construction personnel in highway work-zones affected?
d. Some reports indicate improved quality of concrete pavement placed during periods of lower temperatures. Other studies have determined that the lack of visibility at night is unfavorable to the inspection efforts of asphalt pavement, as surface flaws are difficult to see. How are the qualities of different products impacted by construction during nighttime hours?
e. What is the impact of nighttime work on state highway agency (SHA) resources? What is the cost increase for SHAs to conduct/inspect nighttime MRR activities?
f. What environmental factors are affected by nighttime operations (Noise, vibrations, night lighting affects on adjoining properties)? How do local permits or ordinances affect work and bidding?

Identify best practices and recommend strategies for nighttime construction operations from analysis of current practices to improve: (a) safety of construction personnel; (b) safety of traveling public; (c) quality of the constructed facility; and (d) productivity of nighttime MRR activities.

The research objective will be achieved through the completion of the following tasks:

1. Literature Search – A literature search should be conducted to review the latest studies on nighttime construction operations. The review should focus on the impacts of nighttime activities on safety, quality, and productivity.
2. Review of Current Practice – Collect information from SHAs and contractors to identify what nighttime construction methods are being conducted for which types of highway MRR projects. Identify advantages and disadvantages in using nighttime construction for projects related to the safety of construction personnel and traveling public, quality of the constructed facility, and productivity of nighttime operations. Additionally, evaluate success and failures of past nighttime MRR projects.
3. Recommendations – Establish recommendations, based on information gathered, to improve safety, quality, and productivity of nighttime operations. Recommendations should also include plans to facilitate implementation of new or innovative ideas.
4. Final Report – The final product of this research will be a report documenting best practices to maximize safety, quality, and productivity in nighttime highway construction work-zones. Additionally, the report must include guidelines to aid SHAs in conducting MRR activities. The guidelines should be aimed at two audiences: 1) SHAs not currently specifying nighttime construction; and 2) SHAs wishing to improve the efficiency of nighttime construction.

♦ Project 10-79
Guidelines for Pavement-Related Pay Adjustment Factors

Research Field:	Materials and Construction
Source:	AASHTO Joint Technical Committee on Pavements
Allocation:	$250,000
NCHRP Staff:	Amir N. Hanna

A number of analysis tools are available to highway agencies that provide an assessment of the impact of various factors on the performance of a pavement section. Additionally, the highway industry in general is migrating from traditional, method-based specifications to end-result or performance-based specifications. Typically, these types of specifications incorporate pay adjustment clauses aimed at capturing the value lost or gained by variance from specified properties and thus serve as an incentive/disincentive to the contractor for performing the work.

Literature review revealed several papers and reports on performance-based specifications, pay adjustments, and pay factors that tend to focus either on one material or material factor or on the general statistics of quality control and quality assurance. Little or no research was found providing general guidance on various approaches for determining incentive/disincentive amounts, value to the traveling public, and their legal ramifications. Because variability in pavement performance caused by construction-related activities can have a significant financial impact to the agency and

ultimately the highway users, research is needed to provide general guidance in these areas.

The research objectives are summarized as follows:

- Determine the procedures currently being used by transportation agencies to set pay adjustment amounts.
- Discuss the legal aspects of pay adjustment and current legal standards involving penalties and restitution as they pertain to highway construction, especially with regard to asymmetric incentives and disincentives.
- Outline the available methodologies for determining pay adjustment amounts and procedures and discuss the benefits and disadvantages of each.
- Provide general guidance to transportation agencies on establishing pay adjustment amounts while realistically considering the predictive and sampling limitations faced by most agencies.

♦ Project 12-82
Developing Reliability-Based Bridge Inspection Policies

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

The National Bridge Inspection Standards (NBIS) mandate the frequency and methods utilized for the safety inspection of highway bridges. These standards have been developed in the context of available knowledge and experience in regard to the performance and behavior of bridges. The NBIS support the important goals of ensuring public safety and providing a framework for decision making regarding funding distribution and eligibility of bridges. The implementation of the NBIS also provides data for the management and maintenance of highway bridges on the local, district, and state level.

The inspection intervals specified in the NBIS require routine inspections to be conducted generally every two years, although it is possible to extend that period to four years with FHWA approval. For bridges with fracture critical elements, two year in-depth inspections also are required. These specified intervals are generally not based on the performance of specific bridge materials or designs, but rather are intervals based on experience and generally what is believed to be reasonable practice for managing almost 600,000 bridges in the national bridge inventory (NBI).

These inspection intervals are equally applied to the entire bridge inventory and may not be appropriate for specific bridges. For example, recently constructed bridges typically experience few problems during their first decade of service. Under the present requirements, these bridges have the same inspection frequency as a 50-year-old bridge that is reaching the end of its service life, and may face severe and rapid modes of deterioration. In the case of bridges with fracture critical elements, newer bridges with improved fabrication processes and designs intended to mitigate the effects of fatigue are inspected on the same interval as older bridges that do not share these characteristics.

A more rational approach to determining the appropriate inspection intervals for bridges would consider the design, details, materials, age, and loading of specific bridges. There is a growing consensus that these inspection intervals could be optimized toward meeting two goals: increasing the safety and reliability of bridges, and decreasing inspection costs.

To meet these goals, the proposed research intends to examine the reliability of bridge materials and systems, in an effort to integrate existing knowledge and experience with policies and practices governing the inspections of highway bridges.

The suggested research also will leverage and capitalize on other active research efforts, including the ongoing NCHRP synthesis topic on bridge inspection practices, which is expected to provide supporting data for the implementation of improved and rational bridge inspection practices. The suggested research also will benefit from support and data provided through the FHWA Long Term Bridge Performance Program, and will leverage the results of that program to develop new practices and policies directly affecting bridge inspection practices.

The objective of the proposed research is to develop rational methodologies for determining the appropriate inspection frequency for highway bridges. These methods will consider the reliability of bridge systems, including design, details, materials, age, and functionality of bridges in determining the anticipated performance and deterioration of bridges and bridge elements. The implementation of tiered inspection methodologies will be considered as a method of improving overall efficiency. The methods will be useful for determining an inspection interval that precedes the onset of critical deterioration modes. This will allow for bridge owners to dedicate limited resources to the most at-risk bridges.

The proposed research envisions a sea-change to the requirements of the NBIS and as a result has both high urgency and high potential payoff. The current approach is having a significant impact on the resources available for the inspection and monitoring of the nation's most at-risk bridges. The successful completion of this research is expected to improve the safety and reliability of highway bridges across the country by allowing bridge owners that ability to identify and focus resources on at-risk bridges. The implementation of the research is anticipated to be achieved through improvements in the policies and requirements that govern bridge inspections to allow a rational approach that improves the safety and reliability of the bridge population across the country.

♦ Project 12-83
Calibration of LRFD Concrete Bridge Design Specifications for Serviceability

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

The primary motivation for development of the *LRFD Bridge Design Specifications* (LRFD) was to derive rational load factors and resistance factors. These factors were determined through a calibration process that helped achieve a consistent level of reliability for all bridge construction materials, within a range of most typical spans and girder spacing. This calibration was performed at the strength limit state under a new vehicular live load that combines the AASHTO Standard Specification's (STD) truck load (HS20) and uniform lane load (600 lb/ft, including a concentrated load). It should be noted that the truck and the lane load are considered separately when designing bridges by STD.

During the development of LRFD, three phases of trial designs were used to compare designs by LRFD and STD Specifications. The trial phases revealed significant discrepancies between designs of prestressed concrete girders by the two specifications. Compared to STD, designs by LRFD typically required additional strands, or lead to reduced span capability or reduced girder spacing, thus impacting economy. Also, compressive stress limits were not assessed. At about the same time, to accommodate a similar discrepancy, the Ontario Ministry of Transport adopted in their LRFD code a load factor of 0.75. Through limited parametric studies performed under PCI's sponsorship, it was determined that a service load factor between 0.75 and 0.80 would align most designs with those performed by STD. A load factor of 0.80 for AASHTO LRFD Service Limit State III (tension) was adopted as a stop gap measure. The need for this artificial load factor came about because in the design of prestressed concrete girders, the service limit state governs the design in most cases.

Other LRFD service limit states not calibrated with respect to STD include deflections, crack control, and fatigue. The magnitude of service loads by LRFD is higher than that by the Standard Specifications. This increase results in higher computed deflections. Further, the crack control criteria are more stringent in the LRFD compared to STD because the same crack width has to be met at a higher service load.

The LRFD Specifications must be calibrated for all service limit states so that new designs are not drastically different than designs by STD.

The objectives of this research are to calibrate the service limit state provisions of the AASHTO LRFD Specifications and to submit the calibrated criteria for adoption in the AASHTO LRFD Specifications for Highway Bridges. The following tasks are proposed to accomplish these objectives: Task 1 – Perform a literature search using TRIS and other databases; Task 2 – Review

pertinent criteria in the Canadian Highway Bridge Design Code, the British Bridge Code, and structural design specifications from other countries; Task 3 – Calibrate the service limit state provisions relative to the STD, which have served well. Limit states to be considered include limiting tensile and compressive stresses, crack control, deflections, and fatigue; Task 4 – Submit the proposed criteria to the AASHTO Technical Committee T-10 for adoption in the LRFD Specifications

According to the National Bridge Inventory, about 50% of bridge superstructures built annually in the United States are of prestressed concrete. Service limit states typically govern the design of these bridges. The AASHTO LRFD Specifications were calibrated at the strength limit state. An arbitrary load factor of 0.8 for Service Limit State III was adopted to address discrepancy with the designs by STD. However, the economy of prestressed concrete continues to suffer as extra strands are needed, or the span capability and/or girder spacing are reduced. Recommendations from this project will be submitted to AASHTO Technical Committee T-10 and ultimately the AASHTO Subcommittee on Bridge and Highway Structures, for adoption in the AASHTO LRFD Specifications for Highway Bridges.

♦ Project 15-38
Design Requirements for Culvert Joints

Research Field:	Design
Source:	AASHTO Highway Subcommittee on Bridges and Structures
Allocation:	$370,000
NCHRP Staff:	David B. Beal

Traditional methods for the structural design of buried culverts ignore culvert distress emanating from longitudinal, shear, and gasket circumferential stresses at the joint. Typically, it is presumed that alignment and bedding stiffness is uniform in the longitudinal direction of the pipe and the gasket insertion pressures minimal. Accordingly, the structural design of the culvert joint is based on the assumption of in-plane loading of the pipe's cross section, that is, in-plane bending (ovaling, yielding, and cracking) and in-plane thrust (crushing and buckling). Longitudinal bending moments and shear resulting from nonuniform loading and/or variations in the bedding support along the length of the pipe or internal ring tension forces from gaskets are not traditionally considered in the design process.

Contrary to traditional design practice, field observations reveal that longitudinal effects may be responsible for a large number of costly culvert failures. One very prevalent failure mode is initiated by longitudinal variations in bedding stiffness resulting in differential settlement of the pipe, which in turn generates longitudinal culvert stresses and relative joint movements. In the recent NCHRP Project 4-24 for HDPE plastic pipe, pipe cracking from the joint integrity of buried drainage pipe was observed to be extremely sensitive to differential settlement. The supposition is that nonuniform bedding stiffness included joint distress, allowing leakage of groundwater and soil into the culvert, thereby losing vast amounts of soil support, and ultimately, collapse of pipe and destruction of pavement. In like fashion, if a joint is cracked, sheared or over-deflected and opened due to circumferential tension forces from a gasket, the resulting leakage has the same effect.

Another well-known longitudinal problem occurs whenever culverts (concrete, corrugated metal, or plastic) are joined into manholes or headwalls. Here the discontinuity of soil support to the stiffer manhole/headwall support is even further aggravated by the softer than normal soil support due to deeper excavations and poor compaction in the vicinity of the manhole/headwall.

More installations are becoming gasketed in order to prevent infiltration of backfill into the culvert. Insertion force from the compression of a rubber gasket during the connection of two pipe exerts tensile forces on the bell and spigot end of the mating pipe. If the pipe is not structurally adequate to resist these forces, either the bell or spigot will deform, crack, or shear. The consequential opening to the backfill will permit further undermining of the culvert and embankment. Conversely, a reduction of confining stress over time in joints due to the nature of the visco-elastic materials utilized for joints also must be assessed with respect to the type of gasket and pipe employed.

It has long been argued that longitudinal distress resulting from less than perfect bedding alignment and stiffness is a problem that should be

cured by placing tighter controls on the construction/installation methods. Although it is correct that the engineering community should strive to enforce proper construction procedures, reality and long experience has shown that construction always will be less than perfect. Thus, in order to avoid costly repairs, it is prudent to incorporate in the culvert design process some design requirements to account for longitudinal distress resulting from less than perfect construction practices.

The objective of this research is to develop joint design requirements for culvert joints to withstand reasonable variations in bedding stiffness and other nonuniform effects that are anticipated form actual construction and installation practice. All culvert materials are included in this objective, e.g. corrugated metal, reinforced concrete, and plastic pipe.

Steps to achieve the objective include: Survey literature and existing culvert installations to quantify all mechanisms and practices that promote longitudinal, joint, and shear distress at culvert joints; establish design criteria for each failure mechanism, pipe type, and associated joint type, including material time effects. These design criteria are to be based, in part, on the development of anticipated loading conditions from research field and laboratory testing; develop a general design model applicable to all pipe types and joints (such as beam segments with specialized joints on yielding foundation). A sensitivity analysis to incorporate variations in material properties, stiffness, rotational movement, and insertion forces will be included as part of this task; incorporate a three-dimensional model as an optional tool in a primary culvert design program such as ANSYS; develop simplified design procedures and evaluation methods, which may be referenced by ASTM or AASHTO specifications. These procedures and methods would define such properties as joint shear strength, pull tests, maximum insertion force, beam strength, and other related items identified under the design criteria development component of this research project.

It is urgent and imperative that, as pragmatic engineers, we recognized construction practices or as-built conditions invariably deviate from the ideal design world. For example, variations in bedding stiffness are a fact of life that cannot be swept under the rug with the notion it is a problem for the contractor, not the designer. Culverts will continue to fail until we incorporate concerns at joint into our design specifications.

♦ Project 17-44
Investigation of Contributing Factors Associated with Cross-Median Crashes and Identification of Appropriate Countermeasures

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety, Washington
Allocation:	$500,000
NCHRP Staff:	B. Ray Derr

Cross-median crashes (CMC) frequently result in high severity injuries and fatalities. Cross-median encroachments (CME) are similar events that occur without striking a vehicle in the opposing lane. Although they may not result in comparable injury severities, the seriousness of CMC and CME (CMC&E) events are of equal concern. Studies of contributory factors associated with CMC&E have typically focused on median width, and several also have explored ADT. A few have looked at the influence of geometry and cross sectional elements. Although these studies have been helpful, they do not explore the full range of causal factors. The influence of interchange ramps, interchange spacing, mixture of vehicle types, peak period volumes, peak period duration, land use, posted speed, and the presence of speed transition zones on CMC&E is not well understood.

There is also a knowledge gap regarding countermeasures appropriate for the varieties of contributory factors. Understanding when a particular barrier system is and is not appropriate is just as important as knowing that cross-median protection is warranted. Evaluation of contributory factors and injury severities, associated with various countermeasures would provide some insight into which countermeasures to employ to reduce the frequency and severity of these collisions.

CMC&E typically occur on the high priority road network and are associated with loss of life, major injuries, user-delay and negative press coverage. Most transportation agencies are placing barrier systems in their highway medians to address CMC&E. For most agencies, these placement

decisions are based on median width and ADT. This approach may not be targeting locations with the highest overall risk for CMC&E, leaving correctable locations behind. A successful outcome from this research would lead to better choices about sites to protect and countermeasure selection. Research findings also could be used to identify locations for increased enforcement and other countermeasures.

The objective of this research project is to identify statistically significant factors and combinations of factors that influence CMC&E frequency and severity. It is anticipated that this research will:

1. Conduct a literature search for previous research on this topic.
2. Conduct a survey of states for unpublished studies, and a list of factors they believe to be useful in identifying problematic locations for CMC&E.
3. Collect and analyze CMC&E accident data from multiple states to identify hotspot areas.
4. Collect additional information on site characteristics as necessary.
5. Perform statistical analysis of variables, identifying individual variables and combinations linked to higher frequencies and severities.
6. Interview CMC&E survivors (if possible) to get more detailed human factor information regarding causation.
7. Investigate if there are countermeasures other than shielding to address CMC&E.
8. Develop a guide for designers, which presents predictive factors and appropriate countermeasures.
9. Produce a project report detailing the findings from this research. The guide for designers should be included as an appendix.

♦ **Project 17-45**
Interchange Safety Analysis Tool Enhancement

Research Field: Traffic
Source: Maryland
Allocation: $700,000
NCHRP Staff: Charles W. Niessner

The U.S. freeway system is aging and becoming more congested; many parts of the freeway system, particularly interchanges, are in need of reconstruction or rehabilitation. Improved safety is a key justification for many interchange improvement projects, but engineers lack a suitable tool to examine the safety performance of existing interchanges and to anticipate the safety performance of new or rebuilt interchanges. A preliminary tool was developed by FHWA to estimate crash frequencies of typical interchanges of freeway and arterial, and freeway to freeway. The Interchange Safety Analysis Tool (ISAT) is a spreadsheet that consolidated crash prediction models and modification factors on most components of interchange systems in urban and rural areas. ISAT provides crash estimates of various typical interchange configurations over an economic life specified by users. This tool however requires significant enhancements to improve the quality of the underlying models, expand to key highway characteristics, and calibrate the models for some state data.

The objective of this research is to develop additional and stronger crash prediction models for freeway and ramp elements, and to create new models for typical ramp terminal intersections and crash models for crossroad segments affected by these terminals. Another objective is to account for additional interchange characteristics or useful variables. And a final objective is to upgrade the interchange safety analysis tool (ISAT) spreadsheet to be more practical and user friendly and compatible with existing procedures. The following tasks are recommended: (1) determine major models and highway characteristics that should be improved and additional models that should be developed and useful variable to be considered; (2) acquire the data and conduct the analysis; (3) update the ISAT program; (4) select two states with adequate data to calibrate the ISAT program and calibrate the models to the selected states to be readily available for direct application; and (5) prepare a final report, and a user manual.

This project will provide the much needed tool to create a more reliable interchange safety analysis tool that is very useful to engineers and planners in conjunction with environmental and traffic impact studies.

Note: The AASHTO Standing Committee on Research combined Problem 2009-G-35, Safety Prediction Methodology for Freeways and Interchanges, with this study.

♦ **Project 19-08**
Costs of Alternative Finance Systems

Research Field: Administration
Source: Federal Highway Administration
Allocation: $200,000
NCHRP Staff: Andrew C. Lemer

Historically, implementing tolling or other means of non-fuel-based taxation and fee collection have required substantial investments in both capital and labor for toll collection, administration, and toll system financial management. The potential to use tolls and pricing is significantly dependent on the ability to introduce technological changes that have the potential to lower the cost of collecting tolls, monitor usage for various forms of pricing, and expand the portions of the network for which revenues can be collected from major limited access highways to virtually any element of the highway system.

However, it also is becoming clear that alternatives to the fuel tax may substantially increase the cost of collecting revenue—especially when initial investments in advanced technologies and collection systems are considered. In addition, commitment to any particular form of pricing or toll collection may affect future performance and efficiency of these systems by setting in place a specific (legacy) infrastructure. Hence, it is desirable to determine the cost and benefits of various pricing systems, evaluate how these are likely to change over the foreseeable future, and assess how compatible various systems are with each other and with the phase-out of the fuel tax. Different approaches to pricing and tolling will have different effects on the efficiency of management of the road system. In addition, the shift in reliance away from fuel taxes and toward alternative pricing systems will affect both the administrative and compliance costs of future revenue generating systems. Ultimately, there must be some balancing of the cost of various pricing systems with the benefits that are likely to occur.

There is a growing literature that raises questions of whether the cost of pricing and tolling systems offsets many of the benefits that pricing can generate. For example, Prud'homme and Bocarejo (*Transport Policy* 12 (2005): 279-287) conclude that the cost of the London congestion charging system exceeds the benefits. While their conclusion has been contradicted by others, the substantial cost is an issue in determining whether alternative revenue systems are desirable and in making comparisons among systems. Even the cost savings of replacing toll collectors with transponder systems has been questioned by Peters and Kramer (*Transportation Quarterly* 57:3 (Summer 2003): 17-31), who find the switch to EZ Pass on The Garden State Parkway increased the administrative cost of the system. The Road User Fee Task Force in Oregon considers the affordability of alternative financing options as an important factor in decision making, and recommends mileage-based user fees partly because the capital cost of a statewide implementation would result in less than a 2 percent increase in the mileage fee rate (Oregon DOT Report, March 2006, *Public Involvement and Road User Charge Development: Oregon's Experience*).

The research will seek answers to the following questions, among others:

- What percentages of revenue raised are the administrative and compliance costs of current and proposed revenue systems, e.g., gas tax, tolls, and area pricing? How are these likely to change with improvements in technology?
- What factors determine the capital and operating costs of alternative revenue collection systems, and how do these factors influence those costs?
- What is the difference in administrative and compliance costs for flat tolls, tolls that vary over time, tolls that vary based on distance, and other variable tolls?
- What would a comprehensive road pricing system cost to implement now and how is that cost likely to change in the future?
- How would evasion and enforcement costs differ for toll and pricing systems as compared to fuel tax systems? How would they differ

between a federally enforced system and a state system?

- What issues are likely to arise in trying to coordinate different pricing and tolling systems?

♦ Project 20-81
Challenges and Successes in Attracting and Retaining a Skilled Transportation Workforce

Research Field:	Special Projects
Source:	AASHTO Highway Subcommittee on Maintenance
Allocation:	$350,000
NCHRP Staff:	Christopher J. Hedges

Many transportation agencies are experiencing difficulty in attracting and retaining skilled employees. Competition with other industries and fields poses a serious challenge to the agencies in their attempt to fill positions. Many agencies are losing substantial numbers of experienced personnel to attrition, and facing serious difficulty in finding replacements. Often, trained employees retire after many years of service, but an equally important issue is that other younger employees leave for higher pay or better working conditions. Without a skilled workforce, accomplishing agency objectives becomes almost impossible. The proposed project will represent a way for agencies to share ideas and practices that have been successfully used to meet their long-term workforce needs.

Without a skilled workforce, all aspects of an agency's transportation program are at risk, with dire consequences to the state and national economy. Some agencies have adopted short-term solutions like outsourcing or supplementing their workforce with consultants or contractors; however, that approach is costly and generally not sustainable over the long term. The long-term strategy of training employees and keeping them within the agency is essential. This project will supplement work that NCHRP 20-72 is currently conducting.

The objective of this project is to identify and document effective strategies for Attracting and Retaining a Skilled Transportation Workforce. The work will include the following tasks. Task 1 – Develop a process to identify programs that state transportation agencies have used to attract and retain skilled employees. Task 2 –Summarize various practices, evaluate the outcomes and the reasons why the practices succeeded or failed. What external factors (state of the economy, population fluctuations) affect program outcomes? Does the program represent a long-term solution that will sustain the fluctuations of economy, demographics, and other external factors? Task 3 –Discuss lessons learned and recommendations on effective practices in establishing programs for attracting and long-term retention of skilled employees. The report should include the above and showcase successes and failures, and explain factors that affected the overall outcome. Develop a best practices guide for attracting and retaining employees.

♦ Project 20-82
Next Generation of the FHWA Transportation Pooled Fund (TPF) Website

Research Field:	Special Projects
Source:	Minnesota
Allocation:	$400,000
NCHRP Staff:	Nanda Srinivasan

The existing TPF website was developed several years ago. Based on discussions with various levels of government and in cooperation with AASHTO's Research Advisory Committee (RAC) it is felt that an upgrade to the TPF website is necessary. The upgrade should enhance capabilities, expand the usage and functionality of the existing TPF website, and include the development of new templates and tools. A business model approach should be used when upgrading the website to assure the core capabilities of the entire research website are examined.

Prior to actually funding an upgrade to the TPF website, an analysis of the website's current and future business processes and procedures should be reviewed at a strategic level. Looking at existing processes and systems from a strategic level will help identify gaps and opportunities and provide a strategic formation of the new website without overlooking the smallest detail. The development of TPF website business model would provide long-lasting value for the website customers.

The business model and requirements that support the new and existing mission critical functions of the TPF website then can be incorporated into the design and deployment of a new TPF website.

The implementation of the new FHWA SP&R Financial Accounting Procedures has increased the urgency of a new and improved TPF website. The need for additional information on the financial status and progress being made on SP&R pooled fund research projects via the TPF webite is essential.

♦ Project 22-26
Identification of Factors Related to Serious Injuries in Crashes of Motorcyclists into Traffic Barriers

Research Field:	Design
Source:	AASHTO Technical Committee on Roadside Safety
Allocation:	$500,000
NCHRP Staff:	Charles W. Niessner

Motorcycle riders now account for more fatalities than the passengers of any other vehicle type involved in a guardrail collision. In 2005, motorcycle riders accounted for 42% of all fatalities resulting from a guardrail collision. Following motorcycle riders were car occupants with 32% of all fatalities in this crash mode. This is particularly surprising as cars compose over half of the vehicle fleet (55%) while motorcycles compose only 3% of the registered vehicles. In terms of fatalities per registered vehicle, motorcycle riders are dramatically overrepresented in number of fatalities resulting from guardrail impacts.

Before the motorcycle-barrier problem can be addressed, there is a critical need to better understand the nature of the problem. Unlike passenger cars, however, there is virtually no in-depth crash investigation data describing motorcycle crashes. The most in-depth study, the Hurt Report, is based upon crash data that is now over 25 years old, and no longer adequately reflects either the motorcycles or barriers currently on the highways. Needed is a new in-depth investigation of serious and fatal motorcycle crashes into roadside barriers, which determines the characteristics of the driver, barrier, motorcycle, and roadway that control the incidence and outcome of motorcycles crashes.

Cable barrier provides an example of a very effective barrier system, which is threatened by this lack of in-depth crash data. Motorcycle activist groups perceive cable barrier as a particular threat to motorcyclists referring to this barrier design as “cheese cutter.” Both in the United States and overseas, these groups have actively lobbied for a ban on this type of barrier. In Norway and the Netherlands, these groups have succeeded in exerting sufficient political pressure to have cable barrier banned. To date however, there is little evidence to either support or refute the claims that cable barrier is more dangerous than w-beam barrier.

Likewise, the lack of crash data prevents any understanding of injury mechanisms in motorcycle-barrier collisions. As an example, impacts into guardrail have been found to be much more dangerous than impacts into concrete barrier. It has been theorized that this difference in fatality risk may be because guardrail posts carry an extra risk to motorcyclists. Under this theory, there is a need to pad or otherwise protect the motorcyclist from the posts. An alternate theory however is that the difference may be related to impact speed. The conjecture is that crashes into guardrail impact may occur at a higher speed than crashes into concrete barrier, and post padding would have little effect. Without in-depth crash investigations, it is not possible to determine which theory is correct.

Equally important to reducing the motorcyclist-barrier fatalities is the need to continue protecting passenger car occupants who are involved in barrier collisions. Programs such as NCHRP 350 crash testing have established an admirable record of safely redirecting errant vehicles onto the road without undue occupant risk. Any suggestion that cable or any other type of barrier should be removed to protect motorcyclists is unacceptable. Rather what are needed are barrier designs, safety programs, and research that can extend the safety record of barrier performance in car collisions to also encompass motorcyclists.

Serious injury motorcycle crashes are increasing. A significant number of these involve a motorcyclist that hits a traffic barrier. However, it is unclear if the impact with the barrier is the most

significant event involved in the injury. It may be possible that severe injuries occur in events prior to the impact with the barrier (such as an automobile impact with the motorcyclist or the motorcyclist hitting the pavement). It is also possible that vehicle improvements or improved training and enforcement may have a greater effect on the reduction of these crashes. This research will help direct the focus of efforts to improve safety for motorcyclists on the nation's highways.

The objective of this research project is to identify characteristics involved in serious injury and fatal motorcycle collisions with traffic barriers. It is anticipated that this research will (1) conduct a literature search for previous research on this topic; (2) develop an evaluation plan that will result in a statistically significant sample of serious injury crashes between motorcyclists and traffic barriers; (3) conduct an in-depth investigation of serious and fatal motorcycle crashes into roadside barriers including driver (age, alcohol, injury outcomes), crash (speed, angle, sliding/nonsliding), barrier (cable, w-beam, impact location), roadway (highway geometrics, pothole), vehicle (make and model of m/c), and environment (day/night, wet/dry, oil); (4) identify crash characteristics where it may be beneficial to further explore countermeasures; and (5) produce a project report detailing the findings from this research.

♦ Project 22-27
Update Roadside Safety Analysis Program (RSAP) Software and Default Data Elements

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

RSAP was developed under NCHRP Project 22-9, "Improved Methods for the Cost-Effectiveness Evaluation of Roadside Safety Feature," to update and enhance the cost-effectiveness analysis algorithms and procedures of the ROADSIDE software included in the Roadside Design Guide (RDG). Subsequently, under NCHRP Project 22-9(2), RSAP was revised and Appendix A was included in the 2002 edition of the AASHTO Roadside Design Guide.

Since the release of RSAP, users have identified some bugs and problems with the program in field applications. Efforts to fix these program bugs and problems resulted in numerous revisions and "patches" to the program over the years. In addition, a number of needed enhancements have been identified that would improve the operation and functionality of the program under current PC operating systems.

Another area of concern is the appropriateness and consistency of the default relationships and data tables embedded in the program. Recent research has improved insights on the relationships about the probability of roadside encroachments, the severity of crashes, and nature of roadside features. The NCHRP projects that led to the development of RSAP did not have the resources to update the relationships and data, so the best available were used. For example, the severity indices tables are believed to need a critical review and updating based upon the results of thousands of RSAP runs made under NCHRP Project 22-12(2), which is aiming to provide guidelines for cost-effective deployment of barriers. Other, more mundane default items, such as costs and lists of basic user-selectable elements in the program, may also warrant updating.

This effort is expected to make appropriate updates to the RSAP documentation to allow an updated version to be included in the next version of the Roadside Design Guide.

The objectives of this project are to rewrite the software and update the embedded default data tables (e.g., severity indices) of the RSAP. To accomplish the project objective the following tasks are recommended: (1) conduct a literature review for updating the algorithms, procedures and built-in data of the RSAP program, including the severity indices; (2) rewrite the software; (3) update the severity indices; (4) conduct beta testing of the program and make revisions; and (5) submit the final report and software.