NCHRP Web Document 51 (Project D10-58): Contractor's Final Report

Construction Engineering and Management Research Program

Prepared for:

National Cooperative Highway Research Program
Transportation Research Board
National Research Council

Submitted by:

Jeffrey S. Russell
University of Wisconsin—Madison
Madison, Wisconsin

Stuart D. Anderson
Texas A & M University
College Station, Texas

David Trejo
Texas A & M University
College Station, Texas

Awad S. Hanna
University of Wisconsin—Madison
Madison, Wisconsin

November 2002

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program (NCHRP), which is administered by the Transportation Research Board (TRB) of the National Academies.

CONTENTS

Acknowledgments, iii

Chapter 1: Introduction, 1

1.1 Background, 1
1.2 Research Problem Statement, 7
1.3 Research Objective, 8
1.4 Research Approach, 8
1.5 Organization of Document, 10

Chapter 2: Data Collection, 11

2.1 Chapter Organization, 11
2.2 Task 1: Initial Questionnaire, 11
2.3 First Round Delphi Survey, 17
2.4 Second Round Delphi Survey, 24
2.5 Combination of Issue Statements, 34
2.6 Task 1: Third Round Delphi Survey, 38
2.7 Task 2: Literature Search, 42
2.8 Chapter Summary, 43

Chapter 3: Draft Research Program Development, 44

3.1 Chapter Overview, 44
3.2 Task 3: Draft Research Program, 44
3.3 Task 4: Develop Plan and Format for the Workshop, 46
3.4 Task 5: Interim Report, 47
3.5 Panel Meeting, 47
3.6 Task 6: Conduct the Workshop, 52
3.7 Literature Search Results, 59
3.8 Chapter Summary, 129

Chapter 4: Recommended Research Program, 130

4.1 Chapter Overview, 130
4.2 Recommended Research Project Overview, 130
4.3 Implementation Plan, 134
4.4 Recommended Research Project Order, 135
4.5 Recommended Research Program, 135
4.6 Implementation Timeline, 172
4.7 Chapter Summary, 173

References, 174

Appendix A. Initial Questionnaire, A1

Appendix B. Results from Initial Questionnaire, B1

Appendix C. Delphi Invitation Package, C1

Appendix D. Delphi Invitation Follow-Up Letter, D1

Appendix E. Delphi Survey Round One, E1

Appendix F. First Round Delphi Follow-Up Letter, F1

Appendix G. Experience of the Delphi Participants, G1

Appendix H. Delphi Survey Round Two, H1

Appendix I. Second Round Delphi Follow-Up Letter, I1

Appendix J. Results from Delphi Survey Round Two, J1

Appendix K. Delphi Survey Round Three, K1

Appendix L. Third Round Delphi Follow-Up Letter, L1

Appendix M. Delphi Thank You Letter, M1

Appendix N. Pre-Workshop Packet, N1

Appendix O. Workshop Participants, O1

Appendix P. Workshop Packet, P1

Appendix Q. Anticipated Keynote Speech "Research –Beyond TEA-21," Q1

Appendix R. Workshop Data Summary, R1

Acknowledgments

The research reported herein was performed under NCHRP Project 10-58 'Construction Engineering and Management Research Program" by the University of Wisconsin – Madison and Texas A&M University. The work undertaken by Texas A&M University was under subcontract to the University of Wisconsin –Madison. Texas A & M University led the way on the Delphi Method, while the University of Wisconsin – Madison directed the remainder of the tasks.

Jeffrey S. Russell, Professor of the Civil and Environmental Engineering Department at the University of Wisconsin –Madison was the principal investigator. Co-investigators were Awad S. Hanna, also professor of the Civil and Environmental Engineering Department at the University of Wisconsin - Madison, and Construction Engineering and Management Graduate Student Caroline J. Brandt. Co-Investigators from Texas A&M University included Stuart D. Anderson, Professor of Civil Engineering, David Trejo, and Civil Engineering Graduate Student Andrew Damron.

During the initial phases of the project, several surveys were completed by State Highway Agency Personnel, Contractors, Private Design Professionals, Federal Highway Administration Personnel and other agencies. Their time and efforts were greatly appreciated by the research team.

In the course of this project a workshop was conducted that brought together fifty-five experts from around the country who were very knowledgeable in the transportation and construction fields. In particular, Corey Hessen and David Stone of FMI Corporation joined the team to help in the planning and to facilitate the workshop. We would like to thank these experts for their hard work in helping to make this research project a success.

The research team would also like to acknowledge the efforts of the NCHRP 10-58 Panel. Members of this panel offered valuable guidance and recommendations during the course of the project.

Chapter 1 Introduction

1.1 Background

Americans depend on highways for transportation, recreation, and business. State Highway Agencies (SHAs) depend on research and the development of improved technology to provide methods to make highways last longer, operate more efficiently and safely, and do less damage to the environment (TRB 1994). SHAs seek innovative ways to deliver high-quality, cost-effective transportation construction improvements. Construction Engineering and Management (CEM) of highway projects represents a portion of the total project cost. Increasing the efficiency of CEM will not only improve the quality of the constructed facility but will also be a cost effective investment for SHAs. The purpose of this research is to identify critical CEM issues. Implementation of future research and development related to these issues will reduce costs associated with highway projects and improve the quality of the constructed facility. The goal is to identify approximately 15 critical issues facing highway CEM.

This research study is the third in a series of projects funded by the Federal Highway Administration (FHWA). The first two research projects, (FHWA-HO-79-1) and (FHWA-RD-90-034) published in 1979 and 1990 respectively, are summarized in this chapter to review and investigate the methodologies used. In an attempt to introduce new ideas and methods into this study, another project conducted by the Civil Engineering Research Foundation (CERF) was also reviewed. The ultimate deliverable of these projects were recommended research programs to aid in solving the CEM problems facing the SHAs.

1.1.1 1979 Report

By the 1970's many states had realized a need for changes in their methods of CEM. Several states agreed to jointly sponsor a study that would identify areas in CEM in which research would improve efficiency or reduce costs in highway projects. A contract between the FHWA and the TRB used funds from participating states to conduct the study.

The first research project was conducted in 1979 by the Transportation Research Board (TRB) and funded by the FHWA is entitled, 'Research and Development Program for Highway Construction Engineering Management" (FHWA 1979).

This study consisted of two phases. First, the TRB conducted two conferences to identify research and development needs, one workshop on the West Coast held in Pacific Grove, California, and the second held on the East Coast in Williamsburg, Virginia. After the issues from the workshops were compiled into a single list, the second phase was used to assess the issues identified at the conferences by sending surveys to the conference participants.

1.1.1.1 Conferences

A steering committee consisting of state and federal administrators and engineers, educators, contractors, and consultants was assembled to conduct the study. The steering committee organized the workshops and selected the participants. Conference participants were selected from all areas of highway construction engineering and management including state highway agencies, universities, contractors, material suppliers, consultants, attorneys, persons from insurance companies, and the FHWA.

The West Coast conference was held first. During the three-day workshop, the participants were given a background analysis of completed and current work in the industry. After the opening session, the participants were separated into four groups and rotated through four discussion sessions on four topics: (1) quality assurance; (2) construction contract administration; (3) pre-construction activities; and (4) personnel and resource management. During these discussion sessions, workshop participants brainstormed and listed critical issues. Over 100 research and development need statements were collected at the West Coast conference.

The East Coast conference was held approximately two months later and formatted with an approach similar to the previous conference. Participants at the second conference generated as many statements as were compiled at the first workshop. From the research and development need statements collected at both conferences, the steering committee composed a combined list totaling 63 statements divided into six categories: (1) quality assurance (QA); (2) contract administration (C); (3) training (T); (4) pre-construction activities (PC); (5) manpower needs (MN); and (6) outside influences (I).

1.1.1.2 Delphi Surveys

The compiled list of 63 statements collected at the two conferences was prioritized using the Delphi technique (The Delphi method used for this study will be discussed in detail in Chapter 2). Two rounds were necessary to identify the group consensus of the top 17 need statements. The participants of the Delphi process were drawn from the attendees of the two conferences.

The first round requested that the participants indicate the importance of the issues on a three-point scale (A = very important; B = important (not urgent); C = little importance). Also, the respondents were requested to rank need statements in each of the six categories in order of importance (1 = highest priority; n = lowest priority, in a category with n statements). Of the 110 questionnaires mailed, 77 were returned and analyzed.

Each of the six categories was analyzed separately by two different methods. First, the mean priority ranking was computed by taking the average ranking of each issue from all of the respondents. A lower ranking was defined as a higher priority. Second, the weighted importance index was calculated using assigned values (A = 3 points; B = 2; C = 1). The importance index for each issue statement was equal to the sum of the points from all 77 questionnaires.

The first-round Delphi survey successfully prioritized the need statements within the six categories. The average mean priority ranking for each category was calculated. The mean priority ranking data was normally distributed, therefore, approximately half of the statements fell above the average value and approximately half fell below. All statements with a mean priority ranking above the average for their respective category were placed on the list for the second-round Delphi survey. The goal of the second-round survey was to identify the overall priorities. The steering committee selected the statements that would be on the second questionnaire. A total of 28 of the 63 statements were selected to be assessed in the second round.

In the second-round Delphi survey, respondents were requested to rank the 14 most critical statements of the 28 listed. Ninety-two questionnaires were received. The steering committee assigned values to the rankings (Rank 1 = 14 points, Rank 2 = 13 points ..Rank 14 = 1 point). From the results of the second-round survey, the top 17 statements with the highest mean priority rankings were selected as the most important research and development needs in CEM. The top 17 research needs identified by the 1979 study are shown in Table 1.1.

Table 1.1 Top Research and Development Needs in CEM Identified by the 1979 Report

Priority Rank	Weighted Mean Priority Rating	Brief Description
1	6.22	Cost Effectiveness - Sampling and Testing
2	6.02	A Study to Redefine the National Transportation Program for the Next 15 Years
3	5.70	Construction Zone Traffic Safety Problems
4	4.99	Minority-Business-Enterprise Quota Indemnification by Federal Funds-Study of Feasibility and Procedures for Implementation
5	4.73	Review of Sampling and Testing Procedures in Regard to Quality Related to Performance of the End Product
6	4.62	Recruiting, Testing, Promoting, and Retaining Qualified Personnel in Highway Construction
7	4.59	Development of a Pre-construction Activity Planning and Scheduling System
8	4.57	The Effect of Non-transportation Programs and Outside Influences on the Design and Construction of Transportation Facilities
9	4.35	Training, certification, and Retention of Non-engineering Personnel for Quality Assurance
10	4.28	Guidelines for Administrative Settlement of Contract Claims
11	4.13	Productivity Standards for Construction-Engineering Personnel

Table 1.1 Top Research and Development Needs in CEM Identified by the 1979 Report Cont'd

Priority Rank	Weighted Mean Priority Rating	Brief Description
12	4.12	Development of Feasible Incentive and Disincentive Contract Provisions Covering Time for Ensuring Timely Completion of Projects
13	3.90	Productivity Utilization of Construction Manpower During Off-Peak Seasons
14	3.82	A Training Program and Guidelines for Specification Writers
15	3.78	Benefits and Disbenefits of Quality Control in Inspection and Testing by the Contractor and Feasibility of Extending Contractor's Responsibility for Quality Control
16	3.71	Development of More Effective Rapid Test Methods and Procedures
17	3.61	Identification of Causes of Contract Claims

1.1.2 1990 Report

The second research project, conducted in 1990 by the TRB and funded by the FHWA, was entitled, 'Research and Development Program for Highway Construction Engineering Management"(FHWA 1990).

An unpublished study (NCHRP 20-07, Task 26) conducted in 1986 assessed the progress of current and planned research of the 17 development need statements collected in the 1979 study (NCHRP 2001). The purposes of the Task 26 report was to identify completed research relevant to the 17 statements, assess the importance of reports similar to the 1979 study, and to indicate whether another research and development program for highway CEM study was deemed necessary.

The findings of the Task 26 report indicated that a significant amount of research has been completed, or was underway, on the 17 research and development need statements identified in the 1979 study. The FHWA was successful in implementing research projects consistent with the 1979 need statements. Due to changing conditions and priorities, a new study similar to the 1979 report was necessary to further assess future research and development needs in highway CEM.

The 1990 study to identify research and development needs began with the review of the 1986 Task 26 report that assessed current and planned research of the 17 previously collected statements. Two conferences were held to identify the initial statements and then the Delphi technique was used to prioritize the research and development needs.

1.1.2.1 Conferences

Conferences for the 1990 research study were held in Pacific Grove, California from September 25 to 28, 1988 and in Leesburg, Virginia on October 30 to November 1, 1988. The participants of these workshops represented all aspects of the transportation construction industry. The format of the two workshops was set up similar to the conferences conducted in 1979. The participants were separated into four groups and each group attended all four discussion sections during the course of the weekend. During the sections, the participants identified problems and areas of needed research in highway CEM.

The steering committee consolidated over 200 issues collected from both conferences into 72 problem statements. They divided the 72 statements into seven topics: (1) pre-construction (PC); (2) specifications and tests (ST); (3) quality assurance-quality control (QA); (4) education and training (ET); (5) manpower qualifications and needs (MN); (6) contract administration (C); and (7) outside influences (OI).

1.1.2.2 Delphi Surveys

The Delphi technique was used to prioritize the 72 statements produced at the conferences. Respondents were requested to rate the importance of each of the issues on a three-point scale (A = very important; B = important (not urgent); C = little importance). Also the respondents were asked to rank the need statements within each of the six categories in order of importance (1 = highest priority; n = lowest priority, in a category with n statements). The participants were then requested to rank the importance of the seven topic areas (1 = highest priority to 7 = lowest priority). Of the 102 questionnaires mailed, 72 were returned and analyzed.

Each of the categories were analyzed separately for priority ranking and importance index. The priority ranking was calculated by adding the rank value (Rank 1 = n points, Rank 2 = n - 1 points ..Rank n = 1 point, in a category with n statements) from each survey. The importance index was calculated using assigned values (A = 3 points; B = 2; C = 1). The total of all surveys was summed and then divided by the number of surveys to obtain the average or weighted overall priority value.

To determine which statements would be selected for the second-round questionnaire, a mean and median value was calculated for both the priority ranking and weighed overall priority value for each of the seven categories. If the priority ranking and weighted overall priority value of the issue was greater than the mean or median for the category, the issue was included in the list of statements assessed in the second survey. A total of 36 problem statements were selected for inclusion in the second round survey.

A total of 79 second-round questionnaires were received and evaluated. The respondents were requested to rank the top 15 issues. To assess the results, values were assigned to the rankings (Rank 1 = 15 points, Rank 2 = 14 points ..Rank 15 = 1 point). Of the 36 problem statements, 16 were determined to be the top research and development needs. The top 16 research needs identified by the 1990 study are shown in Table 1.2.

Table 1.2. Top Research and Development Needs in CEM Identified by the 1990 Report

Priority Rank	Weighted Rating	Problem Title
1	572	Performance-Based Specifications for Highway Construction
2	492	Construction Claims and Their Resolution
3	452	Development of More Effective Rapid Test Methods and Procedures
4	445	Constructability Review
5	441	Improving the Quality of Work on Highway Projects
6	378	Alternate Methods to Facilitate Timely Reconstruction
7	375	Responsibilities for Quality Management
8	369	Effectiveness of the DBE Program
9	365	Evaluating the Effects of Specifications and Other Contract Requirements on Staffing
10	352	Retaining Quality Professional and Technical Personnel
11	333	Constructability and Operability of Pavement Drainage Systems
12	325	Certification Programs for Construction Engineering Technicians
13	312	Rut Resistant Asphalt Concrete Pavements and Overlays
14	304	Management Skills for Construction Personnel
15	251	Recruiting Qualified Highway Construction Engineering Personnel
16	248	Optimizing the Use of Consultant Versus In-House Staff for the Design and Construction of Public Works

1.1.3 Assessing Global Research Needs

In 1996, CERF published a study that evaluated global construction research needs entitled, 'Engineering and Construction for Sustainable Development in the 21st Century: Assessing Global Research Needs" (CERF 1996). The methods used in the study were similar to those used in the FHWA reports published in 1979 and 1990. The Delphi technique was used to identify and assess issues related to meeting future infrastructure development needs in an environmentally responsible manner. A select list of Delphi participants was composed of leading construction industry practitioners, academics, and government officials representing over 20 countries. Differing from the FHWA studies, CERF used the Delphi technique to identify research needs as the primary stage in the research study.

The results of the Delphi survey helped organize the issues facing the global construction industry into five categories: 1) management and business practices; 2) design technologies and practices; 3) construction and equipment; 4) materials and systems; and 5) public and government policy. Experts in the areas of each category were selected to write papers on the topics. The findings were presented at a symposium in Washington D.C. in 1996.

The first-round questionnaire conducted by CERF contained a section that requested the participants identify current practices, problems with the practices, barriers impeding implementation of completed research, and gaps between research and practice for various issues. The use of this series of questions in the CERF questionnaire is applicable to a section of this research project where problem areas, barriers, and gaps must be identified for each critical issue and used to formulate research problem statements. The question format and phrasing from the CERF questionnaire was used as a model to design the third-round Delphi survey for this research project. Respondents were requested to identify problem areas, barriers, and gaps for each of the critical issues. A complete discussion of the third-round Delphi survey is presented in Chapter 2.

1.2 Research Problem Statement

SHAs continue to seek innovative ways to deliver high-quality, cost-effective transportation construction improvements. CEM costs typically range from 5 to 15 percent of the construction contract amount. Reducing these costs could potentially save millions of dollars for contracting agencies.

Strategies to reduce CEM costs must ensure that the quality of completed projects is not compromised. A reduction in service life of the completed project will result in additional costs that far exceed any savings that could be achieved through reduced CEM costs. Therefore, a well-conceived program of research is needed that (1) supports the highest priorities, (2) builds on completed work, and (3) promotes the successful implementation of the research findings. This program will provide contracting agencies with tools and information to manage the risks associated with implementing innovative CEM practices.

The 1990 FHWA report, "Research and Development Program for Highway Construction Engineering and Management," recommended a priority program of research and development needs for CEM. The report documented the results of an effort prompted by the American Association of State Highway and Transportation Officials' (AASHTO's) Highway Subcommittee on Construction. The effort was initiated by the FHWA under the sponsorship of 18 states and administered by the TRB.

Although there has been considerable research in each of the areas identified in the 1990 FHWA report, priorities may have changed, and further research and implementation efforts need to be assessed. At its August 1998 meeting, the AASHTO Highway Subcommittee on Construction again recognized the need for a coordinated approach to research that focuses on important priorities and implementation techniques.

1.3 Research Objective

The objective of this study is to develop a research program for the AASHTO Highway Subcommittee on Construction that identifies and prioritizes opportunities for improving CEM of transportation projects.

1.4 Research Approach

The objectives were accomplished through the following seven tasks:

Task 1: Questionnaires. Important short and long-term transportation CEM issues affecting SHAs were identified through the use of two types of questionnaires.

Task 2: Literature Search. Information was gathered on the top 15 issues identified in Task 1. The states of knowledge and practice for each issue were summarized; past research products and implementation efforts—successes and failures were evaluated, and barriers to implementation were identified. Gaps in existing knowledge and failures in the implementation of successful research were also identified.

Task 3: Develop Draft Research Program. A draft research program that addresses the gaps in knowledge and implementation identified in Task 2 was developed. The program includes preliminary research problem statements (title, brief scope and objective, and estimated costs and time) that meet the important needs related to CEM of transportation projects. Recommendations for implementing the research program were also addressed.

Task 4: Develop Plan and Format for Workshop. A plan and format for the 2 1/2 day workshop was developed. The purpose of the workshop was to review and evaluate the draft research program, suggest modifications, and recommend priorities. The workshop involved experts in the various subject areas and included representatives from a cross section of the transportation construction community.

Task 5: Submit Interim Report. On November 1, 2000, an interim report was submitted that documented the results of Tasks 1, 3, 4, and progress to date on Task 2.

Task 6: Conduct Workshop. The workshop was held at the National Academies' Beckman Center in Irvine, CA on March 5 and 6, 2001. After the workshop the activities and results were summarized. The research program and problem statements were revised accordingly.

Task 7: Submit Final Report. On August 1, 2001, a draft final report will be submitted documenting the entire research effort. The recommended research program, including individual research problem statements, and an implementation plan shall be incorporated into the final report and, in addition, be available as a stand-alone document. The results of Task 2 will also be thoroughly and completely described to represent a significant portion of the final report documentation.

Figure 1.1 summarizes the research methodology for this research project.

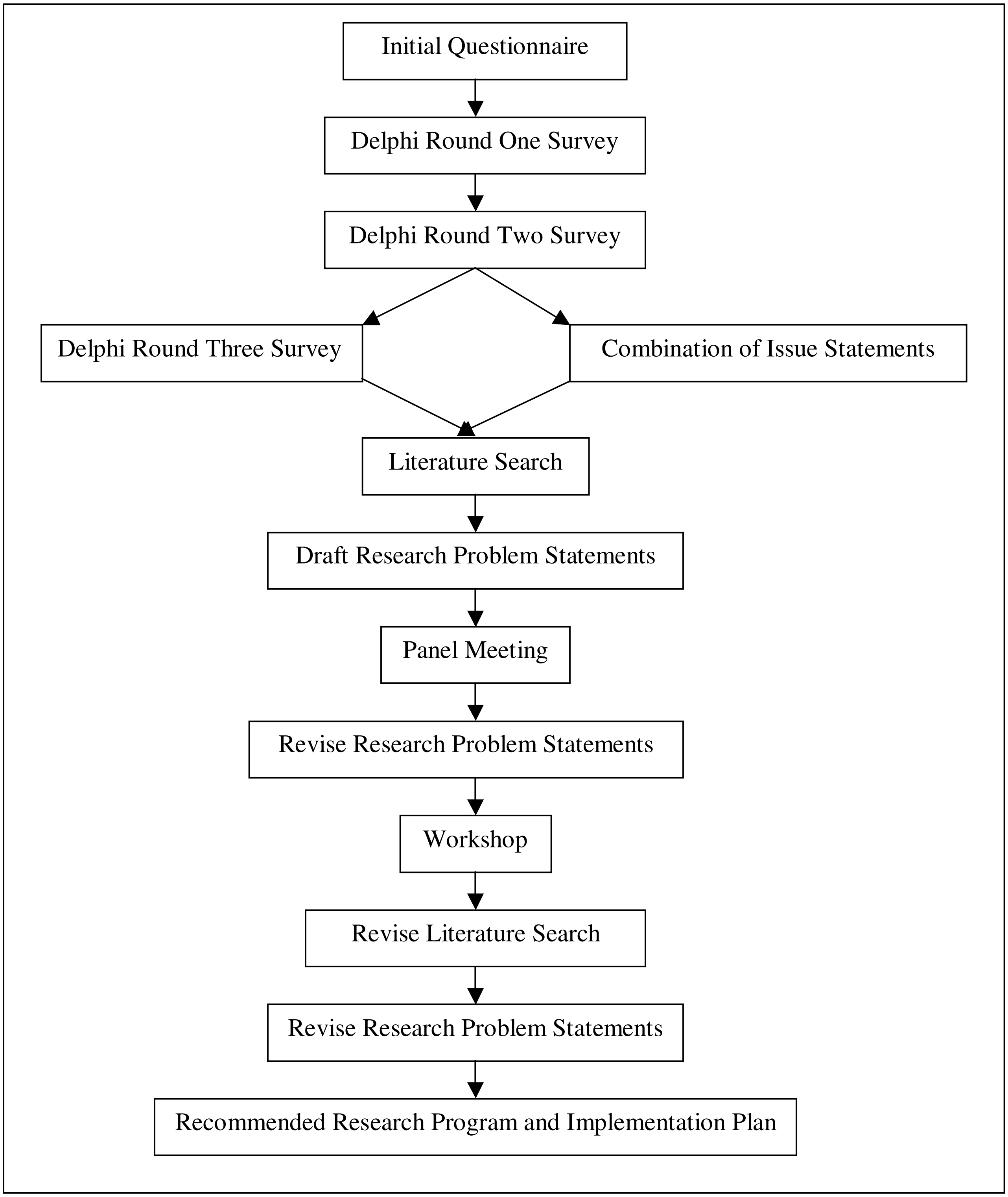


Figure 1.1 –Research Methodology

1.5 Organization of Document

This document is organized in four chapters. The first chapter explained the background and need for this research study. Chapter two will detail the process used to collect the necessary data for this research study. Chapter three summarizes the method used to analyze the data and iterations made to obtain the final recommended research program. Chapter four lays out the final recommended research program.

Chapter 2 Data Collection

2.1 Chapter Organization

This chapter explains the method for the data collection used for this research study. It begins with the initial questionnaire, which was the starting point for the data collection. The second section explains the Delphi method used to obtain the final 20 issues. The third section summarizes the methodology to determine the 15 issues used in the literature search. Next, the third round Delphi survey is discussed. This survey was used to compliment the literature search. Finally, the methodology for the literature search is discussed.

2.2 Task 1: Initial Questionnaire

The purpose of the initial questionnaire was to create a starting point for the Delphi method (the Delphi method will be explained in detail later in this chapter). The initial questionnaire surveyed SHA personnel from the 50 states. The questionnaire asked the personnel what problems are currently a concern for CEM and what problems they foresee in the future for CEM.

2.2.1 Questionnaire Preparation

The initial questionnaire for the first phase of Task 1 consisted of three sections. The first section requested general information about the respondent. The second section, Part I, asked the respondent to identify the five most important current and future issues facing the SHAs. The third section, Part II, asked the participants to rank the issues from past NCHRP studies to determine if they are still important today. The past issues were grouped within the seven categories that the research team planned to use for this project. They were: (1) State Highway Agency (SHA) staffing; (2) Innovative Contract Methods; (3) Quality Control/Quality Assurance (QC/QA); (4) Performance-Based Specifications; (5) Innovation in Construction Equipment; (6) Innovation in Rapid Test Methods and Procedures; and (7) Reconstruction Issues. The initial questionnaire was then pre-tested by two SHA personnel; one in design and one in construction.

2.2.2 Mailing the Questionnaire

On May 15, 2000, 747 questionnaires were mailed to CEM industry professionals in all 50 states. The names and addresses of the SHA personnel were taken from the January 2000 *AASHTO Reference Book, Member Department Personnel and Committees*. The participants included district and central office management, design and construction engineers, materials engineers, region/district engineers, and planners. The questionnaires were also mailed to the TRB state representatives, the NCHRP 10-58 panel and 10 trade associations. A copy of the initial questionnaire is included in Appendix A.

2.2.3 Respondent Characterization

One hundred twenty three responses were received. The respondents represented all 50 states and all positions surveyed. Two trade association representatives also replied. A respondent summary can be found in Table 2.1.

Table 2.1 Initial Questionnaire Respondent Summary

Position	Number Distributed	Number Responded	% Number Invited that Responded	% of Questionnaire Respondents
Trade Associations	77	3	3.9	2.5
State Highway Associations				
Upper Management				
Commissioner	21	2	9.5	1.7
Director	43	7	16.3	5.8
Secretary	45	3	6.7	2.5
Engineering				
CEM	73	41	56.2	33.9
Design	72	9	12.5	7.4
Materials	51	11	21.6	9.1
Transportation	51	6	11.8	5.0
Maintenance	46	6	13.0	5.0
Bridge	43	7	16.3	5.8
Research	36	9	19.4	5.8
Pavement	29	4	13.8	3.3
Quality	27	4	14.8	3.3
Contract Management	25	3	12.0	2.5
Planning	24	3	12.5	2.5
*Miscellaneous	21	5	23.8	4.1
Total	747	123	16.5	100

*Bituminous, Corrosion, Inspector General, Programming, Specifications Engineers

2.2.4 Data Analysis

Each issue from the questionnaire was documented using a spreadsheet. Similar issues were grouped into categories or combined. One hundred eighty one issues were identified, with 15 being from previous NCHRP studies. The frequency of occurrence of each issue was also tabulated from the participant responses.

An average rank on a scale of 1 to 5 (1 being most important and 5 being least important) was calculated for each issue. An overall ranking for each issue from all respondents was determined from the average rank. A separate rank was also determined for Part I and Part II.

Additionally, since CEM personnel submitted the greatest number of responses, and this project is focused on improving the CEM section of the SHAs, their responses were separated and compared to the overall responses.

A list of the top 25 issues from Part I, identification of the five most important current and future issues facing the SHAs, as identified by the respondents is shown in Figure 2.1. These were identified by ranking the issues identified in Part I by first the number of occurrences and then by the average rank.

- Recruitment and retention of qualified personnel
- Development of performance based specifications for all aspects of highway construction
- Claim management
- Funding
- Contractor quality control
- New technology - its use, impact and skills required
- Information management - cost effective system for collecting/sharing construction data/information, electronic documentation
- Compliance with current and future environmental restrictions/requirements
- Optimize highway systems operations - utilize existing facilities to their fullest extent
- Reduced staffing with increased workload
- Federally mandated/ recognized, but unresourced work
- Safety
- Public relations/impact on communities/ marketing
- Regain previous quality of plans
- Ability to train staff
- Constructability and quality plan development
- Recognition of risk - the cost of allocating risk to the contractor and developing ways to fairly allocate risk.
- Development of strategies to minimize construction delays once construction starts
- Performance based quality control/ quality assurance tests
- Innovative delivery systems and appropriate QC/QA
- Competing for college graduates and/or experienced personnel with private sector
- Staff and contractor expertise
- Implementation of AASHTO transport site manager to assist in construction administration
- Reconstruction of highways with high traffic volumes
- Keeping all staff abreast of new technology and practice

Figure 2.1 –Top 25 Issues from Part I of Initial Questionnaire

A list of the top 25 issues from Part II, ranking the issues from past NCHRP studies, as identified by the respondents is shown in Figure 2.2.

- Recruiting, testing, promoting, and retaining qualified personnel in highway construction
- Construction-zone traffic and safety problems
- Development, implementation and evaluation of performance - based specifications for highway construction
- Implementation and evaluation of sampling and testing procedures in regard to quality as related to performance of the end product
- Alternative construction methods and techniques to facilitate timely reconstruction
- Contractor performed QC and QA testing
- Development of feasible incentive and disincentive contract provisions covering contract time for assuring timely completion of projects
- Constructibility review
- Training certification and retention of non-engineering personnel for quality assurance
- Identification of causes of contract claims
- Development of cost effective sampling and testing problem
- Development of a preconstruction - activity planning and scheduling system
- Development of more effective rapid test methods and procedures
- Adequate/Existence of certification programs for construction engineering technicians
- Constructability and operability of transportation facilities
- Development of standardized design/build contracting procedures for highway and bridge construction
- Warranties
- Training and workforce development
- Warranties
- QC/QA testing that is better linked to performance
- Dealing with reduced staffing levels
- Appropriate partnering and value engineering activities
- Alternative construction methods/ delivery systems
- Traffic handling during construction
- Equipment that reduces environmental impacts

Figure 2.2 –Top 25 Issues from Part II of Initial Questionnaire

When comparing the issues from Part I of the questionnaire to Part II, the future issues, Part I, seemed to overlap with the issues from the previous NCHRP studies, Part II. The overlapping issues are listed in Figure 2.3.

- Recruiting, testing, promoting, and retaining qualified personnel in highway construction
- Construction-zone traffic and safety problems
- Development, implementation and evaluation of performance - based specifications for highway construction
- Alternative construction methods and techniques to facilitate timely reconstruction
- Contractor performed QC and QA testing
- Constructability review
- Identification of causes of contract claims
- Constructability and operability of transportation facilities
- Training and workforce development
- Performance-based QC/QA testing
- Reduced staffing levels with increased workload
- Alternative construction methods and delivery systems

Figure 2.3 –Overlapping issues from Part I and II of Initial Questionnaire

A comparison of the responses from CEM personnel to the overall respondents was completed. Part I of the questionnaire was used for this analysis. A list of the top 30 issues most important to the CEMs is shown in Figure 2.4. The italicized issues were the issues from Part I of the questionnaire that were in the top 30 for CEMs, but not from the aggregate data. For example, '*Project Scheduling*' made the top 30 for CEM, but not the list in Figure 2.1, Top 25 Issues from Part I of the Initial Questionnaire.

- Recruitment and retention of qualified personnel
- Development of performance based specifications for all aspects of highway construction
- Claim management
- Funding
- Contractor quality control
- New technology - its use, impact and skills required
- Information management - Cost effective system for collecting/sharing construction data/information, electronic documentation
- Compliance with current and future environmental restrictions/requirements
- Optimize highway systems operations - utilize existing facilities to their fullest extent

Figure 2.4 - Top 30 Issues Most Important to Construction Engineers and Managers (cont'd on next page)

- Reduced staffing with increased workload
- *Federally mandated/ recognized, but under resourced work*
- Safety
- Public relations/impact on communities/ marketing
- Regain previous quality of plans
- Ability to train staff
- *Constructability and quality plan development*
- Recognition of risk - the cost of allocating risk to the contractor and developing ways to fairly allocate risk.
- Development of strategies to minimize construction delays once construction starts
- Performance Based Quality Control/ Quality Assurance tests
- Innovative delivery systems and appropriate QA/QC
- Competing for College graduates and/or Experienced Personnel with Private Sector
- *Staff and Contractor Expertise*
- *Implementation of AASHTO transport site manager to assist in construction administration*
- Reconstruction of highways with high traffic volumes
- *Keeping all staff abreast of new technology and practice*
- *Innovation in Construction Materials - Use of composites/ longer lasting materials*
- Constructability & Maintaining Traffic of Rehabilitation Projects
- *Adequate trained staff*
- *Project Scheduling*
- Manage traffic during construction and system preservation activities

Figure 2.4 - Top 30 Issues Most Important to Construction Engineers and Managers Cont'd

Complete lists of each analysis along with the corresponding cited frequency (i.e. number of hits) and average rank can be found in Appendix B.

Fifty-seven issues from the overall ranking were used as input for the Delphi Method.

2.3 First Round Delphi Survey

2.3.1 Selection and Invitation of Delphi Participants

The methodology for selecting participants needed to be carefully planned and tailored to the research topic. Selected participants should represent a wide variety of backgrounds to guarantee a wide base of knowledge (Rowe, et al 1991). The number of respondents should be large enough to ensure that all perspectives are represented, but not so large as to make the analysis of results unmanageable by the research team (Linstone and Turoff 1975).

Respondents were selected from panels of completed NCHRP research projects, participants in the initial questionnaire, and academics conducting research in highway CEM. An invitation package was sent to 113 professionals. The package included an invitation letter, background information about the research project, the Delphi technique, and a response form. The invitation package is included in Appendix C. The invited professionals represented all disciplines of the highway construction industry, including SHA officials, contractors, consultants, suppliers, FHWA officials, academics, and trade association professionals.

Since the AASHTO Highway Subcommittee on Construction sponsored this research project more SHA professionals were invited to participate in the Delphi process than any other group. The goal was to have more SHA professionals as Delphi respondents than any other organization since SHAs were funding the research and it was to their benefit to express their ideas and concerns about critical issues in transportation CEM.

Fifty-one of the 113 invited professionals replied to the invitation indicating their willingness to participate in the Delphi process. A follow-up letter was first mailed to the remaining potential participants re-emphasizing the importance of the project and the need for their involvement. Sixteen replied to the letter and a total of 67 professionals agreed to participate in the Delphi process. The number of professionals that were invited and agreed to participate in the Delphi process represented the areas and disciplines listed in Table 2.2. The follow-up letter to the invitation packet is given in Appendix D.

Table 2.2. Discipline and Number of Professionals Participating in the Delphi Process

Area	Discipline	Invited	Agreed Pre Follow-up	Agreed Post Follow-up	Agreed Total
SHAs	Construction Engineering	36	15	7	22
	Design	12	9	1	10
	Materials	9	4	2	6
	Management	13	7	0	7
Industry	Construction	13	4	3	7
	Design	9	4	0	4
	Association	6	1	1	2
	Suppliers	2	0	1	1
Other	Academics	6	2	1	3
	FHWA	7	5	0	5
Total		113	51	16	67

2.3.2 Survey Preparation

The first-round Delphi survey was composed of five sections and requested that the respondents assess and prioritize 33 issue statements identified by the initial questionnaire. The first-round Delphi survey is attached in Appendix E. The focus of each section is described as follows:

Part I: Requested that the respondent enter information about his or her experience and expertise in highway CEM. Questions in this section were tailored to fit the respondents' area of employment (SHA, contractors, suppliers, consultants, FHWA, associations, and academics). For example, SHA professionals were requested to enter the jurisdiction of the agency office where they work (Central/State, District, Field) and academics were requested to indicate their involvement within which specific areas of research in CEM. This information is critical to validate and sort the survey data.

Part II: Requested the respondent to assess the importance and need for future research and development of 33 CEM issue statements on a five-point scale.

Part III: Requested the respondent to prioritize and rank the top 15 statements in Part II.

Part IV: Requested the respondent to add research and development needs in the highway CEM industry that had been omitted or needed to be rephrased from Part II.

Part V: Requested general comments on the survey or research project.

Extreme caution was emphasized while designing the questions for the first-round survey. Questions and issue statements must be phrased in such a way to eliminate bias. Before the first survey was sent to the Delphi respondents it was pre-tested and completed by three members of the NCHRP research panel to assure that the questions were clear and that the objectives of the survey would be fulfilled. The three research panelists all suggested that the questionnaire was too lengthy and requested the assessment of too many issues. To remedy the situation, the panelists suggested that some could be combined to form a survey that was easier to complete and could result in a better response rate. The list of issues to be assessed by the Delphi respondents was shortened from 57 to 33 issue statements by combining issues. The pretest confirmed an acceptable content, format, and methodology for the first-round survey.

2.3.3 Respondent Characterization

After the suggested changes were incorporated, the first-round Delphi questionnaire was sent to the 67 industry professionals who agreed to participate in the research process. Forty-one respondents returned the first-round questionnaire. A follow-up letter was sent to the remaining respondents requesting the completion of their survey. The follow-up letter is available in Appendix F. A total of 59 first-round questionnaires were received. The respondents that submitted the first-round Delphi survey represented the areas and disciplines listed in Table 2.3.

Table 2.3. Respondents First-Round Delphi Survey

Area	Discipline	Agreed to Participate	Completed 1st-Round Pre Follow-up	Completed 1st-Round Post Follow-up	Completed 1st-Round Total
SHAs	Construction Engineering	22	14	7	21
	Design	10	5	4	9
	Materials	6	3	1	4
	Management	7	5	1	6
Industry	Construction	7	6	0	6
	Design	4	3	1	4
	Association	2	1	1	2
	Suppliers	1	1	0	1
Other	Academics	3	2	0	2
	FHWA	5	1	3	4
Total		67	41	18	59

Part I of the first-round survey requested the respondents to answer questions about their experience in the construction industry. The participants represented a highly experienced, broad-based compilation of highway construction professionals. The average lengths of experience of respondents representing each discipline are shown in Table 2.4. Areas of expertise indicated by the respondents are listed in Table 2.5. Additional information on the experience of the Delphi participants is available in Appendix G.

Table 2.4. Experience of First-Round Delphi Survey Respondents

Area	Discipline	Completed 1st-Round Total	Experience Average In Years	Area Average In Years
SHAs	Construction Engineering	21	26.9	27.0
	Design	9	24.1	
	Materials	4	22.5	
	Management	6	34.5	
Industry	Construction	6	28.2	28.5
	Design	4	28.3	
	Association	2	23.0	
	Suppliers	1	42.0	
Other	Academics	2	33.0	30.0
	FHWA	4	28.5	
Total		59		27.6

Table 2.5. Expertise of First-round Delphi Survey Respondents

Discipline	Area of Expertise	Number of Respondents
SHA	Agency Management	4
	Project Management and Engineering	7
	Pavement / Bridge Design	1
	Construction Engineering / Administration	21
	Materials	5
	Traffic Engineering	2
Contractor	Executive Management	3
	Project Management	1
	Field Supervision	1
Supplier	Product Development / Product Research	1
Consultant	Executive Management	1
	Product Management	3
	Design Engineering	1
FHWA	Pavement	1
	Research	2
	Traffic Management	1
Association	Research	1
	Pavement Design	1
Academic	Construction Engineering Research	2
Total		59

2.3.4 Data Analysis

Part II of the First-Round Delphi Survey requested the respondents to assess the issue statements from the Initial Questionnaire on a five-point scale. The purpose of this section was to promote thought about the individual transportation issues. "Extremely Important (5)" specified that the issue is very critical to highway CEM necessitating future research. "Not Important (1)" specified that the issue is not a significant problem in the industry and does not require future research. The mid-range values (2,3,4) implied different degrees of importance. The assessment of the individual issues on the five-point scale was designed to assist the respondents when completing the ranking of the top 15 issue statements in Part III of the survey.

The analysis of the responses to Part III of the first-round Delphi survey was accomplished using a method called Relative Index Rating (RIR). RIR is a means to report the respondents' rankings on a 0 to 1 scale (Cook 1997). A value of 15 points was assigned to a rank of "1", 14 points for a rank of "2", ... 1 point for a rank of "15", and 0 points for an unranked issue. The sum of points for each issue was divided by the total number of points possible (15 points times the total number of respondents). For example, issue statement number 13 "Safety of public and workers during highway reconstruction and maintenance" received 421 points, out of 885 (15 x 59) points possible. Therefore, its RIR is equal to 0.476 (421 / 885). A sample calculation is displayed in Table 2.6.

Table 2.6. Sample Relative Index Rating Calculation

Rank	No. of Respondents	Points per Rank	Total Points
1	12	15	180
2	3	14	42
3	3	13	39
4	4	12	48
5	1	11	11
6	1	10	10
7	2	9	18
8	3	8	24
9	1	7	7
10	1	6	6
11	6	5	30
12	1	4	4
13	0	3	0
14	0	2	0
15	2	1	2
Unranked	19	0	0
Total	59	--	421

The group ranking of the issue statements in Part III of the first-round Delphi survey is displayed in Table 2.7. The RIR values are in the right column of Table 2.7; the higher the RIR value, the more critical the issue is according to the group of Delphi respondents.

Table 2.7. First-round Delphi Survey Results

Rank	Issue Statement	RIR
1	13. Safety of public and workers during highway reconstruction and maintenance	0.476
2	5. Alternative construction methods and techniques to facilitate faster reconstruction	0.442
3	15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	0.431
4	23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	0.411
5	33. Management of traffic during highway construction projects – Project staging of highway projects	0.380
6	12. Training and workforce development of personnel	0.372
7	19. Development, implementation, and evaluation of performance based specifications for highway construction	0.371
8	10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	0.330
9	30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	0.328
10	28. Use of more durable materials in highway construction	0.325
11	11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	0.325
12	27. Strategies to minimize construction delays once construction starts	0.323
13	21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	0.298
14	9. Impact of construction projects on communities and necessary communication between agency/contractor and general public	0.275
15	29. Review of the constructability of transportation facilities in the planning and design phases	0.260
16	1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects	0.251
17	6. Deficiencies in quality and clarity of construction plans	0.228
18	3. Compliance with current and future environmental restrictions/requirements	0.228
19	4. Contractor performed QC and QA testing	0.220
20	7. Night and weekend construction to reduce traffic implications	0.197

Table 2.7. First-round Delphi Survey Results Cont'd

Rank	Issue Statement	RIR
21	31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	0.171
22	2. Integration of contractor warranties into project contracts	0.163
23	20. Management of contract claims (including identification of causes of claims)	0.155
24	32. Development of standardized design-build contracting procedures for highway and bridge construction	0.153
25	22. System for electronically collecting and distributing construction information	0.148
26	8. Allocation of financial risk between the agency and contractor	0.144
27	18. Training certification and retention of non-engineering personnel for quality assurance	0.141
28	14. Appropriate partnering and value engineering activities	0.098
29	16. Use of pre-construction/pre-project planning and project scheduling systems	0.097
30	26. Availability and adequacy of certification programs for construction engineering technicians	0.096
31	25. Use of recycled materials in highway construction	0.079
32	24. Construction equipment that reduces environmental impacts	0.068
33	17. Operability of construction equipment in relation to constructibility of transportation facilities	0.018

Part IV of the first-round survey requested the respondent to list critical issues that were omitted from the list of 33 statements assessed in Parts II and III. Additionally, if any issue from Parts II and III was phrased in a confusing manner or could be interpreted multiple ways, respondents were requested to clarify and rephrase those issues. Issues identified or rephrased by multiple Delphi participants were included for assessment and prioritization in the second-round Delphi survey. The new and rephrased issues identified by more than one Delphi respondent are listed in Table 2.8.

Table 2.8. New and Rephrased Issues

Issue Statement	New or Rephrased
34. Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway work-zones	New
35. Assessment and verification of current life cycle cost methodologies	New
36. Implementing electronic information systems to integrate bid estimating, project management, and construction management	New
37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	New
4-R1. Contractor performed QC	Rephrased
4-R2. Contractor performed QA	Rephrased
14-R1. Appropriate partnering activities	Rephrased
14-R2. Appropriate value engineering activities	Rephrased
22-R. Using automation technology in a system for collection and distribution of design and construction information	Rephrased

General comments collected by Part V of the survey varied widely. Many respondents prioritized the more general themes (technology, performance, quality, scheduling, safety, training, and staffing). Other participants clarified their area of expertise or identified the importance of future research in the highway industry. The complete list of the comments received is available at the end of Appendix G.

A comprehensive summary of results from the first-round Delphi survey is available in Appendix G. The results were analyzed and it was determined that a second Delphi round was necessary to reach a group consensus on the top research needs and analyze the new issues identified. A change in RIR values (an increase in high priority issues and a decrease in low priority issues) would indicate movement towards a consensus of the participants.

2.4 Second Round Delphi Survey

2.4.1 Survey Preparation

The second-round Delphi survey was composed of four sections and requested the respondents to re-evaluate and prioritize the 33 issue statements and the nine additional statements identified by Part IV of the first-round survey. The second-round Delphi survey is attached in Appendix H. The focus of each section is described as follows:

Part A: Requested the respondent to re-evaluate the 33 issues, on a five-point scale, from the first-round survey based on their first assessment and the group median value.

Part B: Requested the respondent to evaluate the nine new issues identified by the respondents of the first-round survey on a five-point scale.

Part C: Requested the respondent to prioritize and rank the top 15 statements from Part A and Part B.

Part D: Requested general comments about the combination of issue statements into topic areas.

Before the second survey was sent to the Delphi respondents, the format and presentation of results were discussed with two members of the research panel to pretest the questionnaire and to ensure that the objectives would be achieved. The research panelists agreed that the second-round survey was complete and concise.

2.4.2 Respondent Characterization

The second-round Delphi survey was sent to the 59 respondents that completed and submitted the first-round survey. Initially, 31 respondents submitted the second-round questionnaire. A follow-up letter was sent to the remaining respondents requesting the completion of their survey. The follow-up letter is available in Appendix I. A total of 53 second-round questionnaires were received. The respondents that submitted the second-round Delphi survey represented the areas and disciplines listed in Table 2.9.

Table 2.9. Respondents That Completed the Second-round Delphi Survey

Area	Discipline	Sent 2nd-Round	Completed 2nd-Round Pre Follow-up	Completed 2nd-Rnd Post Follow-up	Completed 2nd-Round Total
SHAs	Construction Engineering	20	10	9	19
	Design	9	3	4	7
	Materials	4	2	2	4
	Management	6	3	3	6
Industry	Construction	6	5	0	5
	Design	4	2	2	4
	Association	2	1	1	2
	Suppliers	1	1	0	1
Other	Academics	2	2	0	2
	FHWA	3	2	1	3
Total		57	31	22	53

2.4.3 Data Analysis

The convergence of a Delphi topic usually implies the narrowing of its frequency distribution and can be best measured by its standard deviation (Nelson 1979). Part A of the second-round survey requested the respondents to re-assess the 33 issues on the five-point scale by evaluating their previous response and the group median response. The feedback of Delphi group results should be in the form of medians (Rowe et al 1991). The standard deviations of the responses for each issue statements from the second-round are less than the standard deviations in the first-round. The decrease in standard deviation for each issue indicates a convergence of the opinions of the respondents. The group average values received on the five-point scale and the standard deviations for each round are displayed in Table 2.10.

Table 2.10. Delphi Survey Five-Point Scale Results

Rank	Issue Statement	2nd-Rnd Ave	2nd-Rnd Std-Dev	1st-Rnd Ave	1st-Rnd Std-Dev
1	13. Safety of public and workers during highway reconstruction and maintenance	4.6	0.63	4.4	0.83
2	5. Alternative construction methods and techniques to facilitate faster reconstruction	4.5	0.58	4.3	0.83
3	15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	4.3	0.96	4.1	1.01
4	23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	4.2	0.77	4.2	0.87
5	33. Management of traffic during highway construction projects –Project staging of highway projects	4.3	0.74	4.1	0.97
6	12. Training and workforce development of personnel	4.3	0.70	4.2	0.84
7	19. Development, implementation, and evaluation of performance based specifications for highway construction	4.1	0.85	4.1	0.89
8	11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	4.2	0.79	4.1	0.81
9	10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	3.9	1.06	3.8	1.21
10	27. Strategies to minimize construction delays once construction starts	4.2	0.72	4.0	0.94

Table 2.10. Delphi Survey Five-point Scale Results Cont'd

Rank	Issue Statement	2nd-Rnd Ave	2nd-Rnd Std-Dev	1st-Rnd Ave	1st-Rnd Std-Dev
11	21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	4.1	0.91	4.0	1.06
12	30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	4.1	0.82	4.1	0.90
13	9. Impact of construction projects on communities and necessary communication between agency/contractor and general public	3.9	0.84	3.8	1.04
14	28. Use of more durable materials in highway construction	4.1	0.85	4.1	0.92
15	7. Night and weekend construction to reduce traffic implications	3.8	0.86	3.7	1.07
16	3. Compliance with current and future environmental restrictions/requirements	3.9	0.89	3.8	0.92
17	1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects	3.8	0.71	3.8	0.88
18	6. Deficiencies in quality and clarity of construction plans	3.5	0.95		
19	4. Contractor performed QC and QA testing	3.8	0.81	3.8	0.87
20	29. Review of the constructability of transportation facilities in the planning and design phases	3.9	0.81	3.9	0.88
21	2. Integration of contractor warranties into project contracts	3.5	0.91	3.3	1.03
22	8. Allocation of financial risk between the agency and contractor	3.6	0.84	3.4	1.02
23	31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	3.8	0.72	3.8	0.87
24	32. Development of standardized design-build contracting procedures for highway and bridge construction	3.0	1.03	3.1	1.18
25	25. Use of recycled materials in highway construction	3.3	1.03	3.3	1.14

Table 2.10. Delphi Survey Five-point Scale Results Cont'd

Rank	Issue Statement	2nd-Rnd Ave	2nd-Rnd Std-Dev	1st-Rnd Ave	1st-Rnd Std-Dev
26	18. Training certification and retention of non-engineering personnel for quality assurance	3.6	0.77	3.5	0.84
27	20. Management of contract claims (including identification of causes of claims)	3.6	0.82	3.6	0.91
28	22. System for electronically collecting and distributing construction information	3.5	0.89	3.6	1.04
29	24. Construction equipment that reduces environmental impacts	3.0	0.89	3.0	1.02
30	26. Availability and adequacy of certification programs for construction engineering technicians	3.3	0.79	3.3	1.01
31	16. Use of pre-construction/pre-project planning and project scheduling systems	3.3	0.78	3.3	0.88
32	14. Appropriate partnering and value engineering activities	3.0	0.98	3.2	1.07
33	17. Operability of construction equipment in relation to constructability of transportation facilities	2.7	0.71	2.9	0.92

Part B of the second-round survey requested that the respondents evaluate the new issues identified by the respondents of the first-round Delphi survey. The first-round respondents identified a large number of new issues as either omitted issues or incorrectly phrased issue statements in the first-round analysis. New issues identified by multiple first-round respondents were selected for assessment in the second-round survey (see Table 2.8). Nine new issues were evaluated on a five-point scale. The results of the assessment of the new issues on the five-point scale are displayed in Table 2.11. If the Delphi respondent believed that one of the new issues was critical, this issue could be included in their top 15 ranking in Part C.

Table 2.11. New Issue Assessment on Five-point Scale

Rank	Issue Statement	Average
1	37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	3.9
2	4-R1. Contractor performed QC	3.7
3	35. Assessment and verification of current life cycle cost methodologies	3.6
4	36. Implementing electronic information systems to integrate bid estimating, project management, and construction management	3.4
5	22-R. Using automation technology in a system for collection and distribution of design and construction information	3.4
6	34. Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway work-zones	3.3
7	4-R2. Contractor performed QA	3.1
8	14-R1. Appropriate partnering activities	3.0
9	14-R2. Appropriate value engineering activities	3.0

The analysis of the responses of the Delphi process for Part C of the second-round Delphi survey was accomplished using the RIR method. The group ranking of the issue statements in Part C of the second-round Delphi survey compared with the first-round Delphi survey are displayed in Table 2.12.

Table 2.12. Second-Round Delphi Survey Results

Rank	Issue Statement	2nd-rnd RIR	1st-rnd RIR
1	13. Safety of public and workers during highway reconstruction and maintenance	0.742	0.476
2	5. Alternative construction methods and techniques to facilitate faster reconstruction	0.581	0.442
3	15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	0.513	0.431
4	23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	0.459	0.411
5	33. Management of traffic during highway construction projects – Project staging of highway projects	0.434	0.380
6	12. Training and workforce development of personnel	0.428	0.372
7	19. Development, implementation, and evaluation of performance based specifications for highway construction	0.371	0.371
8	11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	0.360	0.325

Table 2.12. Second-Round Delphi Survey Results Cont'd

Rank	Issue Statement	2^{nd}-rnd RIR	1^{st}-rnd RIR
9	10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	0.341	0.330
10	27. Strategies to minimize construction delays once construction starts	0.331	0.323
11	21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	0.316	0.298
12	30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	0.296	0.328
13	9. Impact of construction projects on communities and necessary communication between agency/contractor and general public	0.282	0.275
14	28. Use of more durable materials in highway construction	0.272	0.325
15	7. Night and weekend construction to reduce traffic implications	0.242	0.197
16	3. Compliance with current and future environmental restrictions/requirements	0.228	0.228
17	1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects	0.214	0.251
18	6. Deficiencies in quality and clarity of construction plans	0.165	0.228
19	4. Contractor performed QC and QA testing	0.164	0.220
20	29. Review of the constructability of transportation facilities in the planning and design phases	0.162	0.260
21	2. Integration of contractor warranties into project contracts	0.125	0.163
22	37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	0.118	--
23	8. Allocation of financial risk between the agency and contractor	0.107	0.144
24	31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	0.103	0.171
25	32. Development of standardized design-build contracting procedures for highway and bridge construction	0.091	0.153
26	25. Use of recycled materials in highway construction	0.074	0.079
27	18. Training certification and retention of non-engineering personnel for quality assurance	0.074	0.141
28	20. Management of contract claims (including identification of causes of claims)	0.073	0.155
29	22. System for electronically collecting and distributing construction information	0.055	0.148
30	24. Construction equipment that reduces environmental impacts	0.052	0.068
31	26. Availability and adequacy of certification programs for construction engineering technicians	0.047	0.096

Table 2.12. Second-Round Delphi Survey Results Cont'd

Rank	Issue Statement	2nd-rnd RIR	1st-rnd RIR
32	16. Use of pre-construction/pre-project planning and project scheduling systems	0.043	0.097
33	14. Appropriate partnering and value engineering activities	0.040	0.098
34	36. Implementing electronic information systems to integrate bid estimating, project management, and construction management	0.024	--
35	4-R1. Contractor performed QC	0.018	--
36	35. Assessment and verification of current life cycle cost methodologies	0.015	--
37	22-R. Using automation technology in a system for collection and distribution of design and construction information	0.015	--
38	14-R1. Appropriate partnering activities work-zones	0.014	--
39	34. Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway	0.010	--
40	14-R2. Appropriate value engineering activities	0.004	--
41	17. Operability of construction equipment in relation to constructability of transportation facilities	0.001	0.017
42	4-R2. Contractor performed QA	0.000	--

The second-round Delphi survey was a beneficial procedure to form a group consensus. The RIR values from the second-round indicate a more consolidated opinion compared with the first-round. The higher ranked issue statements received a higher RIR in the second-round than in the first-round, while the lower ranked issue statements received a lower RIR in the second-round than in the first round. The changes in the RIR values indicate that several of the respondents with outlying opinions edited their responses after viewing the first-round results.

Delphi respondents have expressed concern about the methods used to rank the issue statements. Some respondents were concerned that since there were more SHA professionals than any other group, priorities of other groups would not be appropriately represented. Other panelists wrote that since SHAs funded the research study, agencies other than SHAs should not dictate research priorities. After analysis of the critical research priorities of the 'SHAs" versus the "others", it was concluded that there was minimal difference between the top 20 rankings of both groups as only three issues ranked in the "others" top 20 did not appear the aggregate top 20 ranking. The ranking of the issue statements by the SHAs and the others are displayed in Table 2.13.

Table 2.13. Ranking of Issues by SHAs versus Others

Aggregate Ranking	Issue Statement	2nd-Round SHA Rank	2nd-Round Other Rank
1	13. Safety of public and workers during highway reconstruction and maintenance	1	2
2	5. Alternative construction methods and techniques to facilitate faster reconstruction	3	1
3	15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	2	8
4	23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	7	3
5	33. Management of traffic during highway construction projects –Project staging of highway projects	6	4
6	12. Training and workforce development of personnel	4	9
7	19. Development, implementation, and evaluation of performance based specifications for highway construction	8	6
8	11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	10	7
9	10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	5	25
10	27. Strategies to minimize construction delays once construction starts	14	5
11	21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	9	15
12	30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	12	12
13	9. Impact of construction projects on communities and necessary communication between agency/contractor and general public	13	14
14	28. Use of more durable materials in highway construction	15	11
15	7. Night and weekend construction to reduce traffic implications	17	10
16	3. Compliance with current and future environmental restrictions/requirements	11	37
17	1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects	16	13

Table 2.13. Ranking of Issues by SHAs versus Others Cont'd

Aggregate Ranking	Issue Statement	2nd-Round SHA Rank	2nd-Round Other Rank
18	6. Deficiencies in quality and clarity of construction plans	18	21
19	4. Contractor performed QC and QA testing	20	16
20	29. Review of the constructibility of transportation facilities in the planning and design phases	19	18
21	2. Integration of contractor warranties into project contracts	22	22
22	37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	21	24
23	8. Allocation of financial risk between the agency and contractor	23	20
24	31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	27	17
25	32. Development of standardized design-build contracting procedures for highway and bridge construction	24	23
26	25. Use of recycled materials in highway construction	32	19
27	18. Training certification and retention of non-engineering personnel for quality assurance	26	26
28	20. Management of contract claims (including identification of causes of claims)	25	27
29	22. System for electronically collecting and distributing construction information	28	29
30	24. Construction equipment that reduces environmental impacts	29	31
31	26. Availability and adequacy of certification programs for construction engineering technicians	30	32
32	16. Use of pre-construction/pre-project planning and project scheduling systems	35	28
33	14. Appropriate partnering and value engineering activities	33	30
34	36. Implementing electronic information systems to integrate bid estimating, project management, and construction management	31	38
35	4-R1. Contractor performed QC	39	33
36	35. Assessment and verification of current life cycle cost methodologies	40	34
37	22-R. Using automation technology in a system for collection and distribution of design and construction information	34	40

Table 2.13. Ranking of Issues by SHAs versus Others Cont'd

Aggregate Ranking	Issue Statement	2nd-Round SHA Rank	2nd-Round Other Rank
38	14-R1. Appropriate partnering activities work-zones	41	35
39	34. Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway	37	36
40	14-R2. Appropriate value engineering activities	36	41
41	17. Operability of construction equipment in relation to constructability of transportation facilities	38	39
42	4-R2. Contractor performed QA	42	42

As shown in Table 2.13, all of the issues ranked in the top 20 by SHA respondents were ranked in the top 20 aggregate ranking. Only three issues that did not fall in the top 20 aggregate ranking were ranked in the top 20 by other respondents (issue numbers 31, 25, and 8 were ranked 17, 19, and 20, respectively by other respondents). Complete results from the second-round Delphi survey are available in Appendix J.

After the results were analyzed, it was determined that a group consensus had been achieved. The changes in RIR values from the first to the second rounds (an increase in high priority issues and a decrease in low priority issues) and a decrease in the standard deviation of the assessment of the issues on the five-point scale indicate convergence. An additional Delphi round to specifically assess and prioritize issues was deemed unnecessary.

2.5 Combination of Issue Statements

Throughout the Delphi process, many respondents commented that some issues in the list of 33 involved similar topics, problems, and possible solutions. These respondents suggested that some like issues be combined. The research team followed the advice of the respondents and NCHRP panelists and combined the top 20 issue statements into 15 topic areas composed of one or more issue statements. These 15 topic areas would become the new 15 top priority issues.

In order to create the top 15 issues the research team analyzed the top 20 issues prioritized by the Delphi respondents. The top 20 issue statements were categorized into section headings. Once the issues were categorized under section headings, they were analyzed to determine if they could be combined with issue statements with similar topics, problems, and solutions. In the following list, the section headings are listed alphabetically. The bulleted issues under each section represent the top 20 issue statements prioritized by the second-round Delphi respondents. The italicized number after each bulleted issue statement represents the reference number of the issue from the Delphi surveys, not its rank. In the section headings, there may be a subsection labeled 'Combined." This subsection lists the new topic areas derived from the issue statements in the section heading. The italicized number(s) in these subsections indicate the issue statement numbers that were combined to form the topic areas.

A. Safety

Original:

- Safety of public and workers during highway reconstruction and maintenance *(13)*

B. Faster and Improved Quality Construction

Original:

- Alternative construction methods and techniques to facilitate faster reconstruction *(5)*
- Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility *(23)*
- Development, implementation, and evaluation of performance based specifications for highway construction *(19)*
- Feasible incentive and disincentive contract provisions assuring more timely completion of projects *(1)*

Combined:

- Overall improvement of the construction process – particularly alternative construction methods and techniques, contracting methods and delivery systems to facilitate faster construction/reconstruction. *(5 & 23)*
- Development, implementation, and evaluation of the use of incentives/disincentives for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility. *(23 & 1)*
- Development, implementation, and evaluation of performance based specifications for highway construction *(19)*

C. Staffing

Original:

- Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects) *(15)*
- Training and workforce development of personnel *(12)*
- Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel *(10)*
- Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies) *(21)*

Combined:

- Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel) *(15 & 10)*
- Training and workforce development of personnel *(12)*
- Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies) *(21)*

D. Manage Traffic

Original:

- Management of traffic during highway construction projects –Project staging of highway projects *(33)*
- Strategies to minimize construction delays once construction starts *(27)*
- Night and weekend construction to reduce traffic implications *(7)*

Combined:

- Innovative strategies to manage traffic during highway construction projects- Specifically relating to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction. *(33, 27 & 7)*

E. Testing

Original:

- Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection) *(11)*
- Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods) *(30)*
- Contractor performed QC and QA testing *(4)*

F. Constructability

Original:

- Review of the constructability of transportation facilities in the planning and design phases *(29)*
- Deficiencies in quality and clarity of construction plans *(6)*

Combined:

- Review of the constructability of transportation facilities in the planning and design phases – specifically deficiencies in quality and clarity of construction plans. *(29 & 6)*
- Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies) *(21)*

G. Materials

- Use of more durable materials in highway construction *(28)*

H. Community Impact of Construction Projects

- Impact of construction projects on communities and necessary communication between agency/contractor and general public *(9)*

I. Environment

- Compliance with current and future environmental restrictions/requirements *(3)*

2.5.1 Top 15 Issues

The new list of top 15 topic areas, after combination, are as follows:

1. Safety of public and workers during highway reconstruction and maintenance *(13)*.
2. Overall improvement of the construction process – particularly alternative construction methods and techniques, contracting methods and delivery systems to facilitate faster construction/reconstruction *(5 & 23)*.
3. Development, implementation, and evaluation of the use of incentives/disincentives for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility *(23 & 1)*.
4. Development, implementation, and evaluation of performance based specifications for highway construction *(19)*.
5. Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel) *(15 & 10)*.
6. Training and workforce development of personnel *(12)*.
7. Innovative strategies to manage traffic during highway construction projects- as specifically related to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction *(33, 27 & 7)*.
8. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection) *(11)*.

9. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods) *(30)*.
10. Contractor performed QC and QA testing *(4)*.
11. Review of the constructability of transportation facilities in the planning and design phases – specifically deficiencies in quality and clarity of construction plans *(29 & 6)*.
12. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies) *(21)*.
13. Use of more durable materials in highway construction *(28)*.
14. Impact of construction projects on communities and necessary communication between agency/contractor and general public *(9)*.
15. Compliance with current and future environmental restrictions/requirements *(3)*.

These top 15 issues were used to begin Task 2. This is the list of the top 15 issues that was modified by discussions at the December 2000 Panel Meeting, and by discussions at the March 2001 Workshop.

2.6 Third Round Delphi Survey

2.6.1 Survey Preparation

The respondents to the Delphi surveys are extremely knowledgeable and experienced in highway construction CEM. An additional questionnaire was composed to gather more information from the Delphi panelists about the top 20 issues prioritized by the first two rounds. However this survey concentrated on the subject matter for the literature search instead of additional consensus of the 15 research issue statements. The complete survey is attached in Appendix K. The survey is separated into two sections as follows:

Part 1: Requested that the respondents identify problem areas, barriers to successful implementation, and gaps in research knowledge for the top 20 issue statements. Identification of problem areas, barriers, and gaps were contract requirements of this project.

Part 2: Requested general comments on the survey or research project.

Before the third survey was sent to all of the Delphi respondents, it was sent to three members of the NCHRP panel to pretest the questionnaire. The panelists confirmed that the third survey was a suitable method to collect ideas and opinions on problems, barriers, and gaps.

2.6.2 Respondent Characterization

The questionnaires were sent to the 53 respondents that replied to the second-round survey. Fifteen respondents submitted the third-round questionnaire. A follow-up letter was sent to the remaining respondents requesting the completion of their survey. The third-round follow-up letter is available in Appendix L. A total of 25 third-round questionnaires were received. A lower response rate to the third-round, compared with the previous rounds, was expected due to the length of the survey and the time commitment involved. The respondents that submitted the third-round Delphi survey represented the areas and disciplines listed in Table 2.14.

Table 2.14. Respondents That Completed the Third-round Delphi Survey

Area	Discipline	Sent 2nd-Round	Completed 2nd-Round Pre Follow-up	Completed 2nd-Rnd Post Follow-up	Completed 2nd-Round Total
SHAs	Construction Engineering	19	4	4	8
	Design	7	3	3	6
	Materials	4	1	0	1
	Management	6	2	0	2
Industry	Construction	5	1	2	3
	Design	4	1	0	1
	Association	2	0	1	1
	Suppliers	1	0	0	0
Other	Academics	2	1	0	1
	FHWA	3	2	0	2
Total		53	15	10	25

The third-round survey is more applicable to the literature search discussed further in Chapter 2 than to the assessment of critical issues. The goal of the third-round survey was to gather information within each of the top 20 issue statements including: (1) problem areas; (2) barriers that limit the specific problems to be overcome; and (3) gaps between research knowledge and industry practice. The information gathered in the third-round survey aided the literature search to ensure that the most critical problem areas within the issue statements were addressed in the final research problem statements.

2.6.3 Data Summary

A summary of comments for each issue from the third-round survey is displayed in Table 2.15. The instructions in the third-round questionnaire requested that the respondents comment on issues that were in their area of expertise. Most of the 25 respondents did not complete the entire survey. Many comments offered limited explanation and were difficult to understand in the context of the issue statement. The purpose of the third-round survey was to supplement the literature search and verify that critical problem areas, barriers, and to ensure that gaps were found in the review of the literature and in the design of the research problem statements. Overall, the information collected from the questionnaires was helpful throughout the process for formulating research statements.

Table 2.15. Summary of Third-round Delphi Survey Results

Issue No.	Issue Statement	Common Themes
1	Safety of public and workers during highway reconstruction and maintenance	• Traffic speeds in work zones and effective enforcement • Public education efforts • Real-time traffic information • Cost/benefit of safety program
2	Alternative construction methods and techniques to facilitate faster reconstruction	• Resistance to new ideas • Cost and risk of implementation
3	Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	• Cost of new methods • Risk of new methods • Resistance to change from low-bid system
4	Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	• Limits on salary levels (agencies not competitive with private industry) • High turnover rate
5	Management of traffic during highway construction projects –Project staging of highway projects	• Detailed traffic planning in design phase of projects • Ability to construct during off-peak traffic periods
6	Training and workforce development of personnel	• Lack of time for training • Development of curriculum • Computer training • Funding for training
7	Development, implementation, and evaluation of performance based specifications for highway construction	• Lack of performance tests • Lack of correlation between specifications and long term performance • Modeling performance
8	Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	• Need testing methods to predict performance • Reluctance to change from traditional practices • Cost
9	Strategies to minimize construction delays once construction starts	• Unexpected site conditions • Poor quality of plans/specifications • Traffic implications
10	Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	• Public agencies do not offer competitive salaries • Shortage of engineers

Table 2.15. Summary of Third-round Delphi Survey Results Cont'd

Issue No.	Issue Statement	Common Themes
11	Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	• More research on NDT methods • Some tests are time-consuming • Resistance to implement new methods
12	Impact of construction projects on communities and necessary communication between agency/contractor and general public	• Lack of public interest • Lack of public understanding • Pubic relations should be bid item
13	Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	• Lack of inspection • Lack of experienced personnel • Cost of inspection • Lack of quality in design and construction
14	Use of more durable materials in highway construction	• Increased first costs • Limited availability • Life cycle costs • Specifications for durability
15	Night and weekend construction to reduce traffic implications	• Availability of materials at night • Availability of personnel at night • Cost of night work • Safety issues
16	Compliance with current and future environmental restrictions/requirements	• Cost/benefits • Unpredictable –lack of control
17	Feasible incentive and disincentive contract provisions assuring more timely completion of projects	• Lack of measurable benefits/costs • Costs • Determining level of incentives/disincentives • Combination with other contracting strategies
18	Deficiencies in quality and clarity of construction plans	• Lack of design experience • High personnel turnover rate • Need standard format for plans/specifications
19	Review of the constructability of transportation facilities in the planning and design phases	• Lack of resources • Constructability reviews are not typically performed
20	Contractor performed QC and QA testing	• Lack of training • Lack of rapid test methods • Lack of trust between agency and contractor

2.6.4 Delphi Thank You Letter

The surveys the Delphi participants completed were extremely time consuming. After the third-round surveys were received, a letter was mailed to each respondent that participated in the Delphi process thanking them for their time and expertise. The thank you letter is available in Appendix M.

2.7 Task 2: Literature Search

The purpose of the literature search was to find information that would (1) summarize the state of knowledge and practice for each issue; (2) evaluate past research products and implementation efforts—successes and failures; (3) identify barriers to implementation; and (4) identify gaps in existing knowledge and failures in the implementation of successful research.

The research team began the literature search in late July 2000. This search commenced after the initial questionnaire had been analyzed and the first-round of the Delphi survey was complete. The issues selected were based upon the first round results and a prediction of the issues would be included in the final list of the top 15 issues.

As each round of the Delphi method was completed, the research team chose additional issues to research. This was done as soon as the team was confident that the issue would be in the top 15-issue list. Once the Delphi method was complete, the research team divided the issues based upon their research background and conducted the remainder of the literature searches.

2.7.1 Literature Search Methodology

When conducting the literature search, numerous databases, websites, and library searches were completed. Some of the many sources included the University of Wisconsin – Madison Engineering Indexes, the Texas Transportation Institute libraries, the United States Department of Transportation website, the Transportation Research Board and National Cooperative Highway Research Program websites, and Transportation Research Information Services (TRIS) online. NCHRP panel and FWHA personnel were also contacted for information.

The following procedure was followed in order to successfully complete the literature search:

1. A database, web browser, or library search engine was selected.
2. A search was then conducted using key words from the issue statement.
3. Abstracts from the article were read to determine whether the article had any relevance to the research project.
4. If relevance was found, the article was then read to find any information relating to the requirements of Task 2.

5. A summary of the article was then written and added to the issue's literature search report.
6. Once that database, web browser, or library search engine was exhausted, the researcher moved on to another database.
7. Once all databases, web browsers, and library search engines were utilized, the initial literature search report was written addressing all the required elements of Task 2.

Literature searches were completed through April 2001. After each milestone, including the Interim Report and the Workshop, more information was provided on both the project requirements and new sources from the NCHRP panel and the workshop participants. From this information, the literature searches were revised and their depth increased.

The results of the literature search will be discussed in Chapter 3.

2.8 Chapter Summary

This chapter summarized the method used to collect the necessary data for this research study. First, an initial questionnaire was used to gather data for the Delphi method. Two rounds of the Delphi method were used to form a consensus for the top 20 research issues. Third, the top 20 issues were combined to make the top 15 research issues. Finally, a third round Delphi survey and literature searches were conducted to gather information regarding the top 15 research issues.

Chapter 3 Draft Research Program Development

3.1 Chapter Overview

This chapter explains how the data from Chapter 2 was integrated and revised to create the final recommended research program. First, a draft research program was created. Then the literature search results and draft research program were discussed during the December Panel meeting and revised upon completion of the meeting. Third, the Workshop was planned. The revised literature search results and the draft research program were discussed again at the March Workshop. Lastly, the final literature search and recommended research program were created from the results of the workshop.

3.2 Task 3: Draft Research Program

3.2.1 Format

Problem statements were developed from the final 15 issues developed in Chapter 2. Synthesized information gathered from (1) the literature search (Task 2); (2) the third-round Delphi survey; (3) the workshop (Task 6); and (4) the expertise of the research team and NCHRP panel was utilized to generate the problem statements. A standard format was followed when developing each problem statement. The format used was referred to as a Second Stage Problem Statement. Instructions for developing these problem statements were furnished by NCHRP. The following is an outline of the format used to describe the research problem statements:

I. Problem Number
II. Problem Title
III. Research Problem Statement
IV. Research Objective
V. Estimate of Problem Funding and Research Period

The problem number represents the NCHRP problem number that will be assigned to the project when it is presented to the Standing Committee on Research. The problem title is the final issue statement title developed for the research problem statements. The research problem statement summarizes the problems facing the SHAs with respect to the issue statement. Information was used from the literature searches, third round Delphi survey, panel meetings, and workshop to create the problem statements. The research objective is the recommended research process to solve the research problem. The estimate of problem funding and research period represents the approximate cost and time of the recommended research project.

3.2.2 Observations

The research problem statements where developed through several iterations over the course of the project. The research team had several general observations regarding the research problem statements throughout the project. These observations are outlined in the paragraphs to follow.

The research problem statements were not originally intended to necessarily represent single research projects. The Delphi process identified the problem statements as critical areas in need of future research. Each identified problem statement encompasses a large problem area. Most of the problem statements could be separated into multiple research projects, each focusing on specific issues within the general problem area. For example, the research problem statement "Safety of public and workers during highway reconstruction and maintenance" could be separated into three research projects as follows: (1) Identify methods to reduce speeds in work zones; (2) Analyze methods to configure highway work-zones to maximize safety; and (3) Assess methods to improve work-zone safety planning. The separation of the research problem statements into more specific sub-topics has not been completely investigated. Panel input would be helpful in this area.

The purpose of the literature review was to identify past research in each area (state-of-the-art), identify current practices (state-of-the-practice), identify barriers to implementation of past research, and identify gaps in knowledge (distance between the state-of-the-art and the state-of-the-practice). The research team has discovered that existing literature does not completely discuss gaps in knowledge and barriers to implementation. An accurate documentation of the implementation of completed research is not available for most issues. More investigation in these areas was needed to determine gaps and barriers. The third-round Delphi survey was specifically employed to compensate for these missing areas in the literature review. The respondents were requested to identify specific problems, barriers to implementation, and gaps in knowledge. A large quantity of data was generated by this questionnaire and incorporated into the research problem statements.

Delphi respondents selected the 15 critical problem issues that require future research. For some of the issues selected by the panel, the problems and solutions are not entirely related to CEM. For example, most of the research in the area of "Recruiting, promoting, and retaining qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel)" is not within direct control of SHAs. The research discovered through the literature review in recruiting and retaining employees was prepared in other fields. An investigation was necessary to relate the information gathered to the CEM discipline.

Another question that needs to be investigated by the research team is, "Can the issues identified by the Delphi survey be addressed by the implementation of future research and development?" The 15 issues were identified as "problem areas in need of future research," but more analysis is necessary to determine if a lack of research is the problem. The cause of the problem area could alternatively be a lack of resources, time, funding, or the use of traditional practices.

The final Second Stage Problem Statements and implementation plan will be discussed in Chapter 4.

3.3 Task 4: Develop Plan and Format for Workshop

The workshop took place March 5 and 6, 2001, in the Beckman Center in Irvine, California. The purpose of the workshop was to improve the depth and scope of each of the top 15 research issues. In order to make the workshop a success, the overall scope and schedule was well planned to insure the attainment of the project objectives. Some of the key ingredients that were required to make a successful workshop were the following: (1) selection of participants; (2) participant interaction; (3) foundation of key issues; (4) professional facilitation; and (5) workshop direction. The team worked closely with Mr. Corey Hessen and David Stone of FMI Corporation, the workshop facilitators, to insure a successful workshop.

The workshop content was focused primarily on the draft research program from Task 3 and the expertise of the research team members, facilitator, and panel. This information served as a basis for a workshop that would review and modify the top priority issues to create a more detailed research program.

3.3.1 Proposed Workshop Participants

It was anticipated that the workshop would bring together 50 professionals, selected by NCHRP, who were knowledgeable in different areas of CEM. The participants of the workshop had the following backgrounds:

- State Departments of Transportation / Federal Highway Administration / United States Department of Transportation Personnel
- Equipment Manufacturers
- Construction Contractors
- Environmental Experts
- Materials Industry Personnel
- Research Experts
- Consulting Firms
- Academics

3.3.2 Pre-Workshop Packet

To increase efficiency and effectiveness of the workshop, the research team distributed a packet of information to participants for review prior to the workshop. This packet of information served to familiarize the participants with the project’s issues and objectives.

The packet contained:
- Background (project objectives, overview of the research process, etc.)
- Objectives and desired outcomes of workshop

- Summary agenda for the workshop
- Summary of research issues and issue objectives

The research issue statements were lettered instead of numbered so as to not bias the workshop participants during the prioritization session. A copy of this packet can be found in Appendix N.

3.3.3 Proposed Workshop Layout

The participants were separated into 6 groups with approximately 8 people in each group. Each group included a research team member and at least one NCHRP panel member in it.

The workshop included 11 breakout sessions. During each of the breakout sessions, each group discussed one of the fifteen priority issues. At completion of the workshop, each issue was discussed by at least 3 groups. Each participant was also asked to identify other issues they believed were important for future research. The final session of the workshop was a prioritization session in which each participant was able to place 1 of their 5 votes on the issues they believed were the most important.

The use of flip charts and laptop computers served to capture the information during the workshop. Each group was assigned a member of the research team to assist in capturing the dialogue.

The research team documented all the information derived from the workshop for review. The feedback from attending professionals greatly helped to refine each problem statement. The results of the workshop are described later in this chapter.

3.4 Task 5: Interim Report

An Interim Report was due November 1, 2000. It included the completed work on Task 1, the Questionnaires, and Task 3, the Draft Research Program. It also contained the work to date on Task 2, the Literature Search, and Task 4, the Format and Plan for the Workshop.

3.5 Panel Meeting

A meeting with the panel was held in Washington DC on December 4th and 5th, 2000 to review the Interim Report that was due November 1, 2000. Input was gathered from the panel to revise the research problem statements and the plan and format for the workshop. The panel also provided additional sources for the literature search, Task 2.

Topics discussed at the meeting were as follows:

- Revision of Draft Research Problem Statements
- Selection of Participants for the Workshop in March 2001
- Revision of the Workshop Plan and Format

3.5.1 Revision of Draft Problem Statements

At the panel meeting the research problem statements were discussed at length. It was decided that the research problem statement titles are actually issue statements that cover a few research projects. Each issue statement has at least three objectives. The objectives were discussed to see if they were within the scope of the research project and if they were researchable. The issue statements were rewritten to better clarify their intent.

The issue statements and objectives were originally grouped according to topic areas. After the recommendations and revisions from the panel were added to the issues, the statements were placed in order of priority as ranked by the respondents of the second-round Delphi survey. A 16th issue, 'New and Emerging Processes and Technologies," was added to the list by the panel to allow workshop participants the chance to express their opinion on additional issues that may be of concern in the future.

3.5.2 Revised Issues Titles and Objectives

The new list of issues and their corresponding objectives in priority order are as follows:

1.Safety of public and workers during highway reconstruction and maintenance
- Reduce traffic speeds in work-zones
- Configure work-zone to maximize safety
- Improve work-zone safety planning
- Use case studies to find out which methods and techniques work to slow down traffic

2. Develop and evaluate new construction methods, techniques, and materials to facilitate faster construction
- Identify construction processes to minimize the impacts of highway construction on highway users
- Investigate the use of modular construction techniques in highway and bridge projects
- Develop a knowledge base for best practice construction methods
- Develop a knowledge base for the best practice construction methods when using non-traditional/new materials
- Identify processes for implementing new materials into practice with examples of successful implementation plans
- Develop user-friendly models that identify potential cost savings for implementing the use of new durable materials

3. Recruiting, promoting, and retaining of qualified personnel in highway construction

- Benchmark employee practices between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel
- Investigate methods for SHAs to provide competitive careers
- Develop optimum strategies for staffing and contract administration
- Evaluate the pool of employees available, recruitment strategies, and corresponding retention rates
- Quantification of the need to invest in human resources

4. Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction

- Develop an empirical method to select the most efficient and economical contracting strategy
- Evaluate the results of various, non-traditional contracting strategies
- Investigate the compatibility between innovative contracting strategies (non-traditional) and the traditional low-bid competitive system
- Assess impact on SHA stakeholder's culture, risk and responsibility.

5. Development, implementation, and evaluation of the use of incentives/disincentives for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility

- Assess current use of incentives/disincentives within contracts
- Determine fair and effective incentives/disincentives
- Create guidelines and examples that uses incentives/disincentives as a contract clause

6. Innovative strategies to manage traffic during highway construction projects – as specifically related to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction

- Investigate the effectiveness of current innovative contraction methods
- Analyze the availability and effectiveness of software applications to simulate and visualize highway construction projects
- Identify recommended guidance, best practices, and training associated with specifying, designing, implementing, managing/operating various travel management and traffic control strategies associated with different types of projects
- Study the impact of shifting more responsibility for traffic control to the contractor

7. Training and workforce development of SHA personnel

- Assess the current training programs used by SHAs related to CEM
- Determine necessary CEM skills and where more training is needed in those skills
- Determine who would deliver training and how it should be delivered
- Investigate institutional barriers to training programs (limited time and out-of-state travel)
- Standardize training programs and create reciprocity between states

8. Development, implementation, and evaluation of Performance-Based Specifications for highway construction

- Assess the current use of performance-based specifications and how their use impacts a project
- Determine whether individual state laws will permit the use of a performance-based specification for public agencies
- Determine which types of project components, i.e. pavements, bridges, etc., will benefit from the use of performance-based specifications
- Provide guidance to SHAs for writing performance-based specifications

9. Performance-based acceptance tests (including investigation of adequate level of construction inspection)

- Assess the current use of QC/QA performance-based tests
- Determine what performance-based QC/QA tests need to be developed and prioritize them
- Develop uniform testing procedures for those determined from above
- Investigate institutional barriers to implementation
- Identify strategies and barriers of why developed tests are not being used
- Develop accelerated field performance test methods for durability

10. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)

- Assess the current ways SHAs are approaching the problem of increased workload with reduced staff size
- Evaluate the use of outsourcing as a technique to contend with reduced staff size
- Develop decision support tool to assess outsourcing of CEM processes versus work retained in-house
- Develop new programs that can be used to contend with this problem and assess their effectiveness

11. Development, implementation, and evaluation of rapid test methods and non-destructive testing (NDT)

- Assess current non-destructive and rapid test methods used in practice
- Determine where the needs are for new non-destructive and rapid test methods
- Create a program that assists in the development and research of new test methods
- Evaluate cost versus benefit of new test methods compared to updating old test methods

12. Impact of construction projects on communities and necessary communication between agency/contractor and general public

- Assess public perceptions regarding impact of construction on motorists and businesses
- Assess the current community involvement programs.
- Determine other types of programs or methods that are needed.
- Create examples that can be used as guidelines for different options of obtaining and making use of community input

13. Compliance with current and future environmental restrictions/requirements

- Evaluate the impact of changing regulations of noise, air, storm water management on construction projects
- Assess the current programs to identify best practices that focus on compliance of environmental regulations
- Determine what other programs or areas of study are needed that will aid the SHAs in compliance of environmental regulation

14. Review of the constructability of transportation facilities in the planning and design phases –specifically deficiencies in quality and clarity of construction plans

- Study the results of projects, successes and failures, that have used a formalized constructability review process (CRP)
- Investigate the use of computer applications in the CRP
- Institute courses to train agency design staff to identify constructability issues in project plans and specifications

15. Expanded use of contractor-performed quality control data for acceptance purposes

- Assess the use and effectiveness of current contractor QC/QA testing
- Examine the states of knowledge and practice of other public agencies
- Determine the areas in which contractor QC data can be applied
- Evaluate cost/benefit trade-offs including impact on construction costs
- Create examples that provide guidance for contractor QC/QA testing

16. New and emerging processes and technologies

This list would be revised again after completion of the Workshop.

3.5.3 Revision of Plan and Format for Workshop

A preliminary plan for the March 2001 workshop had been developed in the Interim Report. During the Panel meeting, the plan was discussed and revised. The research team worked with the lead facilitator, Corey Hessen of FMI Corporation, and the panel members in planning and conducting the workshop to insure a successful workshop. The final plan for the workshop and the results is discussed later in this chapter.

3.6 Task 6: Conduct the Workshop

The workshop was conducted on March 5th and 6th, 2001 at the Beckman Center in Irvine, California. The knowledgeable participants shared their knowledge and provided comments about the draft research problem statements. A summary of the participants by their specialty can be found in Table 3.1. A list of the participants can be found in Appendix O.

Table 3.1 Workshop Respondent Summary

Position	# of Participants	% of Participants
Academic	9	16
Contractor	6	11
Private Engineer/Design	7	13
Equipment	1	2
FHWA	6	11
NCHRP	4	7
QA/QC/Testing	2	4
State Highway Administration		
Construction	10	18
Design	4	7
Management	5	9
Transportation Research Board	1	2
Total	55	100

3.6.1 Workshop Pre-Facilitation Session

The panel members met early Sunday evening, March 4, 2001, with the facilitators Corey Hessen and David Stone for a facilitation training session. At this session, the panel members who were to be facilitators were trained to facilitate their groups and were able to ask any questions about the workshop and how it would be conducted.

3.6.2 Welcome Reception

Later Sunday evening, panel members, research team members, and the participants met for a welcome reception at the hotel. All attending were able to socialize and familiarize themselves with the attendees. A workshop packet was distributed to each participant for their use during and after the workshop. A copy of the workshop packet can be found in Appendix P.

3.6.3 Workshop

Monday morning, all attending the workshop met in the hotel lobby for the bus ride to the Beckman Center. Upon arrival, the 2-day, fast paced workshop began. On Monday morning the participants listened to an introduction into the NCHRP and an introduction to the research project. They participated in an icebreaker and the first breakout session. The Keynote Speaker, Mike Ryan, could not make it to the workshop due to adverse weather conditions. However, a copy of his speech 'Research –Beyond TEA-21" can be found in Appendix Q.

After lunch, three more breakout sessions were held, one of which was brainstorming for future issues. After the breakout sessions, the groups reconvened to provide feedback to the research team on the first day of the meeting. At conclusion of the day, participants were bussed back to their hotel.

Day two of the workshop consisted of six more breakout sessions. Four of the breakout sessions included discussion of the group's assigned issues. At the fifth breakout session, each group was able to select an issue they wanted to discuss, but had not been previously assigned. During the last breakout session, each group discussed one of the brainstormed issues from the previous day.

At the end of the second day, the groups came back together to prioritize the issues. Each participant received 5 dots. Each issue, including the brainstormed issues, had been written on isle paper and taped up around the room. The participants then walked around the room and placed a dot on the five issues they felt were one of the five most important. The prioritization of the issues from the workshop versus the final Delphi Rank is displayed in Table 3.2.

Table 3.2. Workshop Prioritization

Workshop Rank	Delphi Rank	Issue Topic
1	6	Impact of strategies to manage traffic during highway projects on construction methods, productivity, schedule, and quality
2	4	Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction
2	8	Implementation and evaluation of performance-related specifications (PRS) for highway construction
2	2	Develop and evaluate new construction methods, processes, and materials to facilitate faster construction
5	1	Improve safety of public and workers during highway reconstruction and maintenance
5	14	Constructability review process implementation plan
7	3	Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel)
7	5	Evaluation of the use of incentives/disincentives (I/Ds) to reduce time to complete highway projects

Table 3.2. Workshop Prioritization Cont'd

Workshop Rank	Delphi Rank	Issue Topic
7	11	Identification, evaluation, and implementation of rapid test methods and non-destructive testing (NDT) to assess quality in the construction process
10	12	Best practices for community outreach and involvement during construction
11	Not ranked	Warranties
12	10	Determination of strategies to offset reduced staff size with increased workload of SHA personnel
13	15	Expanded use of contractor-performed quality control processes for acceptance of highway projects
14	9	Development and implementation of performance-related acceptance tests
15	7	Training and workforce development of SHA personnel
16	13	Best practices to aid SHA construction engineers and managers in managing environmental restrictions and requirements

After prioritization of the issues, the participants were then able to voice their concerns and compliments about the workshops. At completion of the workshop, participants were bussed back to their hotel.

3.6.4 Post Workshop Meeting

The morning after the completion of the workshop, the panel and the research team met to discuss the workshop and the path forward. All were pleased with the workshop results. A few key dates were decided upon and the final format for the report was discussed. It was requested that three Second Stage Problem Statements be developed for the panel to submit to the AASHTO Standing Committee on Research (SCOR). The problem statements were:

1. Evaluation of the Use of Incentives/Disincentives (I/D) to Reduce Time to Complete Highway Projects
2. Expanded Use of Contractor-Provided Test Results for Acceptance on Highway Projects
3. Analysis of Nighttime Construction Activities and Impacts on Safety, Quality, and Productivity

These statements are included in Chapter 4, the Recommended Research Program.

3.6.5 Workshop Data Summary

Approximately 20 days after completion of the workshop, participants were sent a summary of each group's input from the workshop. A copy of the summary can be found in Appendix R.

3.6.6 Final Issue Statement Titles and Objectives

The issue titles and objectives were revised after the workshop. Numerous future issues were identified. Certain future issues were expanded upon. Their summary can be found in Appendix R.

The revised Issues Statement Titles and Objectives are as follows:

1. Improve safety of public and workers during highway reconstruction and maintenance
   - Develop innovative methods to improve safety in work-zones.
   - Identify and develop best practices to configure work-zone to optimize safety.
   - Develop guidelines for consistent work-zone safety planning to include public relations, scheduling, road closures/detours, construction sequencing, configuring work-zones, worker safety, and utilizing barriers.
   - Use case studies (maintenance, rehabilitation, and reconstruction) to determine which methods and techniques effectively improve work-zone safety.

2. Develop and evaluate new construction methods, processes, and materials to facilitate faster construction
   - Identify faster construction methods and processes to minimize the impacts of highway construction on highway users.
   - Investigate the use of precast modular construction techniques in highway and bridge projects.
   - Develop knowledge base for best practices of rapid construction methods.
   - Develop knowledge base for best practices of rapid construction methods when using non-traditional/new materials.
   - Identify processes for implementing new materials into practice with examples of successful implementation plans.
   - Develop user-friendly models that identify potential time-savings for implementing the use of new durable materials.

3. Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel)
   - Investigate methods for state highway agencies to provide competitive careers.
   - Benchmark employee practices between the public sector, private sector, and other disciplines for entry level employees and/or experienced personnel.
   - Develop optimum strategies for staffing and contract administration.

- Evaluate the pool of employees available, recruitment strategies, and corresponding retention rates.
- Quantify the need to invest in human resources.

4. Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction.
   - Develop a method to select the most efficient and economical contracting strategy based on known specific project factors, characteristics, sizes, complexities, owner objectives, and constraints.
   - Evaluate successes/failures of innovative contracting methods on past projects (emergency and non-emergency projects) including effects on schedule, cost, quality, competition, and highway users.
   - Investigate the compatibility between innovative contracting strategies (non-traditional) and the traditional, low-bid competitive system from both the owner and contractor perspectives.
   - Assess impact on SHA stakeholders' culture, risk, and responsibility.

5. Development, implementation, and evaluation of the use of incentives/disincentives and contract provisions to improve cost, effectiveness, timeliness, and quality of the constructed facility
   - Assess current use of incentives/disincentives within contracts
   - Determine fair and effective incentives/disincentives
   - Create measurable and objective criteria to aid in the use of incentives/disincentives
   - Create guidelines and examples that use incentives/disincentives as a contract clause

6. Impacts of strategies to manage traffic during highway projects on construction methods, productivity, schedule, and quality
   - Investigate the effectiveness of innovative contracting methods (A+B bidding, lane rental, incentives/disincentives) to influence timely completion of projects and minimize construction complications on traveling public and businesses.
   - Evaluate the use of existing software applications for traffic design and assess the impacts of various construction operations (e.g. lane closures) on traffic flows.
   - Identify recommended guidance, best practices, and necessary training associated with various travel management and traffic control strategies associated with different types of projects.
   - Study the impact of permitting more flexibility of traffic management methods to the contractor.

7. Training and workforce development of SHA personnel
   - Assess the current training programs used by SHAs related to Construction Engineering and Management (CEM)
   - Determine necessary CEM skills for SHA personnel
   - Evaluate the use of mentoring programs as a training tool

- Evaluate how the necessary CEM skills relate to the managerial career path, for example, what skills are needed at what level of career?
- Evaluate the use of technical career paths as a possible career path for SHA CEM personnel
- Develop innovative model training programs which are designed to overcome traditional institutional barriers (limited time, out-of-state travel, funding)
- Identify opportunities and procedures to create partnerships between SHAs, contractors, and consultants to standardize training and increase the potential audience
- Develop cost-effective training programs that can be maintained and updated to provide SHA personnel the necessary CEM skills

8. Implementation, and evaluation of performance-related specifications (PRS) for highway construction
   - Assess the current use of PRS and how their use impacts a project in terms of time, cost, and quality
   - Determine which types of project components, i.e., pavements, bridges, etc., will benefit from the use of PRS
   - Provide guidance to contractors for bidding and working under PRS so as to minimize life-cycle costs
   - Provide the training/education of SHA and contractor personnel needed to implement PRS
   - Develop performance models and criteria, not only for pavements, but all types of construction
   - Evaluate the methods to develop PRS and provide guidance to SHAs for writing effective PRS
   - Develop an AASHTO guide for PRS which provides guidance to SHAs for writing effective PRS

9. Identification, evaluation and implementation of performance-related acceptance tests
   - Assess the current use of performance-related acceptance tests
   - Determine properties needed to predict performance
   - Determine the performance-related tests that need to be developed and prioritize them
   - Develop uniform testing procedures for those determined from above
   - Determine the cost-effectiveness and needed level of acceptance testing
   - Identify institutional barriers to implementation and recommend strategies to overcome them

10. Determination of strategies to offset reduced staff size with increased workload of the SHA personnel
    - Assess the current ways SHAs and others are approaching the problem of increased workload with reduced CEM staff size
    - Evaluate the use of outsourcing versus more efficient use of resources

- Develop decision support tool for SHA personnel use to assess outsourcing of CEM processes versus work retained in-house
- Develop new strategies to address this concern and assess their effectiveness
- Create a best practices guide with case by case examples to aid SHA personnel on selecting the correct approach

11. Identification, evaluation, and implementation of rapid test methods and non-destructive testing (NDT) to assess quality in the construction process
    - Identify current non-destructive and rapid test methods used in practice
    - Assess cost/time savings vs. quality tradeoff of the results of the identified test methods
    - Create a best practices guide for SHA personnel that displays all available non-destructive and rapid test methods
    - Determine and prioritize where the needs are for new/improved non-destructive and rapid test methods

12. Best practices for community outreach and involvement during construction
    - Assess public perceptions regarding impact of construction on motorists and businesses
    - Assess the current community involvement programs
    - Compare the benefits of having a public involvement program versus the cost of the program
    - Identify and develop uniform methods for SHAs to use to obtain public feedback on agency construction programs on a regular basis
    - Develop best practices for community outreach and involvement during construction which includes all current SHA efforts to date

13. Best practices for managing environmental restrictions and requirements
    - Evaluate the impact on SHA CEMs with respect to the current and impending regulations of noise, air, storm water management.
    - Assess the current programs available to SHA CEMS that focus on compliance of environmental regulations
    - Create a program to facilitate the communication of environmental decisions that were made in pre-construction planning/permitting stage to the construction team
    - Determine what other programs or areas of study are needed that will aid the SHA CEMs in compliance of environmental regulation
    - Create a best practice guide to aid SHA personnel in complying with environmental restrictions/requirements

14. Constructability review process implementation plan
    - Study the results of projects, successes and failures, that have used a formalized constructibility review process (CRP), document the benefits, and indicate where the CRP is ineffective and in need of alteration.
    - Development of a user-friendly method to measure costs and benefits of a CRP.
    - Identify methods to overcome barriers to successfully implement a formal CRP.

- Institute courses to train agency staff (design and construction staff) to identify constructibility issues in project plans and specifications.

15. Expanded use of contractor-performed QC processes for acceptance of highway projects
    - Assess the current states of knowledge and practice for quality testing.
    - Evaluate the current system for its effectiveness in increasing the quality of the project.
    - Identify where contractor tests results are used for acceptance and evaluate its impact on the project.
    - Examine the states of knowledge and practice of other public agencies
    - Assess the current practices and/or problems with verification and validation of contractor test data for acceptance
    - Create certification programs for technicians to insure unified testing procedures for all tests
    - Determine the areas in which contractor test data can be applied
    - Evaluate cost/benefit trade-offs including impact on construction costs
    - Create examples that provide guidance for the use of contractor test data in verification and acceptance testing

16. Future Issues Identified
    - Warranties and Risk Allocation
    - Unified Testing and Implementation Plan for New Durable Materials
    - Remote Construction and Maintenance
    - Information Technology Systems
    - Planning to Eliminate Delays Caused by Utilities
    - Computer-Based Systems for Project Management / Bidding / Distribution of Information

3.7 Literature Search Results

At the panel meeting after the workshop on Wednesday, March 7, 2001, it was requested that the literature searches be narrowed down to include only information directly relating to research projects and implementation programs for SHAs. The results of the final literature search are contained in the following sections.

3.7.1 Improve Safety of Public and Workers During Highway Reconstruction and Maintenance

INTRODUCTION

Highway construction represents a significant risk to workers and the traveling public. The management of highway projects must address safety hazards to workers and highway users. The presence of high-speed traffic in the work-zone introduces a unique risk, making highway construction work more precarious than other types of construction (Andrew and Bryden 1997). Highway construction activity has shifted from the construction of new facilities to the reconstruction and maintenance of existing facilities. The shift in the type of construction work, plus the increase in number of highway users and vehicle miles traveled, has created an increased opportunity for conflict between road users and construction workers and equipment (Hall and Lorenz 1989).

In addition, highway work-zone accidents are expensive due to "medical expenses, workers' compensation benefits, liability, property damage, loss of productivity, administrative time for reports, wages paid to injured workers, cleanup and repair, adverse publicity, third-party liability claims, and equipment damage" (Andrew and Bryden 1997). Vehicle accidents lengthen traffic delays through work-zones, thus increasing the financial/time loss of highway users (Andrew and Bryden 1997).

Highway MRR activities present different construction safety concerns. Maintenance operations typically move faster than reconstruction, require less time, and occupy less area. Maintenance procedures require alternative safety practices and equipment that are more mobile than methods used for reconstruction projects (Trujillio et al. 1995, Ward et al. 1993).

Traffic accidents in construction work-zones are caused by a combination of factors, including driver error, inadequate vision, poor road surface condition, construction obstructions, inadequate traffic control, and improper management of material, equipment, and personnel in construction (Noel et al. 1988). Successful work-zone safety management will minimize traffic accidents and thus reducing deaths and serious injuries to both the traveling public and highway workers in work-zones. Work-zone safety management consists of three phases: *engineering, traffic enforcement, public awareness*. Engineering must include adequate plans, specifications, and design with special consideration given to work-zone safety. Traffic enforcement of the traveling public by law enforcement personnel can maintain safe driving speeds in the work-zone. Public awareness campaigns can alert the road users of the importance of safe speeds and alertness in highway construction work-zones (Andrew and Bryden 1997).

The responsibility of appropriate work-zone safety falls on all parties involved as stated by Evans in the 1990 article "Highway Construction Site Safety" in *Highways and Transportation*:

> "We must remember that the primary objective is to reduce the horrific number of fatalities and injuries that occur every year in the construction industry. Client, designer, specifier or contractor, all have a role to play in achieving this objective, and all should consider how best they can contribute to the total effort."

STATES OF KNOWLEDGE AND PRACTICE

Many State Highway Agencies (SHAs) have realized the magnitude of the problem of work-zone accidents on construction and maintenance projects and have implemented policies and plans to minimize accidents. The following is a list of work-zone safety procedures for various SHAs (sources are SHA department websites, unless otherwise specified):

- A contractor bidding on a Florida Department of Transportation project must include the cost of police patrol, in the bid amount, to enforce the work-zone speed limit (Ingram 1993).

- Illinois Department of Transportation uses unmanned radar units to slow down traffic speeds in work-zones. The radar unit records vehicle speeds and also sets off 'fuzz-busters" causing drivers to slow down. The program is low cost and effective in decreasing speeds (11 Ways 1990).

- Iowa Department of Transportation has tested a plan that uses two portable, changeable message signs on each end of the work-zone warning of congestion, stops, and lane closures. SHA personnel who continually monitor traffic conditions using a laptop computer equipped with a cellular modem activate the signs. Traffic is monitored using cameras and the public is notified by advisory radio. The information gathered in this research project was successfully tested and determined to be valuable for similar projects in the future (Gent 1998).

- Michigan Department of Transportation (MDOT) and Michigan State Police have formed an alliance to increase law enforcement in work-zones. MDOT has budgeted $175,000 for special overtime State Police patrols in construction zones to enforce traffic speeds and safety. MDOT also stresses the "Three Es of Work Zone Safety," including education, enforcement, and engineering.

- Missouri Department of Transportation works with highway patrol to enforce safety and reduce speeds in work-zones (Ingram 1993).

- New Jersey Department of Transportation uses radar guns to control speed. A vehicle traveling over the limit will cause a message board to flash a 'Slow Down Now" signal. The gun also activates radar detectors (11 Ways 1990).

- New York State Department of Transportation (NYSDOT) has implemented a plan to increase work-zone safety. The objectives of the plan are to provide adequate safety for public and workers, minimize travel delays and maintain access to nearby businesses, and provide opportunity for contractors to complete quality work at a reasonable cost. Responsibilities for safety include a clear statement of safety and health policy and responsibilities, contractual requirements in construction contracts, program management and control procedures, traffic-control management procedures, and evaluation and improvement of safety operations. The contractor is responsible for all work necessary for the safety of public and workers. The contractor must equip, train, and supervise workforce and is responsible for all work safety of subcontractors. The safety requirements should be in project specifications so contractors can estimate price of safety plan implementation into the bid price. Contractors that practice adequate work-zone safety should not be at a competitive disadvantage in the bidding process (Andrew and Bryden 1997).

- Nevada passed a bill in 1997 that doubles fines for traffic violations in construction, maintenance, and permit work-zones.

- Oregon Department of Transportation (ODOT) has implemented several new policies to reduce accidents in highway work-zones. A million dollars have been allocated to provide increased police traffic patrols in work-zones across the state of Oregon and double fines for traffic infractions have been imposed. Also ODOT is separating work from traffic with barriers when practical, doing some work at night to lessen exposure, and increasing traffic control planning efforts.

- The state of Pennsylvania doubled fines or work-zone traffic violations and the Pennsylvania Department of Transportation has reported a decrease in fatalities and injuries since implementation (Ingram 1993).

- South Carolina Department of Highways and Public Transportation (SCDHPT) argues that its employees are well trained in work-zone safety through special seminars and safety meetings (Ellison 1988).

- Texas State Department of Highways and Public Transportation has implemented a policy to minimize vehicular accidents caused by pavement edges and dropoffs in construction work-zones (Ivey et al. 1988).

- Washington State Department of Transportation (WSDOT) implemented a program in August 1997 for work-zone traffic control assistance from the Washington State Patrol (WSP). Both the WSP officer and WSDOT inspector must fill out a one-page checklist to assure that both agencies concur on the methods of safety and enforcement.

- Wisconsin Department of Transportation is using extra surveillance by state patrol to reduce the speed of traffic before it reaches the work-zones (Ingram 1993).

- The very popular and successful 'Give 'Em a Brake" public awareness campaign, implemented by many states (including California, Kansas, Michigan, Nevada, Oregon, Texas, Washington, and others), has stressed the importance of traffic safety in construction work-zones.

IMPLEMENTATION BARRIERS

Several SHAs are faced with safety challenges. Some of these problems include a lack of training of contractor personnel, lack of safety equipment (message boards, signs), high vehicle speeds through work-zones, inadequate traffic control, engineering/management specifications, and the large cost of liability suits (Ha and Nemeth 1995).

Most SHAs have procedures to address work-zone safety for their employees, but very few address the safety of contractor and consultant personnel (Andrew and Bryden 1997).

The cost of a work-zone safety plan can be extremely expensive. In 1991, NYSDOT spent approximately $10 Million on work-zone traffic control (Andrew and Bryden 1997).

GAPS IN EXISTING KNOWLEDGE

The Manual on Uniform Traffic Control Devices (MUTCD) presents a guideline for determining speed limits on roads free of construction, but does not suggest a procedure for determining speed limits in work-zones (Migletz et al. 1999).

North Carolina DOT uses safety records as a qualification to bid on highway projects. Contractors with high EMR, OSHA safety records may not bid on North Carolina highway jobs. Research is needed to investigate if this qualification process increases work-zone safety and decreases accidents (Dr. Anderson).

PAST RESEARCH –UNKNOWN IMPLEMENTATION

The following is a list of completed research with unknown implementation:

- Four ways to reduce traffic speeds in work-zones
  - Manual on Uniform Traffic Control Devices (MUTCD) flagging.
  - Innovative flagging
  - Stationary police cruiser with lights and radar on
  - Uniformed police traffic controller

  This research should be analyzed considering the following assumptions: All data was collected under ideal traffic conditions (level of service A). Law enforcement methods demonstrated a potential for long-term speed reduction capability. All data collected from areas of high (existing) speed control. Traveling public must already be aware of high level of traffic speed enforcement to make law enforcement in work-zones effective (Noel et al. 1988).

- NCHRP 3-41(2)
  - Assess the implementability of the procedure for setting work-zone speed limits
  - Document the effect of vehicle speeds of work-zone speed limits
  - Make recommendations to redefine procedures
  - Prepare guidelines to facilitate implementation (Migletz et al. 1999).

- FHWA has released two video tapes designed to inform highway workers the appropriate method to delineate permanent and temporary concrete barriers, and the proper method to apply the use of flashing arrows panels in work-zones (Lasek 1993).

- The FHWA has implemented a training course targeted at work-zone inspectors of the traffic control plans and devices. This course helps improve the inspector's understanding and knowledge of the project traffic controls and safety in the work-zone (Lasek 1993).

- The study of safety vests to alert motorists to the presence of maintenance personnel has been investigated. Vests must be highly visible against a variety of backgrounds and under all illumination conditions. The vests will make working personnel easier to detect by motorists (Brackett et al. 1985).

3.7.2 Develop and Evaluate New Construction Methods, Processes, and Materials to Facilitate Faster Construction

INTRODUCTION

Highway construction and reconstruction projects can cause significant delays for highway users and may contribute to a financial loss for area businesses. Decreasing the construction time of highway projects will minimize the impacts on commuters and commerce. Innovative construction methods, processes, and materials can decrease the construction duration, minimize construction traffic delays, and/or increase the quality of the constructed facility.

Methods

Literature and industry professionals have identified three methods to facilitate faster highway reconstruction:

- Investigate the use of innovative techniques that will decrease the construction schedule (such as asphalt paving reconstruction techniques, Portland Cement Concrete (PCC) paving reconstruction techniques, and bridge reconstruction and maintenance techniques).

"Roadway pavements fail prematurely for a variety of reasons – improper design, use of inferior materials, poor construction, environmental conditions, and several other causes. Additionally, they sometimes simply wear out from age and traffic" (Kearney and Huffman 1999). Rehabilitating and/or reconstructing highway pavements should consider the project cost, schedule, and pavement quality. In the past, it has been common practice to rehabilitate many pavements with a HMA overlay, regardless of the pavement condition or type of failure. The HMA overlay was easy, fast, less costly, and usually rode well and maintained a good appearance. Other, more durable and cost-effective solutions include cold in-place recycling (CIR), hot in-place recycling (HIR), and full-depth reclamation (FDR) (Kearney and Huffman 1999). "Several surface preparation techniques have been used before placing a hot-mix asphalt (HMA) overlay in attempt to minimize reflective cracking. Some of the most common techniques are rubblization, crack and seat or break and seat, and saw and seal" (Bemanian and Sebally 1999). "The National Asphalt Pavement Association (NAPA) has produced a comprehensive report and procedure for designing HMA overlays for crack and seat and rubblized pavements (Bemanian and Sebally 1999).

Possible methods to rehabilitate PCC pavements are: 1) rubblization; 2) crack and seat; 3) unbonded concrete overlay; and 4) reconstruction. "Because of limited funding, and more demand for the use of these funds, the proper selection of cost-effective rehabilitation strategies for PCC pavements is needed" (Bemanian and Sebally 1999). Additionally, more timely methods to reconvene traffic flows on reconstructed PCC pavements are critical.

Precast or precast prestressed concrete bridge deck panels can be used to rehabilitate bridge decks. "This system can be used advantageously to reduce construction time, hence, lowering the cost imposed by the rehabilitation process." "Durability and reduced speed for maintenance, ease of construction, along with maintaining traffic without interruption of traffic flow are advantages in using precast or precast and prestressed concrete deck panels in bridge rehabilitation"(Issa et al. 1995).

Processes

Since the purpose of faster construction operations in traffic zones is to minimize the impacts on highway users, it would be an incomplete study to omit the investigation of more efficient processes to manage traffic during highway reconstruction. Construction traffic management is a substantial part of any highway reconstruction project. An effective traffic management plan must maximize the safety of the highway users and construction personnel and minimize the impacts on normal traffic flows (Krammes 1990).

A current project funded by the National Cooperative Highway Research Program (NCHRP) 10-50A is entitled, "Guidelines for Selecting Rehabilitation Strategies for Rigid Pavements Subjected to High Traffic Volumes." The study is developing a formal decision process and guidelines to assist SHAs in evaluating and selecting maintenance, rehabilitation, and reconstruction (MRR) strategies for rigid pavements in high traffic volume situations. A substantial focus of this process and guideline relates to early and increased involvement of traffic and construction expertise when evaluating alternative MRR strategies.

Materials

The US infrastructure is experiencing significant deterioration. This deterioration has resulted in significant research programs in testing, evaluation, repair, and development of materials, with the intent of producing more durable, longer lasting infrastructure systems. In 1987, the Strategic Highway Research Program (SHRP) was established by Congress as a 5-year $150 million research program to improve the performance and durability of our nation's roads (FHWA 1998). Work was implemented to develop and evaluate innovative technologies for roadway construction, maintenance, and operations and the efforts were divided into four program areas: asphalt, concrete and structures, pavement performance, and highway operations. In 1993, the Civil Engineering Research Foundation (CERF) proposed a national program to exploit the potential use of high performance steel and concrete for improving the competitiveness and quality of the US construction industry (CERF 1994). The National Institute of Standards and Technology (NIST) in collaboration with CERF currently supports 19 projects investigating the development of new materials for the infrastructure. The CERF program calls for a ten-year, $2 billion program of technological research, development, and deployment to accelerate the commercialization of high-performance CONstruction MATerials (CONMAT) and systems (Building and Fire Research Laboratory 2000). Currently, the role of the U.S. Department of Transportation (DOT) is to promote the use of high-performance materials for transportation infrastructure at the state level (Lane et al. 1996). Thirumuli (1998) reported that 70% of basic materials research is linked to improving material performance, yet he noted that the transportation industry is not ready to utilize such materials in the near future.

The performance of a system is only as good as it's weakest link. Construction managers, engineers, and contractors are often reluctant to utilize new materials due to limited availability of data on the long-term performance of such materials (both laboratory and field). Past experience with implementing new materials unsuccessfully have resulted in confusing recommendations by researchers and SHAs (Parks and Reis 1997, Weyers et al. 1997). Because there is often a relatively high initial cost, higher risks and unknown long-term performance information associated with the use of such materials, many states are reluctant to take on such a venture. Thus, the implementation of high performance materials is stifled at both the contractors and SHA levels. In addition to the resistance by SHAs and contractors, developers of new infrastructure materials are often unable to implement the use of these materials due the high costs associated with laboratory and field performance testing and long time requirements for the acceptance of such materials by regulatory agencies.

Thus, from a materials research perspective, significant research is underway to develop new materials for infrastructure facilities. There is a continued need to develop these new infrastructure materials, but there is a larger need to develop accelerated test procedures that predict the field performance of new materials. The increased risks and costs associated with implementing the use of these new materials should be overcome by forming partnerships with shared funding and knowledge between various organizations (both public and private). From a construction perspective, there is also a critical need to determine factors that influence the long-term field performance of newly developed materials.

STATES OF KNOWLEDGE AND PRACTICE

In the area of methods, the Florida Department of Transportation (FDOT) specifies a method of phase reconstruction to minimize the impacts on local businesses and road users ("Train" 2000). Modular bridge construction methods have been implemented in France for efficiency and economy (Muller 1993). Tests have been conducted on modular pavement systems for durability (Sharp et al. 1998) but how these modular pavement construction methods could facilitate faster reconstruction is unknown. Future research is necessary to investigate the use of modular construction techniques in pavement reconstruction. Contracting strategies, such as A+B bidding (cost plus time), often encourage contractors to use available and/or new technology and expertise to complete the construction phase as timely as possible by adding a monetary value to the time of the project.

In the area of processes, the Ohio Department of Transportation (ODOT) uses a life cycle cost analysis to select the type of pavement to be used ('Life" 2000). Not all states use all aspect of a LCCA.

Factors that influence the performance of a material in the laboratory are often not the same factors that influence the performance of a material in the field. Work is needed to identify and document the current practice in infrastructure construction. Practices that affect the performance of new materials in the field require investigation and documentation to develop the best practice for implementing the use of new materials and thus, developing guidelines for high performance construction practices. Accelerated field test methods are needed to assist in the implementation and validation of new materials.

IMPLEMENTATION BARRIERS

Construction engineers and contractors understand that the safest guide for present and future contract decisions is to observe past practice. Agency professionals acquire their skills and methods of operation by learning from their predecessors. Since the surest way to complete a highway project is to use what has worked in the past, the applications of innovative methods are limited and are unlikely to change without the promise of return ("Innovative" 1991). Additionally, the unfamiliarity or availability of new materials or construction methods also limits implementation.

Increased initial costs of materials and equipment, perceived risks, and a lack of accelerated field test methods decrease the likelihood that engineers and contractors will want to utilize new highway infrastructure materials. Construction materials, methods, and practices can significantly alter the durability performance of infrastructure systems. The lack of information on the previous use of new materials leads to a limited knowledge base about the benefits and costs of new methods and materials. The knowledge base is often limited by the contractor's unwillingness to share innovative methods and techniques, specifically techniques that offer advantages over other contractors.

Current reconstruction strategies are often incorrectly adapted from new construction techniques. For example, a method that is efficient for a new construction project is not always the best option for a reconstruction project where additional factors are involved such as traffic delays and further safety concerns. A constructibility analysis of new reconstruction techniques is necessary.

GAPS IN EXISTING KNOWLEDGE

There is currently limited documentation available on how construction methods influence product performance. More so, less information is available on what factors associated with each construction type (concrete, asphalt, steel, coatings, composites, etc.) most influences product durability and performance. Information is required to document standard practices. From this, best practices can be developed.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

NCHRP 10-50A is close to completion. Case studies using actual projects have been used to demonstrate the applicability of these guidelines. However, full implementation will not occur until the guidelines are published and available to SHAs.

3.7.3 Recruiting, Promoting, and Retaining of Qualified Personnel in Highway Construction (including supervisors to staff projects)

INTRODUCTION

Recruiting and retaining employees in the highway industry is a critical issue. Smart, ambitious, and highly motivated employees are difficult to manage. Attracting and retaining these people is a challenge. "Not only do they have to be compensated well, but they also demand work that develops their skills and matches their personal interests" (Berggren 1999). Since technical employees have different goals and interests than other types of employees (Murray 1999), a slightly different plan must be employed to successfully recruit and retain quality workers. "First, a technical manager needs to provide outstanding compensation. Second, the organization needs to provide an excellent benefits package. Finally, an organization needs to develop a reputation for having highly effective, well-trained employees and top-quality products or services that are on the cutting edge in the company's industry"(Soat 1996).

There are five keys to attract, develop, and retain quality personnel (Berggren 1999):

1. Remain market-based: The overall package has to be market competitive, but sure to include non-cash forms of benefits in your assessment of your payments.
2. Document explicit criteria: Develop explicit criteria for all payments.
3. Communicate: Share that criteria, the resulting compensation and the market benchmarks with all staff.
4. Be disciplined: Apply the criteria for all staff –existing and new hires.
5. Choose the right levers: Use the right compensation levers to reward the right skills and contributions.

Successful recruiting will minimize the employee turnover rate (Soat 1996). Therefore, most of the focus of previous research in the field is on the recruiting methods.

Definition of Recruiting:

"Recruiting involves locating individuals, with appropriate qualifications and in sufficient numbers, and encouraging them to apply for jobs with a particular organization. The basic purpose of recruiting is to ensure a sufficient pool of applicants from which the most qualified individual may be selected"(Caruth et al. 1988).

In general, state highway agencies are unable to offer employees the same pay scales and benefits as private companies. Also, many public agencies lack technical career paths that reward and support the development and retention of staff with valuable specific skill areas. As a result, state agencies have a low personnel retention rate as many state employees, with experience in hand, accept higher paying positions with private engineering/contracting firms. The demand of transportation construction, reconstruction, and maintenance work is increasing and thus, the demand for quality personnel throughout the industry is critical. Experts in industry indicate that many personnel have shifted from public employment to private employment, the demand for new technical staff falls more heavily on state agencies.

Currently, there is a shortage of civil engineers interested in transportation careers. In a National Cooperative Highway Research Study (NCHRP), several methods were identified to increase the interest in the civil engineering profession. The techniques from the study are being used to promote student awareness of civil engineering career options (Mason 1994). The implementation of K-12 outreach programs can introduce an interest in science and math to grade school students. A lack of interest in math and science fields leads to less qualified engineers available for work in the highway construction industry (Rosenbaum 2000).

STATES OF KNOWLEDGE AND PRACTICE

Recruiting

- Successful hiring must be (Murray 1999):
  - Rapid: quickly respond to resumes and make offers, the organization that moves quickly through the hiring process gets all the good people
  - Focused: potential employees must have the skills to do the work and the personal traits necessary to fit in the organization
  - Candid: fair and equal process
  - Decisive: someone directly involved with the interviewing process must have the authority to make an offer or reject a candidate
- Recruiting model (Caruth et al. 1988).

Salary

- Common flaw: for each level of skill, salary and bonus ranges are created to ensure compensation relative to contribution. This causes problems (Berggern 1999).
- Salary should reflect the employee's overall skills. The broader the skills and the deeper the experience..the higher the salary. For each skill set, there is a market price. An organization needs to compare salary ranges for competitors to be competitive in recruiting and retaining quality employees (Berggren 1999).
- Create sublevels within each level (mature, experienced, and new). The skills necessary for each sublevel should be documented and each should have a different salary. The salary range in each level is not linear. The salary increase between new and experienced is smaller than between experienced and mature (Berggren 1999).
- An organization must have competitive salaries to get quality people and then have competitive salary adjustments to retain these people (Murray 1999).
- Paying an employee what he/she thinks they are worth will eliminate dissatisfaction at the work place. However, paying a salary exceeding what the employee thinks they are worth will not increase the motivation level (Soat 1996).
- Salary is not just money. It is an index of the employee's value to the organization (Soat 1996).

Bonuses

- Tuition reimbursement program that provides funds for employees for continuing education (Berg 1991).
- Performance incentives are bonuses to reward employees for one-time actions, for achieving company goals, or scoring high on evaluations (Berg 1991).
- Annul bonus can be divided up across the employees based on their contributions made in the current year. By unlinking bonus from salary, organizations can pay larger bonuses to lower level employees who made large contributions and smaller bonuses to higher level employees who made little contributions (Berggren 1999).
- Signing bonus is a one-time payment that is ideal for addressing marketplace inequities or unusual demand. May work extremely well to recruit employees with prestigious education without upsetting the organization's salary levels (Berggren 1999).

Benefits

- Flexible benefit packages that allow employees pick and choose. A younger employee does not care about death or retirement; they look more toward cash compensation. PG&E uses FlexDollars which can be moved into various levels of medical, dental, and life insurance, and/or purchase additional vacation hours. All unused FlexDollars are paid in cash at the end of the year (Berg 1991).
- When an organization has a benefits package that is subpar, it sends a message to its employees: "We don't really care all that much about our technical employees and their family's needs"(Soat 1996).

Reputation

- To attract potential employees, the organization must have a good reputation of employees and of products or services. If the organization is well known for having talented employees and producing a quality project, other qualified people will want to work for the organization. The treatment of employees and potential employees also has an impact on the reputation of the organization (Soat 1996).

Recruiting Methods

Internal recruiting

- Identification of current employees who have the skills necessary to fill higher level positions is necessary (Caruth et al. 1988).

Employee referrals

- "Current employees can be one of the most valuable resources for helping to find excellent new technical employees." The referrals can be either formal or informal (Soat 1996).

Recruiters

- Executive recruiters: work for a fee, usually a percentage of the annual salary of the position (Berg 1991).
- In-house recruiting: many organization prefer to promote from within to save consulting fees, boosting employee moral, and assuring themselves of a ‘tired and true”employee who already knows the system (Berg 1991).
- Reasons to hire search consultants (Cronin 1981):
  - urgent need to solve problem quickly
  - lack of time for top corporate officers or personnel administrators to engage in traveling or interviewing
  - need for confidentially
  - lack of recruiting apparatus or busy personnel department
  - squeamishness about approaching employees in other companies

Professional Organizations

- Professional organizations can be a great source of qualified candidates. Also, membership in such groups will enhance the organizations reputation (Soat 1996)

Advertising

- Advertise: for all positions in local papers (Berg 1991).
- Print media is sufficient to reach qualified people who are looking for a new job, but is insufficient to attract people who are not actively searching for a new job (Bredwell 1981).
- Help-wanted ads must contain not only information about the job but also information presented in a way that effectively portrays a message about the job and the company (Schreier 1983).

Direct mail

- A direct mail campaign can help fill a specific position. Letters can be sent to potential employees to inform them of the opening (Soat 1996).

Universities

- College recruiting: for entry-level positions, send college recruiters to college campuses (Berg 1991).

Internships

- ‘Internship programs provide a relatively inexpensive way for an organization to get to know potential future job candidates was well as vice versa”(Soat 1996).

Retaining

- Deferred compensation works when premature turnover is a significant problem. The bonuses can be set up for any individuals who are at high risk of leaving the organization. Payouts can be a simple fixed amount or tied to performance. The bonuses paid out over time can retain key employees (Berggren 1999).
- Non-cash rewards such as additional responsibility, travel, personal recognition, benefits, or staffing assignments help retain quality employees (Berggren 1999).

- Technical employees leave one firm for another for money, but also to be able to work on things that are exciting for them (Brendan 1996).

Proper recruiting

- Individuals who have a clear understanding of what the job entails will be more likely to perform the job well (Breaugh 1981).
- Proper recruiting methods and hiring of employees that fit the position and organization well are more likely to stay with the organization. The successful methods to recruit and employee are the same to retain the employee: salary, benefits, bonuses, etc. (Soat 1996).

Treating people with respect

- "People do not like being ignored or being treated condescendingly by their supervisor. Conversely, people enjoy being treated with respect. When a manager of technical employees is able to convey his feeling of respect for his staff members, this is viewed very favorably by them" (Soat 1996).

IMPLEMENTATION BARRIERS

- Recruitment advertising is expensive (Bredwell 1981).

- Competitive salaries SHAs vs. private firms.

- Many managers make poor assumptions in assuming that money is not important to technical employees and that they can attract quality people with average pay (Soat 1996).
- "Organizations that fail to recognize the realities of the marketplace and to make a strong commitment to compete are not going to succeed in the race to find and retain good people" (Murray 1999).

GAPS IN EXISTING KNOWLEDGE

- "Although recruiting sources have been linked to employee turnover rate, whether such sources are systematically related to worker performance, absenteeism, and attitudes has not been documented. In addition, because of the types of samples used in the previous studies, some relatively common sources of recruitment (e.g., college placement offices) have not yet been examined. Clearly, additional research on sources of recruitment is needed (Breaugh 1981).
- Recruiting research can identify sources of employees and what types of employees will succeed in the organization (Caruth et al. 1988).
- Current recruiting strategies do not emphasize the benefits of state/public employment. Since state agencies are generally not able to offer competitive salaries and financial benefits compared to private companies, new recruiting strategies are needed to stress the advantages of public employment.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- ‘Research has shown that employee referrals are among the best sources of long tenure employees and newspaper advertisements and employee agencies are among the worst”(Breaugh 1981).

- From experiments and research, it is clear that the recruitment method is strongly related to job performance, absenteeism, and work attitudes. It appears that organizations would benefit from examination of recruiting sources (Breaugh 1981).

- TV and radio advertising can be used to reach and attract competent people who are not actively looking for a new position or organization (Bredwell 1981).

3.7.4 Overall Improvement of the Construction Process – Particularly Alternative Construction Methods and Techniques, Contracting Methods and Delivery Systems to Facilitate Faster Construction/Reconstruction

INTRODUCTION

'State Highway Agencies (SHAs) are experiencing pressure to improve cost, time, and quality in project development and construction of facilities. In an effort to address these issues, SHAs must be proactive in pursuing innovative practices when programming and executing projects. One area where many agencies are encouraging innovation is in construction contracting" (Anderson and Russell 1999). Contract time of highway projects is one of the most important aspects of the entire construction process. Not only does it affect areas such as budgeting, resource planning, local economies, and claims issued, but also reasonable contract time may avoid higher bid costs as well as decrease the possibility of disputes between the contractor and the contracting agency (Herbsman et al. 1995).

Price is important, but it has become an increasing burden on considering the other necessary product requirements such as timeliness, durability, and quality (Harp 1991). "The construction industry is increasingly aware that projects have costs beyond the direct cost of construction. This is particularly true to in public construction, where first cost has traditionally been the primary concern. Factors such as lost sales, commuter delay, and disruption of commerce are real costs to a community. For these reasons, it is frequently in the public's best interest to reduce the time of construction" (Reseigh 1997). Additionally, some projects are undertaken in heavy traffic zones causing extreme traffic congestion and negative impacts on the business community (Herbsman et al. 1995).

Innovative contracting strategies have many impacts on project considerations such as the allocation of risk and the compatibility with the existing low-bid system. The determination of the best project delivery method depends on the owner's objectives and priorities as to allocations of risks, the functions of the project, the quality of the project, its cost, and time requirements. The process of risk allocation has begun when the owner decides on the project delivery methodology. The single decision that will most greatly affect relationships and risk allocation on a construction project is the choice of project delivery method (Groton and Smith 1997). The existing, low-bid, system, has created many problems in past years including, delays, low quality, and numerous claims (Herbsman and Ellis 1992). Despite all the problems with the low-bid method, an attempt to revise it has been portrayed as almost un-American (Harp 1991). The low-bid, design-bid-build system has resulted in quality projects when the work is well defined and is constructed by capable, experienced contractors and has eliminated favoritism in procurement. However, the low-bid system may not be the best system in all cases.

STATES OF KNOWLEDGE AND PRACTICE

A technique and typical method to accelerate the construction phase of highway projects is to offer financial incentives to the contractor. If the "cost of time" is competitively bid as part of the project (through A+B, I/D, lane rental, and so on), contractors are forced to be creative and use their expertise to devise new methods to complete construction in less time with the desired level of quality.

Several innovative contracting techniques are discussed in the "Alternate Contracting User's Guide" and "Alternative Contracting Program Preliminary Evaluation" both produced by Florida Department of Transportation (FDOT 1997 and 1999).

- A+B (Cost plus time) – In most cases, it is the contractor, who can best determine the most reasonable amount of time necessary to complete the project. This technique encourages a contractor to capitalize on a particular construction method or process that would speed construction.
- Incentive/disincentive (I/D) – Bonuses and penalties are assessed on a daily basis and can be used to achieve specific milestones within a project or to encourage timely completion of the total contract.
- Design/Build – The bid packages are awarded based on design quality, timeliness, management capability, and environmental sensitivity. By allowing the contractor to optimize its workforce, equipment, and scheduling, the design/build concept offers a degree of flexibility for innovation. "From the agencies perspective, the potential time savings is a significant benefit. Since design and construction are performed through one procurement, construction can begin before all design details are finalized" (FDOT 1999). Additionally, since the contractor and designer are the same organization, claims are greatly reduced.

The following is a list of current innovative contracting practices by select state agencies:

- Each of the innovative methods addressed is based on the principle of cost reimbursement to the contractor for contract time reduction. The following are methods that consider value of time. Due to the value of time, contractors will be more inclined to complete construction faster. (Herbsman et al. 1995).
  - Bidding on cost/time (A+B bidding)
  - Incentive/disincentive
  - Bidding on cost/time combined with incentive/disincentive
  - Lane rental
- South Carolina Department of Transportation (SCDOT) is implementing twenty-seven years of planned work and compressing it into seven years to take advantage of low interest rates, to avoid paying the inflation cost of construction, and to get a large number of projects constructed faster. SCDOT is partially funding work by issuing state highway bonds. "Another innovation came about by forming partnerships with the private sector as a way for the SCDOT to do more with less through outsourcing. The SCDOT entered into a public-private partnership with consulting and resource management firms (CRMs) to speed work without increasing the size of the state agency" (Kudelka 2000).
- Non-destructive testing with onsite decision making will minimize delays from transporting samples to labs that only operate during daylight hours. Some agencies use non-destructive tests to determine adequate strength at early stages. These types of tests are necessary for fast-track concrete paving (Cole and Voigt 1995).

- "The Northridge earthquake in California caused substantial damage to a number of major transportation facilities. Return of these facilities to service was critical to the recovery of the region. An A+B bidding process formed the basis for the reconstruction of the Santa Monica Freeway. The successful contractor bid a duration equal to the Engineer's Duration but completed the work in 47% of the time earning a bonus almost equal to the original award price"(Reseigh 1997).
- 'For the Cumberland Gap Tunnel between Virginia and Kentucky, the use of the A+B method resulted in a reordering of the bids and the reduction of the original Duration Estimate by 180 days (Reseigh 1997).
- Florida Department of Transportation uses alternative contracting methods including A+B, Lane Rental, Design/Build, Incentive/Disincentive to accelerate contract completion and to control cost overruns on construction projects ("Alternative" 2000).
- Indiana uses A+B bidding to save time to reduce travel impacts to the public ("A+B" 2000e).
- Michigan utilizes the A+B technique with an I/D clause to tap contractor ingenuity as to how to get the work done in the least possible time ("A+B"2000a).
- Mississippi reduces traveler delays by restricting lane usage and charging the contractor for lane closures ("Time"2000).
- Missouri Department of Transportation has successfully reduced construction time on contracts using I/D with A+B Bidding. However, I/D clauses on some projects has increased project cost, so I/D clauses should be project specific ("A+B"2000f).
- New York uses A+B contracting methods to reduce duration of construction delays in urbanized areas ("A+B"2000d).
- North Carolina has implemented an A+B clause in over 20 projects to allow contractors to competitively set contract time that, in turn, will accelerate construction ("A+B"2000b).
- Ohio restricts contractors who are behind schedule on current DOT projects or are consistently fail to meet DOT project deadlines from bidding on future projects ('Pre-qualification"2000).
- Oklahoma Turnpike projects encourage contractors to schedule work during off peak periods by implementing lane rental and minimizing the length of lane closures ('Construction" 2000). Oklahoma Department of Transportation has used A+B bidding to encourage innovation from the contractors to reduce construction time and user delays ("A+B"2000c).
- Oregon has used an aggressive lane rental policy on several reconstruction projects. Lanes are rented in 15-minute increments. Charges are based on road user costs, can be as high as $50,000 per lane per hour during peak travel times and as low as $0 per lane per hour at night ('Lane"2000).
- Utah has implemented A+B Bidding, I/D contract clauses, and Design-Build contracting strategies to successfully minimize traffic disruptions by quicker completion of construction ('Frequent"2000).

IMPLEMENTATION BARRIERS

- There are three typical barriers that limit the implementation of innovative contracting strategies to highway projects. There is *resistance to change* by public agencies and general contractors from the current, traditional low-bid system. The change in cost resulting from the use alternative contracting methods is a critical factor. Additionally, limited agency *resources* and personnel influence the selection of innovative contracting methods that accelerate the construction process.

- Agency officials understand that the safest guide for present and future contract decisions is to observe past practice. SHA professionals acquire their skills and methods of operation by learning from their predecessors. Each agency has its own techniques and standards set within a guiding legal framework. Engineers and specification writers generally follow past practice in developing their contract specifications ('Innovative" 1991). Since the safest, surest way to complete a highway project is to use what has worked in the past, the application of innovative strategies is limited. Public agencies are reluctant to invest in innovation without the promise of return ('Innovative" 1991).

- The demands on highway agencies are greater than what the financial resources can accomplish. Therefore, the need to keep costs associated with project planning as low as possible always affects decisions on highway contracting practices ('Innovative" 1991). Also, the addition of an I/D clause in the project contract can unpredictably increase the cost of the project.

- An accelerated construction schedule influenced by innovative contract methods such as A+B or I/D bidding may increase the requirements for agency staff to supervise, inspect, and manage the administration of the project. Lack of agency personnel resources limits the utilization of faster-construction contract provisions.

GAPS IN EXISTING KNOWLEDGE

- Many highway agencies have used innovative contracting strategies attempting to influence the contractor to accelerate construction. However, a more thorough analysis in necessary to select and evaluate these strategies.

- Presently, there is not a method to select best contracting strategy based on known project factors, characteristics, size, and complexity. An empirical method must be developed to determine the types of projects that are most likely to be successful under an A+B with I/D construction contract (Anderson and Russell 1999).

- There is not a complete documentation of the results of the schedule times-savings gained or lost in the projects constructed using innovative contracting strategies to accelerate construction. For example: How does the use of A+B with I/D bidding impact contract performance and agency budgets (Anderson and Russell 1999)?

- A method is needed to evaluate the quality of the facility constructed using innovative contracting strategies that decrease project duration. Also, an analysis should be conducted to investigate life cycle costs associated with faster construction schedules (Anderson and Russell 1999).

- Incentives, lane rental, etc. costs SHAs available funds. Is it possible for SHAs to recover portions of user cost savings?

- There is a lack of information on the relation between innovative contracting strategies and the competitive bidding process.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

The most recent research efforts directed at this issue have focused mainly on delivery and contract methods. However, these research efforts have not been available for a sufficient period of time to assess their level of implementation (Scott 1997 and 1998). While many agencies are using contracting methods like cost-plus-time and lane rental and design-build delivery, very few have systematic selection processes to determine which method is most appropriate for a given project situation. Scott (1997 and 1998) attempts to provide some guidance in this area. Anderson and Russell's (1999) contracting guidelines for warranties, multi-parameter bidding and best value contracting will be published in 2001 by the NCHRP.

3.7.5 Evaluation of the Use of Incentives/Disincentives (I/Ds) to Reduce Time to Complete Highway Projects

INTRODUCTION

I/Ds have traditionally been used as a means of aligning the goals of the contracting agency with those of the contractor. Contract incentives/disincentives (I/Ds) are a clause in which the effect will ideally increase the quality of the end product while decreasing the construction time of the project. Contractors have more motivation to produce higher quality work at a faster rate because not only is their reputation at stake, but they will also have the potential of earning more money on a project.

I/Ds can have many positive effects on a construction project, if used correctly. Productivity levels can increase, scheduled dates can be met on time or even early, and/or the end product can be superior to previous products. However, in order to successfully use an I/D clause, they must be both fair and effective, and of mutual monetary benefit to all parties of the project.

Development of I/D clauses has been ongoing for quite a few years. They have been used in certain construction projects with some success. It is important to evaluate a project carefully in order to decide if I/Ds are right for that project.

> The use of incentives and disincentives (I/Ds) for project completion time has helped highway agencies in various states to reduce construction time significantly. However, I/D provisions increase costs to the contracting agency, and should therefore be used sparingly. For these types of contracts to succeed, it is necessary for the contracting agency to be extremely careful in the development, documentation, and execution of I/D clauses (Jaraiedi et al 1995).

This document summarizes the current information concerning using incentive and disincentive provisions in contracts.

STATES OF KNOWLEDGE AND PRACTICE

- This paper provides guidance on the use of incentive contract strategies within collaborative organizational structures in general and within strategic alliances in particular. It concentrates on the use of incentive strategies in European construction and engineering organizations. Observations in the research showed that incentive strategies are used in alliancing-style arrangements, either project specific or longer-term, to reinforce a mutual approach to the work (Smith 1999).

- This paper summarizes A+B bidding; a method Indiana Department of Transportation has used since 1996. A+B bidding is cost plus time bidding. A is the traditional bid for contract items, and the work to be done under the contract; B is time with an associated cost and is used in low bid determination. All A+B contracts have an incentive/disincentive provision in them. The disincentive provisions are incorporated into the contact to discourage the contractor from overrunning the time bid for work. The incentive provision is included to reward the contractor if work is completed earlier than the time bid (Bertram 2000).

- Florida Department of Transportation has also been using A+B bidding, along with other contract methods. This paper summarizes the methods Florida has been using. In 1996, the Florida Legislature authorized the Florida Department of Transportation (FDOT) to use accelerated contracting techniques on construction projects, and limits innovative contracting to $60 million in contracts annually. Alternative contracting techniques include the following: A+B, Lane Rental, Design/Build, Warranty Clauses, No Excuse Bonus, Lump Sum, Liquidated Savings, and Incentive/Disincentive (Bauer 2000).

- Michigan Department of Transportation has used A+B bidding and I/D clauses to effectively reduce motorist delay. MDOT wanted to minimize the time required to complete work thereby reducing the amount of traffic inconvenience. By utilizing the A+B technique along with an I/D clause, MDOT has been able to tap contractor ingenuity as to how to get the work done in the least time possible (Fort 2000).

- This paper considers an example of how I/Ds were used. Remediation of the Marathon Battery Superfund Site in Cold Spring, NY required excavating contaminated marsh deposits and dredging contaminated river and cove sediments of the Hudson River. The contract documents included changed condition and value engineering clauses which would allow the contractor to propose alternative methods to suit field conditions and to exercise freedom and imagination with incentives for sharing cost savings. In fact, the contractor proposed a number of value engineering changes which were reviewed and accepted by the government (Simmons et al 1994).

IMPLEMENTATION BARRIERS

- A cost benefit analysis needs to be done to find a good balance between incentives and disincentives. If a penalty is too large compared to the benefit of producing a higher quality product, the contractors will not work on the job.

- Contractors may be scared away by the thought of receiving a penalty/disincentive for low quality work. Education of contractors and owner alike needs to be set up on the cost versus the benefit of using incentives.

- State law requires award of contract to low bidder. Provisions to contracts need to be made to allow a contractor to be awarded the contract by lowest bid, and then receive extra money on top of contract price if the quality is higher.

GAPS IN EXISTING KNOWLEDGE

- This topic has been researched a great deal. However at the present time, there is no comprehensive understanding of:
    - What SHAs are using I/Ds.
    - How the I/Ds are implemented through contract provisions.
    - What criteria are appropriate to consider when applying I/Ds to projects.
    - Are I/Ds cost-effective and fair to all parties.
    - What impacts to I/Ds have on project quality and safety

- More models or examples need to be developed of where incentives/disincentives are being used. The models and examples then need to be made into guidelines to aid agencies in incentive/disincentive use.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- The Federal Highway Administration created a guide for the development and administration of incentive/disincentive provisions for early completion on highway construction projects or designated phases. It provides guidance for project selection, project development, determination of the I/D amount and time, and contract administration of I/Ds. It also presents an I/D checklist to follow when preparing contract special provisions and a suggested scheduling specification (Willett 2000).

- In research conducted jointly by the University of Wyoming and the Wyoming Department of Transportation, current pavement construction smoothness specifications throughout the United States were collected and analyzed. A survey consisting of 13 questions dealing with pavement smoothness specifications, devices used for these specifications, and incentive and disincentive policies were sent out to all 50 state departments of transportation. Forty-five of the agencies responded to the survey. The responses were summarized in a computerized database and analyzed for trends. Departments using I/Ds seemed to agree that if used correctly, they had a positive effect on the projects (Ksaibati et al 1995).

- In this research, the current use of I/D contracts in many states and the experience of several contractors were examined. Then, a general set of guidelines was developed for the use of I/D provisions in highway construction or refurbishing contracts. The guidelines aid in determining which projects should contain the I/D provisions and how to structure the I/D provisions to achieve maximum success (Jaraiedi et al 1995).

- A summary of National Cooperative Highway Research Program (NCHRP) Project 20-7, Task 23, is presented. The project evaluated nine selected topics concerning highway contracting practices and payment procedures. The topics include alternate bids, turnkey projects, incentive and disincentive provisions, retainage, documentation, methods of measurements, partial payments, payment for materials in storage or on hand, and acceptance and final payments. Included are recommendations for improving agency practices (Newman, Hejl 1984).

- This paper discussed the use of incentives to better quality management. Quality management is a systematic approach to concrete quality assurance problems within specified limits for materials and methods. Concrete construction is a manufacturing system where each product is unique but the process is identical to those of mass production systems. Quality can only be controlled and must be controlled by the organization doing the work. The quality control should be implemented properly with financial incentives for a contractor who does the job more economically, saving money both initially and through the project's entire life cycle (Shilstone 1997).

- This paper discussed a type of contract used for constructing underground tunnels in which incentives can be used to decrease the time or better the cost of the project. A model tunnel contract (MTC) is a commercial agreement by which all costs of construction are paid, as and when incurred. The contractor's profit is a fixed sum that does not vary with cost or schedule and can be changed only if major work features are added or deleted. However, the contract may contain incentives whereby the contractor can earn additional profit for bettering cost or time objectives (Pond 1996).

- This article reviews the subject of incentives as used in construction contracting. Examples of incentive programs are briefly described: limited damages; bonus/penalty clauses based targets; milestone and completion bonuses; award free contracts; report card bonus; partnering; total quality management program; suspension of withholding retention; value engineering clauses; client-funded worker bonus program; client-funded safety awards; preference on additional work; promoting multiple contractor operation (Neil 1991).

- This paper examines the compatibility of various construction contracting methods with certain types of owners and projects. Contracting methods, as defined in this paper, consist of four parts: scope, organization, contract, and award. An owner must create an appropriate contracting method for each project. Choosing certain methods can decrease the project duration, provide flexibility for changes, reduce adversarial relationships, allow for contractor participation in design, provide cost savings incentives to the contractor, and provide alternative financing methods. Guidelines are established to help the owner choose the organization, contract type, and award method most applicable for their project and themselves (Gordon 1994).

Past and Present NCHRP studies:

- In NCHRP 1-31 Smoothness Specifications for Pavements, the objectives of the research on flexible, rigid, and composite pavements were to (1) determine the impact of initial smoothness on (a) total quality of the pavement as constructed, (b) ride quality of the pavement over its life, and (c) the pavement service life; (2) determine the effects of existing smoothness specifications on the initial as-constructed smoothness; (3) determine cost-effectiveness of smoothness specifications, including incentives and disincentives; and (4) recommend methods to specify and measure initial smoothness on construction projects (Smith 1996).

- The objective of NCHRP 10-49, Improving Contracting Methods for Highway Construction Projects, was to develop comprehensive guidelines for implementing selected non-traditional contracting methods for highway construction projects. It will be necessary to: (1) evaluate and refine the construction warranties and multi - parameter bidding (i.e., cost + time + other factors such as quality) contracting methods; (2) identify, evaluate, and refine contracting methods not used for highway construction in the United States, that are within the low-bid system, require minimum SHA resources, and maintain product quality; and (3) develop criteria and guidelines for applying methods from items 1 and/or 2 above within highway construction contracts (Anderson, Russell 2000).

- The objective of NCHRP 2-23, Development of an Update to the 1977 AASHTO Redbook, is to develop recommendations for updating the AASHTO Redbook entitled, A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements 1977. The new manual will address benefit/cost analysis for highway improvement projects. The update should provide decision makers with a clear description of the approach and understanding of the results of project benefit/cost analyses. It should also provide practitioners with sufficient detail to perform these technical analyses. Specifically, it should concentrate on highway-user benefits and costs and on project-level analyses. It should incorporate current benefit and cost factors, along with methods for keeping them updated. It should provide for both detailed and simplified levels of analysis. This manual should concisely reference available tools and techniques for evaluating improvements for other modes of transportation and summarize the relationships and differences among these techniques (Pozdena 2000).

3.7.6 Innovative Strategies to Manage Traffic During Highway Construction Projects – as Specifically Related to Project Staging of Highway Projects and Strategies to Minimize Construction Delays such as Night and Weekend Construction

INTRODUCTION

The aging of state and local roads and highways and the availability of funding by the Intermodal Surface Transportation Efficiency Act (ISTEA) have increased the number of major highway reconstruction projects (Higgins 1993). Large highway reconstruction projects can cause significant disruptions to existing travel patterns and economic activity. Reducing the impacts on highway users and businesses requires that innovative and effective transportation management actions be developed and implemented (Janson et al. 1989). Reconstruction activities could be expedited by closing the facility, but in most situations, the remaining transportation network would not be able to accommodate the redirected traffic volumes. The traffic management plan developed during design must reach an acceptable balance between: 1) maximizing the safety and efficiency of the reconstruction activity; and 2) minimizing the impacts on highway users and businesses (Krammes 1990).

One approach to reducing the impact of lane occupancy during construction is to work off-peak hours such as nights or weekends. In the United States, 85% of SHAs are scheduling night reconstruction. The advantage in performing reconstruction activities at night is due to a significant decrease in traffic volumes during these times. Lower traffic volumes during reconstruction lead to a decrease in delays for highway users. The disadvantages of night work include increased safety hazards due to fatigue and poor visibility conditions and increased costs associated with off-peak reconstruction. Other factors should be investigated to assess the feasibility of night reconstruction including the length of uninterrupted work time available, agency/contractor experience with night work, productivity, quality, noise, light glare, temperatures for paving, and availability of materials (Elrahman and Perry 1998).

Many policies, specifications, standards, design manuals, and procedures do not encourage timely completion of reconstruction projects. Traffic control plans do not persuade or require contractors to minimize traffic delays by application of incentive or disincentive provisions. Also reconstruction contracts often do not require the use of ITS technologies to facilitate traffic management during reconstruction activities.

STATES OF KNOWLEDGE AND PRACTICE

The following is a list of current traffic management practices by various state highway agencies:

- California Department of Transportation uses a Traffic Management Plan (TMP) as a "cohesive program of operational and demand management strategies designed to maintain acceptable levels of traffic flow during periods of construction activities."

The TMP coordinates personnel and agencies to minimize congestion caused by construction and makes highway work-zones safer for both workers and motorists ("Caltrans" 2000).

- Maricopa County in Arizona permits road closures during construction after a benefit/cost analysis. "The county is aware of the cost of the project to both the county as well as the traveling public. Road closures are expected to permit the construction to be completed quicker, at lower cost and with greater safety to both the contractor's workers and the motorists" ("Road" 2000).
- Florida Department of Transportation's policy on lane closures during construction is that the work zone design plans maintain the existing number of lanes for the various work phases. No lane closures will be permitted on interstate construction where only two lanes of travel normally exist ("Lane" 2000).
- In Massachusetts, "analyses are performed, during design, based on volume and reduced capacity due to the work zone. If the expected delay approaches or exceeds 12 minutes, other alternatives or work hours are to be considered" ("Twelve" 2000).
- North Carolina limits lane closures to 1 to 2 miles. Maximum length is based on traffic volumes, percent grade, and directional traffic demand ("Limited" 2000).
- In Pennsylvania, contractors are required to remove lane closures if not working multiple shifts. Lanes may only be closed during work periods ("Removal" 2000).

IMPLEMENTATION BARRIERS

Implementing the use of an effective traffic management plan is expensive. A study conducted by the California Department of Transportation found traffic management strategies during reconstruction range in cost from 5% to 31% of total reconstruction costs for project (Higgins 1993). In many SHA contracts, the construction management plan is not a pay item and the responsibility, risk, and cost are not completely covered by either the public agency or the contractor.

Numerous software applications and computer simulations programs are available to successfully model the impact of construction activities on traffic flows. However most agencies and contractors lack personnel with adequate training to operate these computer programs. In addition SHAs do not have personnel and technology to distribute real-time traffic information to the traveling public.

Reconstruction work scheduled during off-peak traffic times results in reduced complications with vehicle traffic, but generates other problems such as decreases in safety and availability of materials.

GAPS IN EXISTING KNOWLEDGE

There is a lack of information available to successfully write contracts and specifications that place the responsibility of the traffic management plan on the contracting organization. SHAs need the ability to contract for various travel management services and the operation of traffic control plans required for a reconstruction project. Many agencies lack the willingness to allocate funding required to procure these resources when necessary.

Limited amounts of data are available on highway capacity levels of a long-term reconstruction zone and the travel responses of motorists to major reconstruction projects. Additional information in these areas will lead to more cost-effective traffic management plans and more acceptable levels of travel impacts (Krammes 1990). Studying the impacts of traffic management plans will lead to guidance, best practices, and training associated with evaluating the impacts of construction and maintenance project staging of traffic operations and effectiveness of various travel management and traffic control procedures.

The use of training programs to employ traffic simulation software tools throughout all phases of the project. Computer software can analyze projects and determine strategies to mitigate the impacts associated with queue lengths, delay, and travel time.

Several areas for recommendations for study and development include "Advanced Traveler Information System message effectiveness, prediction models for detour effectiveness, models to assess impact of short-term detours on performance of urban streets, prediction models for the effectiveness of non-mandatory diversions and detours in preventing congestion, and creation of safety data bases for lane diversions, lane closures, and urban street detours" ('Get" 1998).

PAST RESEARCH – UNKNOWN IMPLEMENTATION

A number of NCHRP Syntheses have been written that discuss, to some extent, this issue (Graham and Migletz, 1994, Saag 1999, and Anderson and Ullman 2000). Moreover, it appears that past research in traffic management tends to be broader than the specific focus of this issue, that is, on innovation related to project staging and traffic management. Further, the impact of nighttime and weekend construction research has been somewhat limited in terms of literature references. Thus, it is difficult to assess the implementation of past research in this area through existing literature.

3.7.7 Training and Workforce Development of SHA personnel

INTRODUCTION

Today's market demands efficiency, quickness, and high quality. The public demands fast construction and reconstruction. With the retirement of the current experienced SHA workforce, opportunities are available for the advancement of young, sometimes inexperienced personnel.

> 'The industry has changed dramatically. There is a loss of expertise and opportunities for training. A State DOT survey party was an excellent opportunity to learn the basics of layout, plan reading, highway design. Those opportunities are no longer there for young State DOT staff (NCHRP Workshop 2001)."

The inexperienced SHA personnel must have the necessary skills to perform their job efficiently and effectively.

At the current time, training programs are available for most incoming college graduates. However, these training programs vary from SHA to SHA. A standardized training program would insure that all incoming SHA personnel receive all the necessary training.

Mentoring can be a valuable training tool if performed correctly. A good mentoring program can hand down priceless knowledge that may be lost in a standardized training program. It can also show each employee the 'big picture' and where they fit into that picture.

Training programs are offered through out a SHA personnel's career. Nevertheless, time constraints for projects, monetary resources, and geographic location tend to prohibit SHA personnel from participating in these programs. This greatly reduces the positive professional impact a person could have at their position.

SHA personnel career paths are evolving and diversifying. Many new demands are placed on SHAs. A technical career path, along with or instead of, a managerial career path could greatly reduce stress on SHAs. Certifying and training SHA personnel on the technical aspects of construction could not only improve, but also revolutionize the industry.

> 'Our society has identified an undeniable correlation between education and success. We also know that ability, coupled with pride of workmanship, is a major factor in producing quality products. Based on these understandings, we must realize the impact that quality certification and training programs will have on the construction of the Nation's transportation infrastructure (Dowd 1995)."

The paths of private and public agencies are crossing more and more. Certain SHA responsibilities are being outsourced to the private sector; SHAs and private companies are calling upon the expertise of consultants to improve their programs. A well-developed training program can benefit all parties involved in the construction industry. Bringing together the different sectors to share knowledge can facilitate lasting partnerships between all industries.

With the age of technology comes the increasing use of computers. Computers are being developed that can reduce the time and effort to produce design documents and can also be used to create project management tools. Personnel first need to have the knowledge to use them and then to be able to implement their knowledge.

This document summarizes the current knowledge concerning training and workforce development of SHA personnel.

STATES OF KNOWLEDGE AND PRACTICE

- Arizona DOT has a new employee orientation program so that new employees can see the big picture, and see how they fit into the program (NCHRP Workshop 2001).

- In response to Federal Aid requirements (23 CFR 637B, October 5, 1995) regarding certification of roadway technicians for quality control/quality assurance (QC/QA) testing, the Arkansas State Highway and Transportation Department (AHTD) sponsored the development of the Center for Training Transportation Professionals (CTTP) at the University of Arkansas, Fayetteville. The HMAC Tech program includes instruction and testing (written and performance) in the areas of sampling, gyratory compaction, volumetric analysis, asphalt content, and field density. As of November 1, 1998 eight HMAC Tech courses have been completed with a total of 150 persons attending, including 67 AHTD and 83 contractor employees (Hall et al 1999).

- The Asphalt Technician Certification Program in Colorado is one of four programs offered by the Rocky Mountain Asphalt Education Center located in Englewood, Colorado. The LabCAT was developed to increase the proficiency of testing technicians and respond to the Federal requirements of having qualified technicians performing sampling and testing on Federal-Aid Projects. The objective of the LabCAT is to certify technicians directly involved with identifying the properties of the final asphalt product in any Quality Control/Quality Assurance (QC/QA) program (Cassidy, Conner 1999).

- This paper describes the development of the Interactive Videodisc Training (IVT) system and a training course on work zone traffic control. The IVT system uses a microcomputer-controlled videodisc player to provide individualized, interactive instruction to the student. A 4- to 6-hour training course, depending on the student, on work zone traffic control was developed. This course can be used to train engineers or technicians in the proper procedures for selecting, installing, inspecting, and removing traffic control devices in work zones (Paniati 1990).

- This document summarizes the Workforce Development Branch of the United States Department of Transportation. The Workforce Development Branch is the principal element of the division in the US DOT with respect to management and general training, technical training, career development, aviation education, special emphasis recruiting, and workforce diversity. It also houses the Regional Learning Center and Lending Library, as well as, the Distance Learning Center (Computer Based Instruction and Interactive Video Teletraining) (Pope 2000).

- This paper summarizes training programs developed that utilize technology transfer. The current need for technology transfer and providing assistance to local officials to solve transportation problems is focused on. Several factors adversely affect the transfer of needed information. They fit into two basic categories: ineffective communication on the part of the giver and a lack of desire or ability to receive needed information by local officials. Programs at technology transfer centers throughout the West have been developed to improve the quality and availability of training. The programs are designed to reduce travel, time involvement, cost, and effort required by the local transportation officials to participate in training activities (Jenkins 1996).

IMPLEMENTATION BARRIERS

- Training can be very expensive. Cost is incurred not only from the program itself, but also from the employee being away from his/her current tasks.

- A manager may have to choose between getting a project in on time or letting the employee responsible for that project go to a training course to increase his or her skills and risk the project be completed late.

- Training may not be high priority in the minds of upper lever SHA personnel. All players involved need to know the value of ongoing, innovative training sessions.

- Uncovering resources can be difficult. People expert in the field, along with materials to train personnel can be hard to find.

GAPS IN EXISTING KNOWLEDGE

- A uniform set of skills that all SHA personnel need to possess/acquire.

- Core courses to train personnel for that uniform set of skills.

- Intermediate and advanced courses that target specific skills needed for specific jobs.

- Other courses besides in-house SHA courses to train employees, such as private and university training programs.

- Training SHA personnel that are too busy to be trained.

- The impact of the use of technical career paths instead of managerial career paths for SHA personnel.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- This paper provides a contractor's perspective of certification and accreditation for Superpave. The need for standardized certification and accreditation programs is presented and discussed (West, Lynn 1999).

- The paper discusses the changes in the responsibilities of the construction contractors in addition to their previous duties in working directly for a resident engineer. These changes require new and different personnel to manage Q-A systems, testing, and coordination of divisions and design requirements. Other factors in reforming the construction industry include training, the efficiency of scale, the extra recording responsibilities of contractors and importance of longer term budgeting to gain maximum return from investment (Wilmot 1994).

- Thirteen actions are recommended in this article for consideration by DOT managers to enhance the durability/longevity of highway bridges. They address design life and load considerations, geometric parameters, design traffic volumes, material requirements, training programs, and preventative maintenance programs (Ramey et al 1997).

- This paper addresses the future directions that graduate education and research should take to fill the needs in highway engineering in the 21st century. Highway engineers will have an increased emphasis on the application of new technologies (Nelson et al 1988).

- This article summarized a study completed by the Better Roads' survey on personnel issues. The top equipment management and maintenance problems are people problems, according to the survey. Nearly half - 48. 3% - of the equipment managers responding cited the difficulties in finding and keeping competent workers, dealing with top departmental management, and training personnel as their most critical problems (Anon 1987).

- The article discusses constructability, specifications, and other aspects of the subject, including training programs for inspectors and project managers, research/development and pilot testing of new products, methods and materials, and others (Blaschke 1989).

- A conference was held on December 9, 1998, at the Washington Convention Center to discuss workforce development and job accessiblity. The conference involved more than 150 public officials, business leaders, and community representatives, and focused on workforce development and job access best practices and recommendations in three concurrent workshop tracks: workers and jobs; education and training; and transportation and child care. Conference participants adopted a resolution supporting several follow-up action recommendations (Metropolitan Washington Council of Governments 1998).

- This paper summarizes a study that concentrated on the benefits of certification programs. To improve the quality of highway construction, proper training is one of the most important tools that the construction team can have. Skilled workers and inspectors produce a better quality product, which makes more efficient use of limited resources and creates a better transportation system. This benefits everyone. The certification component of this program is important for many reasons. For the employee, it rewards the efforts associated with improving their abilities, and instills in them a sense of accomplishment and pride in their work. For the contracting agency, certification provides confidence in the abilities of their inspection workforce; and for the contractor, certification provides assurance that the workforce constructing and inspecting projects are trained, qualified, and maximizing effective performance (Dowd 2000).

Past or Present NCHRP studies:

- The ultimate goal of NCHRP 20-25 Training Needs for Highway Construction Personnel was the development of a nationally acceptable training program that specifically supports certification for agency, consultant, and contractor personnel involved in highway construction. The objective of this project was to provide a needs assessment and design a framework for a training program to improve the quality of highway construction (Carter 1990).

- After the completion of NCHRP Project 20-25, Training for Highway Construction *Personnel,* this project was created to develop course descriptions and lesson-plan outlines for the courses identified in the national construction training program developed under*,* comprehensive training packages for teaching three courses, and a plan for promoting and facilitating the use of the recommended training program (Carbajal 1994).

3.7.8 Implementation and Evaluation of Performance-Related Specifications for Highway Construction

INTRODUCTION

Pavements represent a very substantial portion of the public's investment in infrastructure. It is essential that this investment be preserved through cost-effective planning, design, and maintenance. One way of achieving this is through the use of long-term performance-related specifications (PRS).

Under quality assurance (QA) specifications, the contractor is responsible for quality control (QC) and the agency is responsible for acceptance. QA specifications have been evolving since they were first introduced in the 60's. While the need to make QA specifications truly performance-related has existed all along, only recently have research advances made the development of performance-related QA specifications possible.

Performance-related QA specifications use performance and life cycle cost models to specify the desired materials and construction quality, and measure the acceptability of the as-constructed product. A framework for performance-related specifications (PRS) has been established, and sufficient research into performance models has been completed to allow development of initial PRS for jointed plain concrete pavement (JPCP) construction/reconstruction. More research is still needed in hot mix asphalt (HMA) performance models for new construction. Virtually no research has been completed for the remaining major types of construction (continuously reinforced concrete pavement (CRCP), concrete overlays, HMA overlays, structures, soils, etc.)

Use of PRS can lower life cycle cost (LCC) of pavements and structures considerably. PRS performance models can also be used within a warranty specification setting, or within other innovative contracting settings (such as LCC contracting). For maximum benefit to be obtained under PRS an organized approach covering several facets is necessary –research, specification development, implementation, evaluation, education/training, and marketing (Kopac 2000).

This paper summarizes the current knowledge concerning performance-related specifications for SHAs.

STATES OF KNOWLEDGE AND PRACTICE

- In May 1998, the Kentucky DOH established a mission to incorporate quality into their construction projects by transitioning, where possible, from method specifications to QC/QA, performance related, warranty, and other innovative specifications for the year 2000. In 1998, a team was formed to evaluate the current edge drain specification and make recommendations and revisions towards a full-fledged QC/QA specification. This paper discusses the historical performance of edge drains in Kentucky and the recent changes in the specification (Fleckenstein, Allen 2000).

- The Wisconsin Department of Transportation is moving toward performance-based specification with their new performance-related specifications. They currently have asphaltic pavement warranty specs, structure painting warranty specs, and 1-year trial of PCC pavement warranty specs (Zogg 2000).

- This paper summarizes the work Focus-Back has undertaken to technologically advance performance-based specifications. They discuss how they will write the text of the building design and construction industry's first commercially available electronic database of performance-based master specifications under development by the Construction Specifications Institute (CSI) and Design Build Institute of America (DBIA) (Anon 1997).

- This paper relates the authors' experience in creating detailed specification requirements for trenchless rehabilitation of a sanitary sewer pipeline in Pleasanton, California. Cooperation within the project team, among the various disciplines involved, produced performance-based, descriptive specifications that resulted in a successful installation (Goodwin et al 1997).

- This paper discusses the NSW Road and Traffic Authority's use of both scrap rubber and SBS modified bitumens in asphalt and for sprayed sealing works. Performance-based specifications are in use for most of these binders and comparison of binder specifications gives some insight into differences between the generic types of binder. The binder specifications are written in terms of both the ARRB elastometer and established techniques such as softening point and penetration. The relationship between these techniques and the results obtained is discussed (Cunningham Gaughan).

- This paper summarizes the use of the Strategic Highway Research Program's (SHRP) performance-based specification in relation to SUPERPAVE. Specific pavement studies of newly constructed, reconstructed or rehabilitated (resurfaced) pavement sections were used to provide an estimate of the relative influence of key pavement elements that affect pavement performance in terms of SHRP SUPERPAVE specification validation. The study was explicitly designed for validation of the SHRP performance-based specifications and the SUPERPAVE mixture design analysis system (Cominsky 1993).

IMPLEMENTATION BARRIERS

- Implementation of performance-based specifications can be very difficult. Their importance needs to be proved not only to designers but also constructors and owners. The mind set of all parties involved in a project with performance-based specifications needs to be that they want to work together to achieve a top quality product.

- To write a performance-based specification, tests must first be available to measure if a product will meet performance. Currently, there are not many tests on the market that reliably and quickly measure performance.

- Also, changing the way the specifications are written can also be the cause of a lot of confusion.

> Many jurisdictions are attempting to replace the prescriptive specifications in their building codes with performance-based requirements. However, if this transition is not carried out prudently, the changes could make the codes more difficult to interpret, harder to administer and, instead of providing an equitable foundation for the selection of construction materials and building designs, render those codes unnecessarily restrictive. To illustrate some of the difficulties which can be faced when changing prescriptive specifications to performance-based requirements, suggestions about how the prescriptive specifications regarding combustible and noncombustible construction in the National Building Code of Canada could be replaced with performance requirements based upon `degrees of combustibility' of building materials are outlined (Richardson; 1994).

GAPS IN EXISTING KNOWLEDGE

- A determination needs to be made of what the required levels of performance are. Also, the fundamental properties along with cost versus benefit of reaching those required levels should be established.

- There seems to be a lack of cases where performance-related specifications were used for projects, especially SHA projects. The results from projects that used performance-based specifications need to be made into a guide to help others trying to transfer specification methods. These results also need to be analyzed to determine how they impacted a project in terms of time, cost and quality.

- Many different projects can benefit from performance-related specifications. A determination which types of project components, i.e., pavements, bridges, etc., will benefit from the use of PRS should be made.

- Using PRS on projects where they have not been used before can be confusing for all parties involved. Guidance needs to be provided to contractors and SHA personnel alike for bidding and working under PRS so as to minimize life-cycle costs

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- The current performance-related specification (PRS) methodology has been under development by the Federal Highway Administration (FHWA) for several years and has now reached a level at which it can be implemented by the impact of varying levels of construction quality. This study focused on the improvement of the key distress and smoothness prediction models used in the PRS for jointed plain concrete pavement (JPCP) (Hoerner, et al: 2000)

- The paper describes a workshop held on May 24-26, 2000, in Orlando, Florida. The purpose of the workshop was to develop a national strategy for the research and implementation of Performance Related Specifications across the country (Ferragut 2000).

- The results of a `shadow' field trial (actual contractor pay was not affected) conducted to demonstrate a Level 1 prototype performance-related specification (PRS) for jointed plain concrete pavement construction are presented. The Level 1 PRS (the most practical PRS method at this time) is believed to be immediately implementable because it uses currently practiced sampling and testing procedures. This paper discusses all aspects of the field trial including the relevant definitions, selection of lots and sublots, sampling and testing plan, calculation of shadow PRS pay adjustments, problems encountered, and a summary of lessons learned (Hoerner et al 1999).

- The Strategic Highway Research Program (SHRP) spent dollar 50 million researching asphalt binders and asphalt mixtures and provided three main products: (1) an asphalt binder specification, (2) an asphalt mixture specification, and (3) Superpave, an asphalt mixture design system that encompasses both the binder and mixture specification. Implementation of the specifications and mix design system will require overcoming several obstacles. Superpave must be demonstrated to be practical and easy to use. The impact of Superpave aggregate requirements on aggregate availability must be determined. The Superpave gyratory compaction procedure has been uniquely defined and then calibrated to traffic volume. The reasonableness of this approach must be tested in widespread application. Perhaps the largest implementation hurdle exists in the performance models. Expensive test equipment is necessary to do the performance-based tests. The performance predictions must be established as reasonable to justify the cost (Huber et al 1996).

- Research was undertaken to provide a performance-based binder specification for the Gulf countries, based on the findings of the Strategic Highway Research Program (SHRP) carried out in the United States, considering the prevailing environmental and traffic conditions and type of locally produced bitumen. (Al Abdul et al 1997).

- The Strategic Highway Research Program project, SHRP-A003A, has introduced new test methods and procedures that can be easily implemented in pavement design and in the development of performance-based specifications. The basic concepts behind the design of a high traffic, high performance pavement is presented, and the concept of the performance point as a methodology to develop site-specific contract specifications is introduced (Sousa et al 1994).

- A performance-based approach to specifying coatings and linings instead of the conventional product-based approach currently used is examined. Focusing on chemical environments, the components that must be evaluated when considering performance-based specifications are outlined (Mokashi 1999).

- Experimental and analytical research was recently performed to develop performance-based specifications and commentary for the fatigue design of modular bridge expansion joints (MBEJ). The resulting proposed fatigue-design and test specifications resulting from this research are discussed (Connor et al 1999).

- A performance-based specification applicable for new and rehabilitated warranted pavements is developed and presented here. The primary purpose of this specification is control of the initial longitudinal roughness of pavements, which will lead to smoother pavements and hence satisfactory long-term performance (Zaghloul et al 1998).

- This study examines the methods of asphalt cost control without quality loss. Research on binders and modifiers is the cutting-edge of promise for meeting the increasingly urgent load demands on U.S. roadways. Billions of dollars could be saved each year by implementing performance-based based specifications (Anon 1990).

- This paper discusses developing a performance-based specification for bituminous crack sealants. Crack sealing is an invaluable method of pavement maintenance that extends pavement service life. Based on a review of the performance concept applied to construction materials and a critical assessment of the current ASTM specification (D 3405) for bituminous crack sealants used in cold climates we propose a modified yet systematic approach towards developing a performance-based specification for bituminous crack sealants. The specification would permit the selection of sealants for very cold climates and would allow predicting the probable effective life based on a numerical model (Masson; Lacasse 1999).

- The Performance Based Studies Research Group (PBSRG) has developed a methodology to process information to reduce risk and cost while at the same time improving construction performance and industry stability. The methodology reshapes the construction environment, changes roles and partnerships, and provides facility owners with a new method of communicating requirements to constructors. The new performance approach allows facility owners to communicate requirements in terms that they understand instead of the often difficult to understand material and construction standards (Kashiwagi, Halmrast 1996).

- The main thrust of this investigation was towards performance specification of concrete for new construction. The objective was to develop a methodology, using established permeation test methods, of estimating concrete durability in structures, and to assess and categorize potential durability of concrete for performance-based specification, compliance and quality control (Dhir et al 1994).

Past and Present NCHRP studies:

- In NCHRP 12-40, Fatigue Criteria for Modular Bridge Expansion Joints, the product of the study was performance-based specifications for the fatigue design of modular bridge expansion joints. In addition to the proposed fatigue design specification and commentary, proposed fatigue test specification and commentary, and fatigue design examples were produced (Dexter 1994).

- In NCHRP 10-54, Quality Based Performance Rating of Contractors for Prequalification of Bidding Purposes, the objectives of this project were to (1) develop a quality-based system for performance-rating contractors for either pre-qualification or bid-selection and (2) prepare an implementation plan as a guide for transportation agencies and industry (Smith, Minchin 1997).

- In TCRP C-09, Paratransit Vehicle Specifications and Related Special Maintenance *Requirements,* the objective of the research was to develop a software tool to assist paratransit providers in (1) determining the appropriate type of paratransit vehicle for a particular operating environment; and (2) developing performance-based specifications for the appropriate paratransit vehicle through an interactive process that examines key trade-offs among the various aspects of the specifications (Balog 1995).

3.7.9 Identification, Evaluation, and Implementation of Performance-Related Acceptance Tests

INTRODUCTION

To predict performance, suitable acceptance tests need to be identified or developed. These tests should give adequate evidence that a construction product will or will not meet its design needs. Some currently used acceptance tests are performance-based and suitable. Other acceptance tests need to be revised and improved to better correlate with performance. In some cases, new acceptance tests will need to be developed.

Acceptance tests should, where possible, be rapid, timely (performed soon after construction), insitu, nondestructive, give full coverage (as opposed to testing a small sample), measure fundamental engineering properties, and have low sampling and testing error. To insure reliable test results, improvements to equipment, sampling, testing and analysis methods, need to be considered.

In some cases, a test correlation to performance may not be adequate when the test is performed immediately after construction. The test may be more suitable (more indicative of performance) when conducted years after construction, as part of warranty specifications. Such tests also need to be identified or developed.

With the reduction of available SHA personnel, more responsibility of testing a construction product is being transferred to the construction contractor. At this time many people do not believe the contractors have the resources and experience to test the products. Some are also concerned about putting a contractor in a position of compromise, if their test results do not meet the acceptable criteria.

This report documents the current practices and research for performance-related acceptance testing.

STATES OF KNOWLEDGE AND PRACTICE

- AASHTO's Quality Assurance Guide for Specifications is summarized. Quality Control Testing for PCC Paving, Structural PCC, HMA, Aggregate Base Coarse and Embankment are listed (FWHA 2000).

- The Database Management System (DBMS) segment contains data related to the highway construction operations such as the state highway specifications, standards, regulations and owner's quality control criteria. The integration of the two systems is achieved by using Environmental Systems Research Institute's `ArcView' software under the Microsoft Windows environment on a personal computer (Udo, Uzoije 1997).

IMPLEMENTATION BARRIERS

- Small contractors may not be able to compete with larger contractors that have the resources to do in-house performance-related acceptance tests.

- At the present time, the general mindset of the highway construction industry is that performance-related specifications and testing are not reliable enough to ensure a high quality project. The SHA is ultimately responsible for the project. Reliable tests needs to be developed and proven to ease SHA personnel minds.

- In certain instances, a contractor may alter the test data to their advantage. Verification testing methods need to be developed and established to insure accurate performance-based acceptance test data.

GAPS IN EXISTING KNOWLEDGE

- Many different research projects related to QC/QA have been completed. SHA personnel have a hard time locating the projects specific to their interest, or if a project is found, the question is that of implementation. A common database needs to be created for SHA personnel use. This database should include information such as track records of contractors, key projects and best practices.

- Many performance-related acceptance tests are in the experimental stages. Precise, unbiased, and reliable tests need to be established for SHA use.

- Industry and owner impact with respect to the use of performance-related acceptance tests is unknown. Their cost-effectiveness along with the needed level of acceptance testing needs to be determined.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- This paper discusses measurement criteria relating to performance-based specifications. To successfully implement any mechanistic pavement design procedure, and to move toward performance-based specifications, it is essential to develop tools that can measure the modulus and Poisson's ratio of each layer. Presented is an approach to such a program based on seismic testing. Field protocols and test equipment, which in a rational manner combine the results from laboratory and field tests with those used for quality control during construction, are discussed (Nazarian at al 1999).

- This paper introduces performance-based testing of steel slag aggregate, particularly volume stability as a recommended measure of the aggregate quality. Practices at the steel maker and the slag processor were examined. The production of acceptable quality steel slag aggregate requires total quality management of all steps of production (Farrand; Emery; 1995).

- This paper summarizes SUPERPAVE software and relates it to performance. SUPERPAVE software encompasses all phases of mixture design from selection of raw materials, aggregates and asphalt binder, volumetric mixture design, performance based testing and performance prediction. Also, SUPERPAVE software is designed for field verification of the mixture and quality control testing. This paper provides an overview of SUPERPAVE software capabilities (Huber 1993).

- The main thrust of this investigation was towards performance specification of concrete for new construction. The objective was to develop a methodology, using established permeation test methods, of estimating concrete durability in structures, and to assess and categorize potential durability of concrete for performance-based specification, compliance and quality control (Dhir et al 1994).

- This report presents comprehensive performance results of a Montana field experimental test section utilizing modified asphalt. The polymer-modified asphalts were used increasingly in rehabilitation of the old pavements. The payment distress was measured according to the Strategic Highway Research Program distress identification manual for long-term pavement performance project. The thermal cracking of the payment is verified by the results of performance based SHRP tests, Direct Tension Test and Bending Beam Rheometer. The thermal cracking of the pavement verified the results in this range of temperature. There existed differences in Pre-construction, Post-construction, First and Second annual distress measurements and the Marshall test properties of the cores (Pradhan, Armijo 1994).

- The environment of an Ontario highway bridge is a harsh one from a corrosion standpoint. Improved structure inspection and evaluation methods have been developed to promote optimum programming of rehabilitation work so that available funds are used most effectively. The recently published Bridge Deck Rehabilitation Manual describes the present repair alternatives, and outlines the decision process for selection of the appropriate technique (Schell; 1986).

- Thorough inspection during a revamp turnaround and prior to restreaming is a vital factor in the success of revamps. Three serious problems came to light when a vacuum tower was recommissioned after a revamp, without adequate inspection. This revamp failed because the problems were not found and resolved during revamp turnaround inspections. The purpose of inspection is to ensure that all new equipment is correctly installed and that all existing equipment is in good working order. Inspection also serves as a final defense against design errors. This article illustrates how inadequate inspection can destroy most of the expected benefit of a revamp (Lieberman, Lieberman 1992).

- Three broad classes of schemes for randomizing inspection schedules are examined in light of two inspection criteria: average or expected time to detection, and probability of timely detection. It is shown that among two classes of inspection schemes, for the criterion of average detection time, no scheme performs better than a simple periodic inspection schedule. A simple periodic inspection schedule is also optimal for the probability of timely detection criterion when adequate inspection resources are available; if this is not the case, the optimal strategy is shown to be one in which inspection opportunities at fixed intervals are 'sampled' or chosen randomly with a fixed probability (Sanborn 1992).

Past and Present NCHRP studies:

- The objective of this research, NCHRP 10-39 Construction Testing and Inspection Levels, was to develop administrative and technical guidelines for transportation agencies to use in establishing methods and optimal levels of inspection and testing for construction programs and projects. Innovation was critical for the successful accomplishment of the research objective (Newman et al 1994).

- This project, NCHRP 10-39A Testing and Inspection Levels for Hot-Mix Asphaltic Concrete, was designed to (1) develop a rational method for determining the minimum levels of agency and contractor testing and inspection activities necessary to satisfactorily construct hot-mix asphaltic concrete (HMA) overlays using the AASHTO Quality Assurance Guide Specification and the AASHTO Implementation Manual for Quality Assurance and (2) apply the findings of this research to other construction activities. The minimum level of testing and inspection is defined in this report as the minimum amount of testing and inspection resources to allocate for a given project. Satisfactorily constructing an HMA overlay is defined as meeting specifications, which are determined by test properties and compliance measures (Russell 1998).

- The objectives of this research, NCHRP 10-52 Performance Tests for Modular Bridge Joints, are to develop performance requirements for MBJS and to develop test methods and test equipment for the prequalification and acceptance of such systems to meet these requirements. In addition, critical issues relating to design, fabrication, installation, and construction inspection shall be identified to ensure that these requirements will provide a suitable service life (Dexter 1998).

3.7.10 Determination of Strategies to Offset Reduced Staff Size with Increased Workload of the SHA Personnel

INTRODUCTION

Experienced SHA personnel are retiring. The private sector is competing for college graduates and experienced personnel. At the same time, highways are in need of maintenance and reconstruction. New highways are being built everyday.

These facts bring upon the question –how are the SHAs supposed to deal with their ever-increasing workload with their reduced staff size?

Three possible answers to this question are to: (1) hire more SHA personnel; (2) create more efficiency in the workplace; and (3) contract out functions once performed by SHA personnel.

In order to hire more personnel, money needs to be allocated for competitive salaries and benefits. Once the money is available, recruiting processes need to be put in place to hire employees. Finally, once new employees are hired, training programs need to be in place to adequately train the new personnel.

To create a more efficient workplace, a complete evaluation of how time and energy is spent needs to be evaluated. Personnel to complete this evaluation need to be designated.

Contracting out functions such as design and inspection creates administrative tasks. It also creates questions such as: (1) will the quality of the projects be reduced, (2) will the SHA personnel be willing to give up the control they once had and (3) will the cost of a project increase due to third party design and inspection.

The following document summarizes the current practices of some SHAs and the research that has been done to combat this problem. As you will see, there are not many published documents concerning this subject.

STATES OF KNOWLEDGE AND PRACTICE

- Many states have been experiencing both an increased highway construction program and a reduction in the amount of construction project staff that are available to administer these projects. At times, these contrasting forces have placed severe demands on the resources of many State Department of Transportation (DOT) construction inspection staff. How do handle increased workloads? A survey on this subject was initiated in early 1998 and the following document is a summary of the responses received by the Secretary for the Contract Administration Task Force for the AASHTO Subcommittee on Construction. Typical strategies include: improvements in office and field equipment, transportation, management techniques, more training and experience, performance specifications, random testing, prioritization of inspection, acceptance by certification and other management techniques.

A Summary of the Coping Strategies Noted by the States:

- Contractor Construction Staking (AK, AR, AZ, FL, LA, KS, MN, MS, NE, NC, ND, NV, TX, VA, WA)
- Contractor Quality Assurance (AR, CO, CT, FL, IN, KS, KY, MN, MS, NY, UT, VA, WY)
- Contractor Profileograph (NV)
- Certified Weighmaster (MS)
- State DOT Manpower Forecasting (AR, NY)
- Seasonal Personnel (NY)
- Consultant Design, Inspection and Contract Administration (AK, AZ, CO, CT, DE, FL, GA, KS, MS, NM, NC, NV, NY, VA, WA)
- Consultant Material Testing (AZ, NM)
- GPS Control (MS)
- Innovative Contracting (AZ, NM)
- Pavement Warranty (MS)
- Prioritized Inspection, Reduced Testing Frequencies, Phase Inspections, Quality Teams (AK, CT, FL, KY, MD, NV, NY, OH, VA, WA)
- Consolidated Pay Item (CT, FL, MN, MS, OH, UT)
- Partial Payment of Materials on Hand (Stockpiled material) (TX)
- Paperwork Reduction (TX)
- Construction Management Software / Automation (KS, KY, NY)
- Student Technical Assistants / Construction Aids (AK, MD, MS, NV)
- Construction / Maintenance Personnel Rotational Assignments (MD, OH, WY)
- Graduate Engineer Recruitment Program (MD)
- Succession Planning (WA)
- District Inspector Transfers (MD, NC, WY)
- Elimination of City/County Project Management Assistance (NE, NV)
- Subdivision Street Acceptance (DE)
- Computerized Scales (AK)

(AASHTO 1998).

- The Kansas Department of Transportation (KDOT) is allowing cities and counties with an engineer on staff to design, let and oversee construction of exempt non-National Highway System (NHS) projects (Dvorak 2000).

IMPLEMENTATION BARRIERS

- Different states are using many different techniques to cope with the problem. These techniques need to be shared among all SHAs to enable SHAs to make educated decisions concerning which is best for that specific task.

- If outsourcing is to be a viable alternative to cope with reduced staff state agencies first need to determine what aspects of construction must be done in-house.

- Outsourcing design and inspection costs money.

- Outsourcing means relinquishing some control over projects, control that some personnel has always had. SHA personnel attitudes and policies need to be revamped to allow for the new way of doing things.

- Technology can greatly decrease the time a task would normally take. Integration of new technology can be difficult due to time, cost, and personnel constraints.

GAPS IN EXISTING KNOWLEDGE

- Outsourcing is one way to adapt to reduced staff size. Other ways to adapt are illustrated above. Further adaptive practices need to be determined and analyzed to find the best practice for the specific situation.

- Time is of the essence in most construction projects. Timely processes need to be developed to allow quick adaptation when personnel are low.

- A best practices guide is currently not available to SHAs to advise them on how to deal with this problem.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- The paper will discuss the experience of the South Carolina Department of Transportation in the use of consulting engineering firms on bridge construction projects. A review of the current management system is provided. The question of who should provide construction inspection services has existed in some form since the beginning of the construction industry. As with other engineering problems, there is not one answer, but there are several solutions which will yield adequate results. The South Carolina Department of Highways and Public Transportation like many other similar agencies, experienced significant growth during the construction of the interstate system followed by a reduction in size as the construction load relaxed. Due to constraints placed on staff size and growth by the state personnel system, the Department lost the ability to react to increases in workload both in the design office and on the construction site (Lewis 1991).

- This study explores the use of the private industry in public construction projects. The national highway system is deteriorating at an alarming rate. Additional highway capacity is needed desperately, as part of multimodal transportation plan designed to increase both mobility and air quality. Allowing the private sector to manage multiple functions of project implementation creates a synergy that goes well beyond what could be achieved by allowing private-sector forces to carry out the various functions independently through simple outsourcing. What remains to be seen is how the various states will assess project needs and structure project delivery and implementation to take advantage of the benefits of design/build, turnkey and super turnkey contracting with the private sector (Henk 1998).

- This paper reviewed past methodologies employed in investigating the comparative cost in-house and consultant design costs. It suggests some improvement and demonstrates their application in a cost comparison of road and bridge designs prepared for the Louisiana Department of Transportation and Development (Wilmot et al 1999).

- The Federal Lands Highway prepared a study that summarized the current practice of SHAs with respect to the amount of service they contract out. The report concentrated on the SHAs (1) level of contracting out, (2) the optimum number of personnel required to deliver internal and outsourced work, (3) how to maintain technical expertise when the services are contracted out, (4) the cost effectiveness of contracting out services, (5) the internal training and development employees must go through, and (6) other factors such as quality, liability, and efficiencies for the constructed product (Calderon et al 2000).

- This report summarizes a survey which asked state transportation agencies to determine the reasons for and extend of outsourcing, among other objectives. The report found that the primary factors that influenced decision to outsource were (1) staff constraints, (2) need for specialized equipment or expertise, (3) policy directives, (4) comparison of cost effectiveness, (5) legal requirements, and (6) other factors such as quality, need for a neutral third party, and political or other pressures from unions or private industry (NRC 1997)

Past and Present NCHRP and TRB studies:

- In NCHRP 20-41, Approaches for Increasing Private-Sector Involvement in Highway Innovation Process, the use of the private industry in public construction projects is explored. Providing highway transportation in the United States is a joint public and private enterprise; but despite their mutual dependence, public and private organizations have no established tradition of cooperation or partnership in the search for innovative methods and materials that could improve the delivery of highway service and reduce its costs. To explore alternative approaches for increasing private-sector participation in the innovation process for highways, TRB convened a 14-member committee whose membership includes public- and private-sector highway executives and research managers, university highway researchers, and experts in innovation and technology transfer. The study is complete, and the committee recommended the establishment of a Strategic Forum for Innovation in Highway Infrastructure. The forum would involve public- and private-sector officials in devising strategies for making rules, regulations, and practices for the highway industry more conducive to innovation (Godwin Menzies 1996).

- In Project 20-55, TRB Study on Future Surface Transportation Agency Human Resource Needs: Strategies for Recruiting, Training, and Retaining Personnel, the study will assess the likely human resource needs of surface transportation public agencies over the next two decades and will make recommendations for recruiting, training, and retaining needed personnel. The study will address both professional and nonprofessional staffing needs for state and local highway and transit agencies and for the private-sector organizations that provide contracted services to these agencies. The study will focus on strategies that agencies can use to ensure that they stay abreast of their changing needs and on approaches that universities and training organizations can take to address agency staffing needs (Godwin 2000).

3.7.11 Identification, Evaluation, and Implementation of Rapid Test Methods and Non-Destructive Testing (NDT) to Assess Quality in the Construction Process

INTRODUCTION

With the need to build highway projects faster and longer lasting, comes to need to achieve quality control and quality assurance faster. One way to achieve this is through non-destructive testing and rapid test methods. These new techniques will allow the construction process to continue while testing is being achieved and/or it will at least not halt construction for a long period of time.

> 'Rapid tests are gaining importance within the framework of quality control because they alone make it possible to recognize early any defects and to intervene to correct them in the course of the production process (Behr 1989)."

According to the current research, there are many procedures under development and experimentation. SHA personnel needs to have access to information such as availability and reliability of new tests, expense of training personnel to conduct the tests, and the methods to analyze the data collected from new testing procedures.

SHA CEMs must be able to find the test that is right for their project, and be able to implement it within construction to decrease the overall time of their project and increase the quality of the overall project.

The following is a summary of information available on new test methods relating to rapid tests methods and NDT. Many different tests methods are available or being developed at this time.

STATES OF KNOWLEDGE AND PRACTICE

- The Nuclear Non-Destructive Testing Laboratory's activities are geared towards the evaluation of existing methods for inspecting concrete, steel, and asphalt, and the development of new methods. The main instrument of the laboratory is a state-of-the-art X-ray computer tomography BIR-ACTIS system. Other instruments include the chloride detection machine GAMMACHLOR, which was constructed in-house at the NDEVC (Saleh 2000).

- SER-CO-TEC is a service company which carries out its activities of self-guarding buildings and constructions through diagnosis and monitoring. The company now controls some of the greatest historical monuments and some of the largest bridges and constructions using non-destructive test (NDT) methods. The methods used by the company to evaluate and control reinforced concrete and masonry structures are presented (Almesberger 2000).

IMPLEMENTATION BARRIERS

- To confidently perform a test and use its results for decisions in construction projects, both the equipment and tests must be proven reliable.

- Materials and techniques vary from state to state and region to region. An adaptive guidebook needs to be developed to aid all SHA personnel in performing performance-related tests, no matter the geographic location.

- Equipment for new test methods can be expensive to obtain. SHA management must be able to see the advantage gained from obtaining the new test equipment and method

GAPS IN EXISTING KNOWLEDGE

- Construction schedules could be shortened if there was more rapid-test methods or non-destructive test methods. However, there are many different tests performed on any given project. The following is a list of a few tests that could have innovative testing procedures developed for them:

- Ground penetrating radar for determining HMA density
- In-place segregation tests
- New volumetric test methods
- HPC concrete tests

A determination needs to be made of which test methods are in the biggest need of revamping, and which test methods most accurately predict long life of the end product.

- Assurance that the new test methods are as good as the old.

- To achieve accuracy and consistency of test results, a standard method of equipment use needs to be established.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- The authors present an efficient method to reduce the number of simulations when dealing with small values of the probability of failure. This technique combines the attractive features of the importance sampling procedures with the properties of the importance zone, located around the design point in the random operating space. A theoretical approach is developed in order to adapt the statistical distributions to the size of the mesh in the case of uniform stress. The proposed methods have been applied to analyze the reliability of civil structures: reinforced concrete structures. (Mebarki, Sellier 1995).

- The data presented results from a two year Strategic Highway Research Program investigation into suitable NDT methods for determining the early age, and residual strengths of highway structures. In the first year many test procedures were evaluated, and a small number identified as the most promising for use in highway structures. In the second year of the program a monolith consisting of a wall and a slab were cast at an exposure site adjacent to a concrete testing laboratory. The trials facilitated the choice of the most effective NDT procedures for future use of sites (Bickley, Read 1992).

- There is a growing need for new FAA standards covering the use of non-destructive pavement testing devices. This project covers the development of standards for the performance of non-destructive testing and evaluation (NDT&E) using commercial, off-the-shelf testing equipment. Initial research efforts will focus on updating the current Advisory Circular to include guidance on falling-weight deflectometer (FWD) use for airport pavements. Emphasis will be placed on verifying repeatability of FWD results and developing improved back-calculation methods (Hayhoe 2000).

- The results of a `shadow' field trial conducted to demonstrate a Level 1 prototype performance-related specification (PRS) for jointed plain concrete pavement construction are presented. This paper discusses all aspects of the field trial including the relevant definitions, selection of lots and sublots, sampling and testing plan, calculation of shadow PRS pay adjustments, problems encountered, and a summary of lessons learned (Hoerner et al 1999).

- This paper discusses the use of chemically stabilized subgrades in routine maintenance and new construction of roadway projects. In 1984 a nonwoven Supac 8NP was installed on secondary state highway SH-131 in Atoka County, Oklahoma, to investigate a more cost-effective means of separation and stabilization. Roadway performance of the geotextile test sections was compared with the traditionally used 610-mm (24-in.) lime-stabilized subgrade control sections, as both the geotextile and the stabilized subgrade were covered by the same pavement structural section. Also evaluated was geotextile survivability and performance after the rigors of construction, the stress of traffic, and aging. Roadway history, fabric and soil sampling and testing, road conditions, and estimation of fabric durability are examined (Guram et al 1994).

- In the past few years, intensive work has been undertaken in Canada on test methods for determining the potential alkali-reactivity of concrete aggregates. The paper summarizes and discusses the principal methods investigated and the results obtained. A decision chart is proposed which retains only two rapid test methods: the petrographic examination (ASTM C 295) and the accelerated mortar bar method (ASTM C 9-Proposal- P 214), in addition to the concrete prism method (CAN/CSA-A 23.2-14A) which is much longer by considered the most realistic test for alkali-reactivity (Berube 1993).

- A full-scale seven-story in-situ advanced reinforced concrete building frame was constructed in the Building Research Establishment's Cardington laboratory encompassing a range of different concrete mixes and construction techniques. This provided an opportunity to use in-situ non-destructive test methods, namely Lok and

CAPO tests, on a systematic basis during the construction of the building. They were used in conjunction with both standard and temperature-matched cube specimens to assess their practicality and their individual capabilities under field conditions. Results have been analyzed and presented to enable comparisons of the performance of the individual test methods employed (Soutsos et al 2000).

Past and Present NCHRP studies:

- In NCHRP Project 21-5, Determination of Unknown Subsurface Bridge Foundations, the objective of the project is to further develop, instrument, and fully validate the surface and borehole nondestructive testing (NDT) technologies with the greatest application range as determined (Olson 2000)

- In NCHRP 10-57 Structural Safety Evaluation Guidelines for Suspension Bridge Parallel Wire Cables, the objective of the research is to develop a manual of recommended practice for inspection and evaluation of suspension bridge parallel-wire cables (Mayrbaurl 2000).

- NCHRP 10-44 Nondestructive Testing to Determine Insitu Material Properties of Pavement Layers, identified insitu material properties necessary to characterize pavement layers, reviewed current practices relative to nondestructive (NDT) test methods for measuring insitu material properties, compiled a summary of the methods currently used or under development, evaluated potential methods for measuring the insitu material properties of pavements, and presented a plan for an experimental investigation to further evaluate and validate these methods (Von Quintus 1997).

3.7.12 Develop Best Practices for Community Outreach and Involvement During Construction

INTRODUCTION

Any construction project, no matter the size, will touch a community in some way. Projects that SHAs develop, design, and construct affect the people in surrounding communities. They not only travel on roads the SHA builds, but they also pay for the roads through their gasoline taxes. Because of this, community members like to have a say, or at the very least be kept informed about how the physical attributes of their community are going to change. Lately the trend of public wanting more value from the construction project seems to be on the rise.

> Customers are increasingly demanding more value in the products and services they receive. They are also becoming more diverse in how they define value in terms of meeting their specific needs (Hedges 2000).

There is a need to identify different ways in which SHA personnel can obtain and use community input to help coordinate construction. However, obtaining public acceptance and support for construction projects can present difficult challenges. Nonetheless, public support could not only assist in streamlining communication between the player, but it may also help the construction of future projects.

> Today, with the increasing public desire for a say about projects which impact their communities, obtaining public 'buy in' can be one of the most challenging aspects of urban pipeline design. The days of 'decide, design and defend' are gone, replaced by a process of community involvement in the design process (Weinberger 1998).

Programs to facilitate cooperation between the community and the SHA could be very beneficial and help create more successful construction projects. Various states have enacted public relation programs to help keep the community informed about the current and future construction projects. However, not every state has a program.

Before a successful program can be created, the current problems need to be assessed.

> It is vital, first, to understand what the public thinks about how transportation is provided and what their feelings are regarding the adequacy of the system and how best to improve it, and, second, to develop and implement techniques for communicating the needed information to fill the identified gaps (Edson 1997).

This document summarizes the current knowledge available on what questions are being asked and how they were answered.

STATES OF KNOWLEDGE AND PRACTICE

- In Iowa, commonly employed to smooth the way during construction (by helping the various contractors coordinate their activities, for example), partnering is now taking the design process out of relative isolation of the department's corridors and moving it - like the temporary office – into the middle of the communities involved (Wallace 1997).

- Community involvement has become an increasingly important part of Federal Aviation Administration (FAA) programs and activities. The FAA Community Involvement Policy Statement issued on April 17, 1995, emphasizes the importance of providing the public with opportunities to participate, where appropriate, in the FAA decision-making process. In adopting the policy, the FAA retains its decision making responsibility and accountability but recognizes that: (1) The public has the right to be informed and, where appropriate, to participate in public policy decisions that affect them. (2) The FAA has the responsibility to make decisions that address public concerns and values and that are consistent with the agency's statutory mission. (3) The agency's key mission is to provide a safe, secure, and efficient national aviation system. This report compiles in a single document various community involvement techniques and practices employed by airport managers. It identifies these techniques, which airports employ them, what techniques are most frequently used, and how successful these techniques have been for their programs. It encourages and facilitates the development and implementation of effective community involvement programs at all airports (1996).

- In Maricopa County Arizona, this practice is used on a project-by-project basis and has been in effect for 3 or 4 years. The county holds a number of meetings with the local neighborhood and business groups to obtain their input into the design of projects. In some of these meetings workgroups are organized to discuss specific issues and then report back to the whole group their recommendations. These meetings give the local citizens a feeling of ownership in the project (Bleyl; 2000).

- In Columbus, Ohio, this best practice has been used in the Columbus area on two large projects, over 250 million dollars, over the last 5 years. The advisory councils are comprised of businesses, neighbor associations, Paving the Way, and other interested parties. They provide a forum for complaints and were involved in developing the communication plan for the projects (Gallagher; 2000).

- In Colorado, concerned about their image in general, Colorado contractors undertook an effort to produce guidance for construction site managers that can improve image and public relations. Contractors associated with the Colorado Contractor's Association (ACC) produced hard-copy guidance (Hopkins; 2000).

- In Iowa, the Department of Transportation has contracted with a public relations firm to raise awareness and educate drivers of the dangers of work zones. Each year thousands of TV and radio spots are used to "get the word out." Information related to specific projects is also developed and distributed (Dickinsin; 2000).

- San Diego Gas & Electric Company is currently constructing a natural gas transmission pipeline crossing through the San Diego area. Pipeline 2000, a 33-mi.-long, 36-in.-diameter, 800-psig natural gas transmission line is being constructed to correct low-pressure areas in the southern and eastern ends of the distribution loop system. During the construction of the pipeline, an extensive community, media, and governmental outreach program has been developed and implemented. Since, the pipeline is being constructed in fully developed, highly urbanized areas, many special design considerations and construction techniques are also being considered (Hale; 1995).

- Construction of the second motorway bridge over the Severn estuary between England and Wales was another triumph of Anglo-French collaboration. Management of the pound 330 million project was split equally between the British and French construction partners and resulted in completion on time, within budget and without loss of life or limb. This paper describes the management strategy adopted for the project, explains the role of the designer and Government's agent during construction and reports on concrete production, quality assurance, safety, environmental, human resources and community relations issues (Kitchener; Mizon; 1997).

- As first conceived more that 20 year's ago, the West Side Highway Reconstruction Project in New York City was a grand interstate highway and urban land development concept that was ultimately defeated due to strong opposition from local community and environmental groups. However, last year's April groundbreaking for its more modest successor, known as the Route 9A Reconstruction Project, represented the culmination of a process that saw unprecedented community and governmental cooperation to design an urban boulevard that balances infrastructure renewal with pleasing design elements to both meet the state's requirements for traffic accommodation and gain the support of neighboring communities (O' Brien; 1997).

- Public agencies are increasingly recognizing the value of project information planning in construction programs, but little research examines the most effective components to include in these plans. The present paper examines two real-world construction projects that were recently completed in Clark County, Nevada, describes the project information and community partnering efforts that were undertaken in these projects, and evaluates these components in terms of the effectiveness of each individual component. It was found that official or unofficial community leaders are a significant, yet often underused, resource and that, within a project, distinct subgroups may exist that require specific attention (Henley; 1994).

- This paper outlines the background to design and construction of a wetland, primarily as a nutrient removal mechanism in the Belubula River. During December 1991 the NSW Department of Water Resources commenced construction of the artificial wetland at the upstream end of Carcoar Dam near Blayney in central western NSW.

The wetland is a multi-faceted project involving substantial research and community involvement. The paper also outlines the direction of research undertaken and the role and nature of community involvement in various aspects of the project (White et al; 1994).

IMPLEMENTATION BARRIERS

- SHA personnel that design and construct a project have not traditionally been training in communication with the general public. At the current time there is no standard program for obtaining and integrating community involvement into a construction project.
- Creating a standard program to facilitate community costs time and money.

GAPS IN EXISTING KNOWLEDGE

- Uniform effective communication channels and methods to get and keep the public's attention when their input is needed is not available.
- There is a level of community involvement that becomes too much. The value of the amount of community involvement vs the cost to obtain it needs to be evaluated.
- Effective community involvement is being achieved on a case-by-case basis. The procedure used to gain that involvement and the results need to be gathered and evaluated, and then shared among the SHAs.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- This paper provides background information on the dollar 2.2 billion Ten Year Pacific Highway Upgrading Program and details the extent of the planning that has been undertaken to ensure value for money and to deliver the program in accordance with Government and community expectations. Effective program planning requires an understanding of the relationship of new road infrastructure with planning and land use. In addition, a long-term strategy for development of the whole highway to dual carriageway standard is needed before the most effective ten-year program can be established (Wielinga; 1998).
- This paper will review examples of decorative insitu concrete as used in a variety of traffic calming devices. It will show that with thoughtful design and attention to detail, the use of insitu concrete not only permits the design and construction of a functional device, but also one that enhances the streetscape. This combination of function and aesthetics leads to the desired result of increasing the amenity of residents. This research was conducted partly due to the growing concern in communities about the need to calm traffic and reduce speeds through residential streets. Several federal and state government guidelines now available on the conceptual design of residential streets and neighborhoods (referenced in this paper)

also demonstrate that more thought needs to be given to the needs of the community in designing streets and traffic calming devices (Matthews; Serruto; 1998).

Past and Present NCHRP studies:

- The objectives NCHRP 20-24(5), *Public Outreach in Transportation Management,* were to recommend to SHAs programs and techniques to better inform the public of transportation issues and identify examples of effective applications. The research has been completed and produced three products: a handbook, research report, and videotape (Edson; 1993).

- The objective of NCHRP 20-24(01), *Using Market Research to Improve the Management of Transportation Systems,* was to help state DOTs to add modern market research techniques to their program development and evaluation methods (Mudge; 1989).

- The objective of NCHRP 25-19, *Evaluation of Methods, Tools, and Techniques to Assess the Social and Economic Effects of Transportation Projects,* is to develop a handbook that identifies, describes, and evaluates existing methods, tools, and techniques that will aid practitioners in assessing the social and economic effects (positive and negative) of transportation projects (Forkenbrock; 2000).

- The objective of NCHRP 20-53, *Using Customer Needs to Drive Transportation Decisions,* is to develop guidelines for transportation agencies on the most effective ways to collect and use data on the needs and expectations of customer segments in order to guide transportation policy and investment decisions. For the purposes of this study, "customers" are considered to be the direct consumers or users of transportation products and services, as opposed to secondary stakeholders or interest groups (Hedges; 2000).

3.7.13 Best Practices for Managing Environmental Restrictions and Requirements

INTRODUCTION

Today now more than ever, the environment plays a key role in everyday activities. Some cities have smog warnings, some have water pollution warnings, and others control vehicle emissions. In order to reduce these and other warnings, regulatory agencies are cracking down.

Along with warnings, there are environmental practices in place to prevent harm to the environment. These practices employ restrictions and regulations on activities carried out in that location. Construction is one practice that now requires many different permits for a given location.

Construction project managers are willing to comply with environmental restrictions. However, it can be difficult at times. The rules and types of permits required seem to change everyday. The costs to comply are also increasing, which in turn increases the cost of the project. Penalties for non-compliance also seem to be increasing. State highway agencies are finding it more and more difficult to comply with the rising environmental regulation.

> Engineers are facing the real challenge in their profession, not in dealing with hazardous waste but in avoiding subsequent lawsuits. A wide range of engineering/contracting firms are exposed to environmental lawsuits. Today's litigious society, coupled with the complexity of environmental regulations, exposes the general contracting and construction industry to a variety of risks (Rosenberg 1995).

Construction Engineers and Managers need to have an effective way to manage all the different permitting and restrictive regulations. The management should include cost saving compliance options. It should also include a way to keep the managers current on what the specific regulation is for their particular project.

This paper documents the information available about compliance with environmental regulation for state highway agencies.

STATES OF KNOWLEDGE AND PRACTICE

- Wisconsin's 21st century transportation plan-will outline a comprehensive transportation system that moves people and goods efficiently, strengthens our economy, protects our environment, and supports our quality of life. Working with DOT, the public will identify Wisconsin's transportation needs-and help to make tomorrow's transportation choices (Thompson 1994).

IMPLEMENTATION BARRIERS

- Certain restrictions and regulations seem like they come out of nowhere. It is difficult for SHA personnel to comply with a standard when the reason behind it is hard to understand, or the effect of compliance cannot be seen.

- To obtain compliance with a regulation or standard, there usually needs to be, at first, an incentive or disincentive to cooperate. When certain regulations have no consequences for not complying, it is difficult to get agencies to cooperate.

- In certain instances, finding a different solution to a problem, or using a different material/process can eliminate having to comply with an environmental regulation. Alternate methods of construction need to be compared with environmental regulations to find the most efficient way a building an environmentally friendly project.

GAPS IN EXISTING KNOWLEDGE

- The numerous and various regulations on noise, air, and storm water management strongly affect the way a Construction Engineer and Manager will manage a project. The different effects from the different regulations are not known.

- During the pre-planning stage decisions are made regarding management of the project with respect to the environment. Many times those decisions are not communicated to the construction team that will actually manage the construction of the project.

- Many different restrictions and regulations are applied to any one project. A standard, or guide, is needed to help SHA personnel effectively manage the permitting and compliance.

- Substitutions in a construction project can reduce the amount of environmental restrictions on a project. This document discusses a few of these types of substitutions. All the different substitutions need to be collected and shared among SHA personnel.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- This paper describes the approach two different regulatory groups have taken regarding water resources. Water resources analysts recognize that water resources planning should be comprehensive and multiply objective in nature, in contrast to planning centered on a single objective, such as flood control or irrigation. Despite this agreement, two basic approaches have emerged over time, each with its own theoretical rationale. One is generally used by the Corps of Engineers and other construction agencies, and the other by the U.S. Environmental Protection Agency (EPA) and other regulatory agencies; neither is really comprehensive. This paper explains the situation we are in and the principles involved; it also explores alternative methods of arriving at better results (Whipple 1996).

- This paper summarizes the relationship of safety and the environment to construction and suggests a program to help comply with both. Many construction safety issues are closely connected to environmental problems. The consolidation of safety and environmental regulation at federal and state levels, either partially or totally, would provide the construction industry with a single agency that would provide uniform and accurate guidance, avoid unnecessary duplication of guidance and information, and virtually eliminate conflicts that are currently caused by multi-agency oversight (Kibert et al 1995).

- This paper describes the construction of a tunnel and the environmental compliance issues related to its construction. The next phase of the METRO subway tunnels project in Washington, DC is the 14th Street Tunnels contract which involves the construction of two 975 m soft ground tunnels. The soil from the tunneling excavation and water from the dewatering wells were constantly monitored throughout the construction as part of the owner's stringent environmental requirements. (Zelenko 1995).

- The impact of environmental regulations on the quality of tunnel groundwater discharges is examined in this paper. Tunnel contractors usually depend on specialty contractors or outside consultants to deal with this issue without carefully examining their activities to minimize the production of contaminants. This approach may not be adequate given increasingly more restrictive environmental requirements. This paper surveys the general practice of the tunneling industry and attempts to identify sources of contaminants which may affect the total suspended solids, oil and grease content, and pH of the discharges (Fong et al 1995).

- This paper uses Federal-Aid Highway Program information for 1990 to 1994 to define a natural experiment that evaluates whether compliance with federal environmental regulations increases construction costs. This is accomplished by considering whether indirect measures of the environmental resources in each state affect construction expenditures for federal-aid highways. Statistical analysis suggests that the expenditures for federal-aid highway construction and repair were influenced by these factors and by the regulatory activities likely to be associated with environmental mandates (Smith et al 1999).

Present NCHRP studies:

- The objective of this research, NCHRP 8-41 Effective Methods for Environmental Justice Assessment, is to identify and develop processes, procedures, and techniques for integrating environmental justice considerations in transportation systems planning and decision making at the statewide, regional, and metropolitan levels. The research will improve the analytical capabilities of states, metropolitan planning organizations, and their planning partners. The research will build on existing community-impact assessment methods and will focus largely on the adaptation and extension of these methods to environmental justice analyses employed at the systems, corridor, and project levels of transportation planning and development (McCready 2001).

- The objective of this research, NCHRP 8-38 Consideration of Environmental Factors in Transportation Systems Planning, is to identify, develop, and describe a process that includes procedures and methods for integrating environmental factors in transportation systems planning and decision making at the statewide, regional, and metropolitan levels (McCready 2000).

3.7.14 Review of the Constructibility of Transportation Facilities in the Planning and Design Phases –Specifically Deficiencies in Quality and Clarity of Construction Plans

INTRODUCTION

Constructibility reviews of highway projects during the planning and design stages have the potential to minimize the number and magnitude of changes, disputes, cost overruns, and delays during construction (Anderson and Fisher 1997a). Cost savings determined in a study conducted by the Arizona Department of Transportation estimated that improvements made possible by a constructibility policy resulted in savings of $68 million in six projects at a cost of only $1.2 million. The cost of the review effort resulted in a benefit to cost ratio of 25 to 1. Thus, for every dollar spent reviewing these projects for constructibility, $25 was returned in savings (Anderson and Fisher 1997b).

Constructibility is defined as the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Constructibility is the integrating of construction knowledge, resources, technology, and experience into the engineering and design of a project (Fisher 1996). The end result should be enhanced plans and specifications for constructibility leading to increased ease and efficiency of construction, with fewer changes (Anderson and Fisher 1997a). The reasons for a constructibility system are to achieve effective designs, achieve efficient construction, and provide feedback to project designers (Ellis et al. 1992).

An effective constructibility review policy can decrease project duration, decrease the quantity of changes, and improve the quality of the constructed facility. Despite of the possible benefits of project constructibility analysis, only 23% of state highway agencies (SHAs) use a formal constructibility policy, as indicated in a 1997 survey (Anderson and Fisher 1997a). Several factors limit the implementation of a formal policy including a lack of design experience, inadequate communication between construction and design personnel, and the absence of a record of past construction changes.

In a report prepared for the National Cooperative Highway Research Program (NCHRP), Anderson and Fisher outlined the necessary steps for a successful constructibility policy at both the *project* and *agency* level.

Organization of a constructibility plan at the *project* level (Anderson and Fisher 1997a):

- Formalize constructibility process to include panning, design, and construction.
- Implement constructibility review tools.
- Use team approach.
- Enhance plans, specifications, and contract documents for constructibility.
- Provide feedback to designers on construction performance design.
- Collect feedback from maintenance and operations personnel.

Organization of a constructibility plan at the *agency* level (Anderson and Fisher 1997a):

- Formalize constructibility policy.
- Establish favorable benefit/cost ratio.
- Allow for alternative contracting strategies.
- Use a constructibility consultant/engineer coordinator.
- Develop constructibility lessons-learned database.

STATES OF KNOWLEDGE AND PRACTICE

Several SHAs have implemented a formal constructibility policy. The following list is a sample of some state agencies and current constructibility practices:

- California uses a formal constructibility review process (CRP) as an iterative process during the design phase. The review includes traffic, design, construction, and maintenance. A CRP would address many of the root causes leading to contract change orders, and delay claims. The premise is that the construction of the project correctly the first time will minimize the contract time and reduce future maintenance problems ("Formal" 2000)
- Colorado, in collaboration with Colorado Contractor's Association, selects a contractor to review and critique plans that are under development. The review allows correction prior to bid advertisement and the start of construction. The policy results in fewer changes during construction and reductions in traffic congestion ("Constructibility" 2000a).
- Indiana reviews constructibility that includes construction phasing, scheduling, designing alternatives, designing traffic control, and investigation of the coordination with other projects. ("Constructibility" 2000b).
- North Carolina Contractor's Association is involved in constructibility reviews in the design process. The process provides a more constructible design by using contractor input during pre-construction phases. Since implementation of the process in 1996, there has been a decrease in project duration and cost, and better traffic control ("North Carolina" 2000).
- Oklahoma uses the knowledge and expertise of contractors to review the constructibility of projects. The practice allows all contractors to review for constructibility, in advance of advertisement of biding, to ensure the best, most economical, and quickest construction methods are incorporated into the design ("Contractor" 2000a).
- Virginia hires a local construction contractor to perform a constructibility review including feasibility, cost, and timing of some projects. The process has been used on "high visibility" projects requiring optimum traffic control and few problems during the construction phase ("Contractor" 2000b).

IMPLEMENTATION BARRIERS

- The four factors that limit the implementation of a constructibility policy are a lack of time, money, available resources, and the use of traditional practices in the system.

- There is inadequate time to review projects for constructibility issues in the planning and design stages. In many projects, time is not available in the planning stages to pursue constructibility enhancements early in the project (Hugo et al. 1990). Most constructibility analyses, whether formal or informal, are driven by project milestones during design, when progress reviews are conducted. They are also conducted late in design, which minimizes benefit/cost of the constructibility policy (Anderson and Fisher 1997a).

- Most public agencies are reluctant to invest additional money and effort in the early project stages (Anderson and Fisher 1997b). The use of a constructibility policy can be expensive. When the benefits of the policy are unpredictable, the justification for allocation of money is complicated.

- Project resources are limited. Adequate time for reviews, availability of funds, availability of personnel for reviews, and lack of the right experience and knowledge limit the use of a constructibility review process (Anderson and Fisher 1997a). A specific question is who can perform the constructibility analysis on public contracts? How can SHAs hire a contractor to investigate the constructibility of a design without legally eliminating the contractor from bidding on the construction of the job? Many SHAs do not have the experienced design staff to prepare quality plans and specifications or perform constructibility reviews (Anderson and Fisher 1997b). This lack of design experience is affected by the high rate of personnel turnover (Hugo et al. 1990).

- Several ingrained factors in the traditional design-construction practice limit the implementation of a new policy. The relationship between design staff and construction staff includes a lack of mutual respect (Anderson and Fisher 1997b) and wide separation defined by insufficient coordination and communication. Additionally, the use of a new policy is slowed by the reluctance to deviate from current and proven standard operations (Hugo et al. 1990).

GAPS IN EXISTING KNOWLEDGE

- Three possible areas in need of constructibility research (Anderson and Fisher 1997a):
    - Case studies –The results of projects with the application of the constructibility review process (CRP) can be studied to document benefits and indicate where the CRP is ineffective and in need of alteration.
    - Technology –Investigate the use of computer applications in the CRP.
    - Continuous improvement – Mechanisms should be studied that provide for continuous improvement of the CRP. As the process is implemented by SHAs, conferences and symposiums could be used to discuss lessons learned, problems, and necessary changes in the CRP.

- One notable problem is the ability of agencies to produce quality plans and specifications. Several factors add to the deficiencies in highway project plans and specifications:
  - Lack of design experience of agency design staff.
  - Lack of communication between construction staff and design staff.
  - Current policies do not capture lessons-learned (Anderson and Fisher 1997a).
  - Laws limit the use of contractors for constructibility review.

- Additional information is necessary to determine benefits and costs associated with a formal constructibility review process. According to a national survey 97% of responding state agencies do not document costs for performing reviews and 88% have no method to quantify benefits (AASHTO 2000). A study by NCHRP (20-07, Task 124) is currently investigating the costs/benefits of constructibility reviews. The results of the study are unknown.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

NCHRP published work on formalizing a constructibility review process (Anderson and Fisher 1997b). While parts of the recommended review process have been adopted by several agencies, there is no indication that any agency has fully embraced the process. Some agencies have indicated their concern that the process described in the report is too resource intensive for full implementation (AASHTO 2000). In the NCHRP study, data collected in 1994 indicated that about 23% of agencies had a formal CRP (1997a). According to data presented to the AASHTO Subcommittee on Highway Construction, only about 26% of the agencies stated that they had a formal CRP in 1999 (DeWitt 1999). This may also indicate a lack of implementation of the process published by NCHRP. The AASHTO Subcommittee on Highway Construction has developed a draft best practice guide for constructibility that may enhance implementation of a formal CRP.

3.7.15 Expanded Use of Contractor-Performed Quality Control Processes for Acceptance of Highway Projects

INTRODUCTION

In the past the responsibility of quality control and quality assurance has fallen on the State Highway Agency (SHA) personnel. Recently staff size has decreased, but the amount of work has not. The SHAs are trying to find ways to complete the work they have before them. Because of this SHAs have to answer questions such as: what functions are they in the position to perform, what functions are they going to quit performing and what are the critical functions that cannot be performed by others. One area in which SHAs are attempting to optimize their resources is through the use of contractor-performed test data for quality assurance purposes.

This is a major demand to reduce duplication between SHAs and contractors. This demand is shifting responsibilities and redefining roles between SHAs, contractors, and FHWA. With this change, there are a number of unanswered questions. For example, what are the risks in this change, is it appropriate for SHA to be doing this, who is using contractor data for acceptance, what tests are they using, did it avoid duplication, did SHA achieve the test results they desired, was a verification process used, was the verification process efficient, was it cost effective, was quality compromised, what level of independence is necessary between contractor-performed tests and quality assurance.

The following document summarizes the available information about the shifting of this responsibility.

STATES OF KNOWLEDGE AND PRACTICE

- In response to Federal Aid requirements (23 CFR 637B, October 5, 1995) regarding certification of roadway technicians for quality control/quality assurance (QC/QA) testing, the Arkansas State Highway and Transportation Department (AHTD) sponsored the development of the Center for Training Transportation Professionals (CTTP) at the University of Arkansas, Fayetteville. Training and certification programs executed by CTTP include Hot-Mix Asphalt Field Technician (HMAC Tech) among others. As of November 1, 1998 eight HMAC Tech courses have been completed with a total of 150 persons attending, including 67 AHTD and 83 contractor employees (Hall, Pylant 1999).

- Since 1992, the California Department of Transportation (Caltrans) has been working to improve quality in construction contracting and ultimately the quality of the product provided to the public. In 1996, Caltrans implemented quality control/quality assurance (QC/QA) specifications for asphalt concrete paving. These specifications require contractor QC and provide rewards or penalties based on statistical quality analysis of eight quality characteristics (Dobrowolski, Bressette 1998).

- The Alabama Highway Department (AHD) developed and implemented a quality control/quality assurance (QC/QA) program for hot-mix asphalt (HMA) construction from 1990 to 1992. Several HMA properties were measured for construction quality control and assurance. The accuracy and precision of measurements increased from 1990 to 1992, indicating improved construction quality, improved technician sampling and testing skills, or both (Parker, Hossain 1994).

- Phoenix, Arizona implemented a quality improvement program approximately 13 years ago and is updating it when applicable. This program brought together members of the Contractor and Consultant organizations to evaluate what the hurdles are to getting projects built faster, safer and at less cost. Following this study, the city invited representatives from other cities to come to Phoenix to review the recommendations and to refine the process (Bleyl 2000).

- The quality-control system described here is in use in one of the Shell Group companies. The system includes a grading system that permits quantification of the level of quality (by means of an index) and thereby a means of monitoring change with time. Additionally, a time (operational) efficiency monitoring system allows operational efficiency to be quantified. Experience shows that the operation of such schemes increases the interaction between the operator and the contractor and forms a challenge to achieve high standards of service quality and performance. Through a higher level of awareness and a specified joint goal, a high-quality level of products and professional services can be reached and maintained. Some innovative new applications, specifically in the area of efficiency of operation (i.e., new tool combinations) have been the result (Graper 1994).

IMPLEMENTATION BARRIERS

- The industry has begun to shift the responsibility of assurance testing to the contractor. In certain projects now, contractors either perform the QC tests themselves, or sub contract the testing out. The final shift of using a contractor's QC data as QA data will take a great deal of trust on the SHA personnel's part.

- In state projects, contractors are awarded the project by low bid. However, it only makes sense that a higher quality project will cost more money. Contractors that want to produce the highest quality work, may not be the ones awarded the job.

GAPS IN EXISTING KNOWLEDGE

- Any number of QC tests can be taken and analyzed on any given project for the many different components produced. An analysis is not been made available on how many QC tests per product need to be taken.

- Some states have been experimenting with using the contractor's QC data as quality verification. The processes used and the results need to be shared among all the SHAs.

- Tests can be performed many different ways. To effectively use test results uniform certification programs need to be made available to both contractors and SHA personnel alike to assure reliability of test results.

- Using contractor data for assurance purposes may not be feasible for all types of projects. Areas in which contractor test data can be applied needs to be evaluated.

- There is no uniform guidance program currently available to SHAs on how to effectively and efficiently use contractor quality data for quality assurance.

PAST RESEARCH –UNKNOWN IMPLEMENTATION

- The objective of this paper is to provide a compilation of state-of-the-practice in QC/QA for HMA construction and provide recommendations for state highway agencies and contractors when modifying or developing a QC/QA specification. State highway agencies and contractors have been implementing quality control/quality assurance (QC/QA) specifications in recent years to advance the quality of hot-mix asphalt (HMA) construction (Schmitt et al 1998).

- The present study evaluates the use of the nuclear gauge as a prospective quality-control tool by comparing nuclear-gauge performance with core density measurements. Density measurements were recorded by the contractor and the highway department using both core and nuclear-gauge methods on four paving projects, and statistical analyses conducted to compare the results. The analyses indicate that there is no statistical difference between the testers (contractor or highway department) or in the variability of the measurements obtained by the different methods (Sanders at al 1994).

- This paper discusses a proposed methodology to assure the final pavement structure under construction will meet the assumed design properties. Through a statistical analysis of the quality control data, for each layer, a check is made to see if these data meet the previously specified standards. In the first iteration process, the assumed subbase properties are evaluated, thus allowing for a first adjustment in the design, and allowing the contractor to adjust his original bid. The subsequent evaluations will define the quality of the contractors' work, allowing adjustments due to poor construction quality until the last pavement layer is built, then if the finished pavement doesn't meet the previously specified requirements, the contractor should be penalized (Torres, McCullough 1991).

3.8 Chapter Summary

This chapter summarized the process used to analyze the data collected and revise the draft research program. It began with the initial development of the draft research program. Next it described how both the literature searches and draft research program was revised through the December Panel Meeting and then the March Workshop. Finally, it displayed the complete results of the literature search for each research issue.

Chapter 4 Recommended Research Program

4.1 Chapter Overview

This chapter explains the reasoning behind the recommended research program and the implementation plan. It also presents the recommended research program.

4.2 Recommended Research Project Overview

4.2.1 Drivers of Change

Throughout this project, a number of drivers of change in the design and construction industry emerged. All of the problem statements fall under one or more of these drivers of change. They include: (1) customer expectations; (2) time; (3) people; (4), technology; and (5) roles, responsibilities, and risk.

4.2.1.1 Customer Expectations

The customer, the driving public, depends upon the nation's highways for transportation to and from work, recreation, and every day activities. As the highway systems extend beyond their design life, poor conditions can influence depreciation of vehicles and make trips less enjoyable for motorists. While highway systems are being reconstructed or maintained, lane closure and sometimes highway closure interferes with lives, which also makes trips less enjoyable. Businesses that are located on a route that is being reconstructed can be affected if an alternate route to the business it is not clear. Also, businesses that depend upon the roadway, such as package carriers, are affected by deterioration of roads and detours or road closures. SHAs are trying to balance customer needs with customer expectations.

4.2.1.2 Time

Time is of the essence today more than ever. The customer is demanding reduced cycle times in all construction projects. The traveling public wants their highway systems smooth and safe as quickly as possible. Time is important to people and they do not want to be delayed. SHAs are attempting to produce higher quality projects (increased service life) in shorter time.

4.2.1.3 People

People are the main resource in any construction project. Finding qualified and experienced people to staff SHA positions is challenging due to the growing competition from other segments of the economy. Job location can also be an important factor to experienced personnel. The locality of a particular position may not be appealing to the perspective employee. Once SHA personnel are employed, finding the time to train them can be a substantial challenge because of heavy workloads of current SHA personnel.

SHAs are trying to create an organization that manages people at all career levels successfully.

4.2.1.4 Technology

Technology is changing rapidly. Technology is a key resource in today's market. New materials, methods, and techniques are being developed to aid in improving construction. This new technology must be tested and certified so it can be used effectively on projects. SHA personnel must actively seek out new technology so that it may be implemented on SHA projects. SHAs are trying to integrate technology into design and construction processes to reduce cost and time and improve quality of the constructed facility.

4.2.1.5 Roles, Responsibilities, and Risk

Roles, responsibilities, and risk allocation are the key to making any project successful. Risk must be allocated to the party in the best position to control and manage it. Each party in the construction project must be familiar with their role and responsibility. Each party must recognize and be comfortable with the level of risk they control during the project. The roles, responsibilities, and risk often change from project to project. SHAs are now attempting to manage them to insure more successful projects.

4.2.2 Overall Categories

From the problem statements, overall categories emerged that can describe a portion of the recommended research program. The drivers of changes are interwoven within each of these categories with some categories including more than one, or possible all drivers of change. The categories are: (1) safety; (2) alternative contract methods; (3) allocation of risk/responsibilities; (4) personnel; (5) faster construction/reconstruction; (6) communication; and (7) environment. Key issues pertaining to each category follow the brief explanation.

4.2.2.1 Safety

Safety is the primary concern of SHAs on any construction project. Both construction workers and the traveling public must be protected from possible dangers on a construction project. Once the highway system is constructed, it must be safe for travel in all types of weather and road conditions. Thus, the following issues have been identified with respect to improving safety.

- Analysis of nighttime construction activities and impacts on safety, quality, and productivity
- Improve safety of public and workers during highway reconstruction and maintenance

4.2.2.2 Alternative Contract Methods

Alternative contract methods can accelerate project time with the use of concepts such as incentives, cost-plus-time, or new delivery systems such as design-build. These new concepts can greatly add to the success of projects if properly applied and implemented. They can also inhibit the success of a project, if all parties are not dedicated to their use. Procedures to implement them must be clear to enable successful application. The following are issues identified for future research relating to alternative contract methods.

- Evaluation of the Use of Incentives/Disincentives I/Ds to Reduce Time to Complete Highway Projects
- Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction

4.2.2.3 Allocation of Risks and Responsibilities

Allocation of risks and responsibilities is an important part of the management on any construction project. Allocation of additional risk through transfer of certain activities to contracted parties can reduce the workload of SHAs and allow SHA personnel to concentrate on core competencies. These issues have been pinpointed as related to allocation of risks and responsibilities.

- Expanded Use of Contractor-Performed QC Processes for Acceptance of Highway Projects
- Implementation and evaluation of performance-related specifications for highway construction
- Identification, evaluation, and implementation of performance-related acceptance tests
- Identification, evaluation, and implementation of rapid test methods and non-destructive testing to assess quality in the construction process

4.2.2.4 Personnel

Personnel are the essential ingredient to the success of any construction project. The expertise and dedication of project personnel determines problem solving efficiency and project productivity. Obtaining and retaining quality personnel is difficult in today's competitive market. High quality, up-to-date training programs are essential for informing SHA personnel on the state-of-the-art technologies and construction and contract methods. A time of unprecedented change emphasizes the need for a fresh look at personnel management issues. Changing times and changing project strategies also means the need for open-minded and flexible personnel. The issues following have been identified as areas of needed future research.

- Recruiting, promoting, and retaining qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced employees

- Training and workforce development of SHA personnel
- Determination of strategies to offset the reduced staff size with the increased workload of SHA personnel

4.2.2.5 Faster Construction

Faster construction and reconstruction is a characteristic sought by both the traveling public and the SHAs. There are many techniques that can be used to accelerate the construction process. Comprehensive knowledge that aids in successful implementation of the techniques can benefit both parties. Hence, subsequent issues have been recognized as areas of necessary future research.

- Evaluation of the use of I/Ds to reduce time to complete highway projects
- Develop and evaluate new construction methods, processes, and materials to facilitate faster construction
- Impact of strategies to manage traffic during highway construction projects on construction methods, productivity, schedule and quality
- Identification, evaluation, and implementation of rapid test methods and non-destructive testing to assess quality in the construction process
- Constructability review process implementation plan
- Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction

4.2.2.6 Communication

Communication is crucial for the success of any process. Communication is carried out between people each day by the use of telephones, electronic mail, paper mail, meetings, and face-to-face contact. Good communications with the public can help keep them informed on the status of the construction project and can help them feel like an important part of the process. Proficient communication between the stakeholders of the construction project can streamline problem solving. The next two issues are topics of needed research with respect to communication.

- Best practices for community outreach and involvement during construction
- Impact of strategies to manage traffic during highway construction projects on construction methods, productivity, schedule and quality

4.2.2.7 Environment

The environmental impact of projects continues to be a major concern and an area of focus in the CEM industry. Rules and regulations are being introduced to protect the environment and its inhabitants from harmful pollutants. A better understanding of the protective restrictions is needed so that they can be proactively implemented. The following issue has been recognized as an area of needed research.

- Best practices for managing environmental restrictions and requirements

4.3 Implementation Plan

The implementation order was derived from first looking at the rank from the Delphi study and then by looking at the rank from the March 2001, Workshop. Since the Delphi study was a three-month process with two iterations, its rank was given a higher priority. The research team determined that a weight of 60 percent be given to the rank from the Delphi study and a weight of 40 percent be given to the rank from the workshop. Table 4.1 displays the Overall Rank assigned to each Topic in addition to the Delphi and Workshop Ranks. Also, in early March, the panel requested that three problem statements be developed immediately after the conclusion of the workshop for submission to the AASHTO Standing Committee on Research (SCOR). These three problem statements will begin the research program.

Table 4.1. Implementation Order

Overall Rank	Delphi Rank	Workshop Rank	Issue Topic
1	2a	2a	Implement the use of new materials into highway construction practice
1	2b	2b	Innovative rapid construction/reconstruction methods
2	1	5	Improve safety of public and workers during highway reconstruction and maintenance
3	4	2	Alternative contracting methods and delivery systems to facilitate faster construction/reconstruction
4	6a	1a	Analysis of nighttime construction activities and impacts on safety, quality, and productivity
4	6b	1b	Impacts of strategies to manage traffic during highway projects on construction methods, productivity, schedule, and quality.
5	3	7	Recruiting, promoting, and retaining of qualified personnel in highway construction
6	8	2	Implementation and evaluation of Performance-Related Specifications (PRS) for highway construction
7	5	7	Evaluation of the use of incentives/disincentives (I/Ds) to reduce time to complete highway projects
8	11	7	Identification, evaluation, and implementation of rapid test methods and non-destructive testing (NDT) to assess quality in the construction process
9	7	15	Training and workforce development of SHA personnel
10	14	5	Constructability review process implementation plan
11	10	12	Determination of strategies to offset reduced staff size with increased workload of SHA personnel
12	9	14	Development and implementation of performance-related acceptance tests
13	12	10	Best practices for community outreach and involvement during construction
14	13	16	Best practices to aid SHA construction engineers and managers in managing environmental restrictions and requirements
15	15	13	Expanded use of contractor-performed quality control processes for acceptance of highway projects

4.4 Recommended Research Project Order

The order is as follows:

1. Evaluation of the use of incentives/disincentives I/Ds to reduce time to complete highway projects
2. Analysis of nighttime construction activities and impacts on safety, quality, and productivity
3. Expanded use of contractor-performed QC processes for acceptance of highway projects
4. Implementation of the use of new materials into highway construction practice
5. Innovative rapid construction/reconstruction methods
6. Improve safety of public and workers during highway reconstruction and maintenance
7. Alternative contracting methods and delivery systems to facilitate faster construction/reconstruction
8. Impact of strategies to manage traffic during highway projects on construction methods, productivity, schedule, and quality.
9. Recruiting, promoting, and retaining of qualified personnel in highway construction
10. Implementation and evaluation of performance-related specifications (PRS) for highway construction
11. Identification, evaluation, and implementation of rapid test methods and non-destructive testing (NDT) to assess quality in the construction process
12. Training and workforce development of SHA personnel
13. Constructability review process implementation plan
14. Determination of strategies to manage the reduced staff size and increased workload of SHA personnel
15. Identification, evaluation, and implementation of performance-related acceptance tests
16. Best practices for community outreach during construction
17. Best practices for managing environmental restrictions and requirements

4.5 Recommended Research Program

The following sections contain the Second Stage Research Problem Statements in recommended order of research. They were developed using the literature searches, workshop data, and knowledge of the panel members and research team members.

4.5.1 Evaluation of the Use of Incentives/Disincentives to Reduce Time to Complete Highway Projects

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Evaluation of the Use of Incentives/Disincentives to Reduce Time to Complete Highway Projects

III. RESEARCH PROBLEM STATEMENT

SHAs are under increased pressure to reduce the length of time to complete their construction projects. This pressure stems from the large number of highway reconstruction projects and the desire to meet customer expectations through minimizing the inconvenience of the traveling public and impact on affected businesses.

At the present time, there is no comprehensive understanding of:

a) What SHAs are using I/Ds.
b) How the I/Ds are implemented through contract provisions.
c) What criteria are appropriate to consider when applying I/Ds to projects.
d) If I/Ds are cost-effective and fair to all parties.
e) What impacts do I/Ds have on project quality and safety.

The inability to answer the above questions leads to inefficient use of SHA resources through (1) underutilization of I/Ds; (2) added cost to develop, implement, and evaluate specific I/Ds within each state; and (3) misapplications of I/Ds to projects.

This project will ensure that SHA resources are used cost-effectively through the appropriate use of IDs on construction projects.

To obtain the required information to reduce the time to complete construction projects, the following questions should be researched:

a) What SHAs have used I/Ds? What has worked? What has not worked and why?
b) How did the SHAs develop the contract provisions? Was the contracting industry involved?
c) How are projects selected that used I/Ds?
d) How is the value of the I/Ds determined? What is the true cost of the I/Ds (including added SHA cost through overtime, staffing, etc.)?

e) How is it determined that the I/Ds have been earned?
f) What impact do I/Ds have on the quality and safety of the project?

IV. RESEARCH OBJECTIVE

To evaluate of the use of incentives/disincentives (I/Ds) to reduce time to complete highway projects.

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

Task 1: Survey SHAs as to their use of I/Ds.
Task 2: Document via telephone interviews or site visits - contract provisions, criteria for project selection, value of I/Ds, lessons learned, true cost, impact on quality and safety.
Task 3: Prepare guidelines that includes a process for selecting, implementing, and evaluating I/Ds

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $250,000 Duration: 24 months

4.5.2 Analysis of Nighttime Construction Activities and Impacts on Safety, Quality, and Productivity

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Analysis of nighttime construction activities and impacts on safety, quality, and productivity

III. RESEARCH PROBLEM STATEMENT

The aging of state and local roads and highways and the availability of funding by the Intermodal Surface Transportation Efficiency Act 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 be 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 our improper use 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?

IV. RESEARCH OBJECTIVE

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:

Task 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.

Task 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.

Task 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.

Task 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.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $200,000 Duration: 24 months

4.5.3 Expanded Use of Contractor-Performed Quality Control Processes for Acceptance of Highway Projects

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Expanded Use of Contractor-Performed QC Processes for Acceptance of Highway Projects

III. PROBLEM STATEMENT

Total funding under TEA-21 has increased. This has resulted in an increase in the SHA construction program. At the same time, SHA have not hired additional staff to assist in implementing a larger program. In fact, in many states, the total number of staff has decreased.

SHAs are having to answer questions such as: what functions are they in the position to perform, what functions are they going to quit performing, what are the critical functions that cannot be performed by others etc. One area SHAs are attempting to optimize their resources is through the use of contractor-performed test data for quality assurance purposes.

This is a major demand to reduce duplication between SHAs and contractors. This demand is shifting responsibilities and redefining roles between SHAs, contractors, and FHWA. With this change, there are a number of unanswered questions. For example, what are the risks in this change, is it appropriate for SHA to be doing this, who is using contractor data for acceptance, what tests are they using, did it avoid duplication, did SHA achieve the test results they desired, was a verification process used, was the verification process efficient, was it cost effective, was quality compromised, what level of independence is necessary between contractor-performed tests and quality assurance.

This project can reduce duplication, improve efficiencies, and optimize the quality assurance procedures for SHAs through reduced resources and level of effort required.

To determine if this shift of responsibility is appropriate, the following questions should be researched:

a) What SHAs have used contractor data for acceptance? For what products and tests? What has worked? What has not worked and why?
b) What are the quantifiable benefits?
c) What contractor training and certification is necessary?

d) What cultural change is necessary for the SHAs, contractors, and FHWA?
e) What is the true impact on quality?
f) What are the current practices using verification and validation test data for acceptance?
g) How frequently should verification testing be performed?
h) How is the contractor test data and the SHA verification test data compared?
i) How large is the difference between the contractor and SHA to be of concern?
j) How do contract incentives influence the use of contractor-performed data?
k) What would be the appropriate application of incentives in the QC/QA process?
l) What are federal agencies doing to implement contractor test results in the acceptance program?

IV. RESEARCH OBJECTIVE

To evaluate the expanded use of contractor-performed quality control processes for acceptance of highway projects.

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

Task 1: Survey SHA and other federal agencies as to their use of contractor-performed test data for acceptance.
Task 2: Document via telephone interviews or site visits, the practices used in these programs.
Task 3: Conduct 4 detailed case studies to demonstrate the attributes/elements of the program, evaluate the effectiveness.
Task 4: Develop guidelines for contractor-performed tests data for acceptance including suggested products, contractor certification, verification testing, and process to recognize difference between contractor and SHA results.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: \$200,000 Duration: 24 months

4.5.4 Implementation of the Use of New Materials into Highway Construction Practice

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Implementation of the Use of New Materials into Highway Construction Practice

III. RESEARCH PROBLEM STATEMENT

The US infrastructure is experiencing significant deterioration. This deterioration has resulted in significant research programs in testing, evaluation, repair, and development of materials, with the intent of producing more durable, longer lasting infrastructure systems. The performance of a system is only as good as it's weakest link. Construction managers, engineers, and contractors are often reluctant to use new materials due to limited availability of long-term performance data. Past experience of implementing new materials unsuccessfully have resulted in confusing recommendations by researchers and state highway agencies (SHAs). Because there is often a relatively high initial cost, higher risks and unknown long-term performance information associated with the use of such materials, many states are reluctant to take on such a venture. Thus, the implementation of high performance materials is stifled at both the SHA and contractor levels. In addition to the resistance by SHAs and contractors, developers of new infrastructure materials are often unable to implement the use of these materials due the high costs associated with laboratory and field performance testing and long time requirements for the acceptance of such materials by regulatory agencies.

Thus, from a materials research perspective, significant research is underway to develop new materials for infrastructure facilities. There is a continued need to develop these new infrastructure materials, but there is a larger need to develop accelerated test procedures that predict the field performance of new materials. The increased risks and costs associated with implementing the use of these new materials should be overcome by forming partnerships with shared funding and knowledge between various organizations (both public and private). From a construction perspective, there is also a need to determine factors that influence the long-term field performance of newly developed materials.

Factors that influence the performance of a material in the laboratory are often not the same factors that influence the performance of a material in the field. Work is needed to identify and document the current practice in infrastructure construction. Practices that affect the performance of new materials in the field require investigation and documentation to develop the best practice for implementing the use of new materials.

Research should address the following questions:

a) What are the barriers to implementing the use of new materials?
b) What are the current practices of SHAs to specify the use of new materials? What are the benefits/problems of these practices?
c) What are the benefits/problems when using new materials in highway construction?
d) How is construction productivity impacted by the use of new materials?
e) How does the use of new materials impact initial cost and life cycle cost of highway construction projects?

IV. RESEARCH OBJECTIVE

Investigate methodologies to use new materials and the barriers associated with implementing the use of these new materials. The proposed study could potentially be divided into four (4) research projects, each focusing on one of the following material categories: concrete/reinforcement, asphalt, steel, and composites.

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

Task 1: Identify processes for implementing new materials into practice with examples of successful implementation plans.
Task 2: Investigate the tradeoffs between productivity, initial cost, and life cycle cost of construction projects when using new materials.
Task 3: Identify specific issues/problems and benefits related to new construction materials.
Task 4: Develop a framework or methodology to quantify the value of change when implementing the use of a new material.
Task 5: Develop knowledge base for best practices when using non-traditional/new materials.
Task 6: Develop a model that identifies the potential time-savings that results from the implementation of new materials.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $400,000 Duration: 48 months

4.5.5 Innovative Rapid Construction/Reconstruction Methods

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Innovative Rapid Construction/Reconstruction Methods

III. RESEARCH PROBLEM STATEMENT

Highway construction, reconstruction, and maintenance projects can cause significant delays for highway users and may contribute to a financial loss for area businesses and taxpayers. Reducing the construction time of highway projects will minimize the impacts on commuters and commerce. Innovative construction methods, processes, and materials can decrease the construction duration, minimize construction traffic delays, and/or may increase the quality of the constructed facility.

Literature and industry professionals have identified three areas to be investigated to facilitate faster highway reconstruction. The critical areas are asphalt paving reconstruction techniques, Portland Cement Concrete (PCC) pavement and bridge deck reconstruction techniques, and bridge reconstruction and maintenance techniques. Thus, the objective of this research project is to investigate the use of innovative techniques from these three areas that decrease construction schedules.

In the past, it has been common practice to rehabilitate many pavements with a hot-mix asphalt (HMA) overlay, regardless of the pavement condition or type of failure. The HMA overlay was easy, fast, less costly, and usually rode well and maintained a good appearance. Other, more durable and cost-effective solutions include cold in-place recycling (CIR), hot in-place recycling (HIR), and full-depth reclamation (FDR), and others. Different surface preparation techniques have been used prior to placing HMA overlay to minimize reflection cracking. The most common techniques include rubblization, crack and seat or break and seat, and saw and seal. The most comprehensive report and procedure for designing HMA overlays for crack and seat and rubblized pavements was produced by the National Asphalt Pavement Association (NAPA).

Possible methods to rehabilitate PCC pavements are: 1) rubblization; 2) crack and seat; 3) unbonded concrete overlay; and 4) concrete reconstruction. Limited funding and more demand for the use of these funds increases the need for a proper selection of cost-effective rehabilitation strategies for PCC pavements. Additionally, more timely methods to reconvene traffic flows on reconstructed PCC pavements are critical.

Bridge construction is critical during highway construction scheduling. One approach to facilitate faster construction is to implement modular techniques with the use of precast or precast prestressed concrete bridge deck panels that can be used to rehabilitate bridge decks. Modular construction can be used advantageously to reduce construction time, hence, lowering the cost imposed by the rehabilitation process. Modular construction techniques during bridgework can lead to ease of construction and traffic management.

Research should address the following questions:

a) What are the best construction methods to increase the speed of construction of concrete pavements, asphalt pavements, and bridge structures?
b) How is the cost of construction and quality of the constructed facility impacted by a decrease in the project schedule?
c) How do modular construction techniques used in bridge construction/reconstruction/maintenance effect project performance and durability?

IV. RESEARCH OBJECTIVE

Develop knowledge base for best practices of rapid construction methods.

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

Task 1: Identify faster construction methods and processes to minimize the impacts of highway construction on highway users.
Task 2: Investigate the tradeoffs between speed, quality, impacts on highway users, and cost of construction when using innovative methods, materials, and/or processes.
Task 3: Analyze the use of precast modular construction techniques in highway and bridge projects.
Task 4: Identify specific issues/problems related to innovative, rapid construction methods.
Task 5: Develop knowledge base for best practices of rapid construction methods.
Task 6: Identify critical requirements to implement faster construction methods (handbook, training, guides, etc.).

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $300,000 Duration: 36 months

4.5.6 Improve Safety of Public Workers During Highway Reconstruction and Maintenance

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Improve Safety of Public and Workers During Highway Reconstruction and Maintenance.

III. RESEARCH PROBLEM STATEMENT

Highway maintenance, reconstruction, and rehabilitation (MRR) represent a significant safety risk to workers and the traveling public. The management of highway projects must address the safety of workers and highway users. The presence of high-speed traffic in the work-zone introduces a unique risk, making highway construction work more precarious than other types of construction. Highway construction activity has shifted from the construction of new facilities to the MRR of existing facilities. The shift in the type of construction work, plus the increase in number of highway users and vehicle miles traveled, have created an increased opportunity for conflict between road users and construction workers and equipment.

Traffic accidents in construction work-zones are caused by a combination of factors, including driver error, inadequate vision, poor road surface condition, construction obstructions, inadequate traffic control, and improper management of material, equipment, and personnel during construction. Successful work-zone safety management can minimize traffic accidents and, thus, reduce deaths and serious injuries to both the traveling public and highway workers in work-zones. Work-zone safety management consists of three phases: (1) engineering; (2) traffic enforcement; and (3) public awareness. Engineering must include adequate plans, specifications, and designs with special consideration given to work-zone safety. Traffic enforcement of the traveling public by law enforcement personnel can maintain safe driving speeds in the work-zone. Public awareness campaigns can alert road users of the importance of safe speeds and alertness in highway construction work-zones.

Highway MRR activities present different construction safety concerns. Maintenance operations typically move faster than reconstruction, require less time, and occupy less area. Maintenance procedures require alternative safety practices and equipment that are more mobile than methods used for reconstruction projects.

Research should address the following questions:

a) How does construction on existing highways impact the safety of the traveling public? What are the best practices to minimize vehicle accidents in highway work-zones?
b) How does the presence of traffic impact the safety of highway construction workers? What are the best practices to minimize construction accidents in highway work-zones? Most SHAs have procedures to address work-zone safety for their employees. What safety strategies are practiced by contractors?
c) The Manual on Uniform Traffic Control Devices (MUTCD) presents a guideline for determining speed limits on roads free of construction. How are safe speed limits determined and enforced through highway work-zones? What are the most effective methods to determine safe driving speeds in construction zones and how to communicate these speed limit changes to the traveling public?
d) MRR projects can have varying effects on construction safety. Safety practices during maintenance projects differ from procedures during reconstruction activities. What characteristics of MRR activities effect the safety of construction/maintenance workers and the traveling public?
e) Some state agencies use safety records as a qualification to bid on highway projects. Contractors with high (greater than 1) Experience Modification Ratings (EMR) and poor Occupational Safety and Health Administration (OSHA) safety records (e.g. lost workdays, recordable cases) may not bid on highway projects. Does this pre-qualification process improve highway work-zone safety?

IV. RESEARCH OBJECTIVE

Identify best practices and recommend strategies for highway MRR activities to improve the safety of workers and the traveling public in highway work-zones.

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

Task 1: Literature Search –Review past studies on highway work-zone safety.
Task 2: Assess specific factors and characteristics in *maintenance* projects, *rehabilitation* projects, and *reconstruction* projects that impact work-zone safety.
Task 3: Identify best practices and innovative methods to configure highway work-zones to enhance safety.
Task 4: Use case studies of MRR projects to determine which methods and techniques effectively improve work-zone safety.
Task 5: Recommendations – Develop guidelines, based on identified best practices, for consistent work-zone safety planning to include public relations/awareness, scheduling, safe traffic speeds, road closures/detours, construction sequencing, configuring work-zones, utilizing barriers, and optimizing the safety of highway personnel and the traveling public.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $300,000 Duration: 30 months

4.5.7 Alternative Contracting Methods and Delivery Systems to Facilitate Faster Construction/Reconstruction

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Alternative Contracting Methods and Delivery Systems to Facilitate Faster Construction/Reconstruction

III. RESEARCH PROBLEM STATEMENT

State Highway Agencies (SHAs) are continually searching for methods to improve cost, time, and quality in project development and construction of facilities. To address these issues, SHAs must be proactive in pursuing innovative practices when programming and executing projects. One area where many SHAs are encouraging innovation is in construction contracting. Contract time of highway projects is one of the most important aspects of the entire construction process. Not only does it affect areas such as budgeting, resource planning, local economies, and claims issued, but also reasonable contract time may avoid higher bid costs as well as decrease the possibility of disputes between the contractor and the contracting agency.

Project price is important, but the weight assessed to project price has become disproportionately high compared to other necessary product requirements such as timeliness, durability, and quality. SHAs are increasingly aware that projects have costs beyond the direct cost of construction. This is particularly true in highway construction, where first cost has traditionally been the primary concern. Motorist delay and disruption of commerce are real costs to a community and should be considered during project planning. It is frequently in the public's best interest to reduce the time of construction. Additionally, some projects are undertaken in heavy traffic zones causing extreme traffic congestion that negatively impact the business community.

Innovative contracting strategies have many impacts on project considerations such as the allocation of risk and the compatibility with the existing low-bid system. The determination of the best project delivery method depends on the owner's objectives and priorities as to allocations of risks, the functions of the project, the quality of the project, cost and time requirements, and constraints. The process of risk allocation begins when the owner decides on the project delivery methodology. The single decision that will most greatly affect relationships and risk allocation on a construction project is the choice of a contracting strategy. The existing, low-bid, design-bid-build system has resulted in quality projects when the work is well defined and is constructed by capable, experienced contractors and has eliminated favoritism in procurement. However, the design-bid-build contracting method may not be the best method in all cases.

Research should address the following questions:

a) How have innovative contracting strategies (including A+B bidding, lane rental, incentive/disincentive provisions, and design build) been implemented on highway projects? What characteristics of the projects or management practices influenced the success of the innovative contracting method?
b) How does the use of an innovative contracting method effect project cost, schedule, and the quality of the constructed facility?
c) How does the use of an innovative contracting method effect construction speed and/or mitigate the impacts on the traveling public?
d) How does the use of an innovative contracting method impact the traditional low-bid system and/or competition between contractors?

IV. RESEARCH OBJECTIVE

Develop a method to aid in the selection of alternative contracting strategies to mitigate the impacts on the traveling public.

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

Task 1: Literature Search – Conduct a comprehensive analysis of past studies on alternative, innovative highway contracting strategies.
Task 2: Review of Current Practice – Evaluate successes/failures of innovative contracting methods on past projects (emergency and non-emergency projects) including impacts on schedule, cost, quality, competition, and the highway users.
Task 3: Identify key drivers for using different contracting methods
Task 4: Investigate the compatibility between innovative contracting strategies (non-traditional) and the traditional, low-bid competitive system from both the owner and contractor perspectives.
Task 5: Assess impacts on SHA stakeholders' culture, risk, and responsibility.
Task 6: Investigate decisions support approaches i.e., types of tools and identify best approach.
Task 7: Develop a quantitative method to select the most efficient and economical contracting strategy based on known specific project factors, characteristics, sizes, complexities, owner objectives, and constraints.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $300,000 Duration: 36 months

4.5.8 Impact of Strategies to Manage Traffic During Highway Construction Projects on Construction Methods, Productivity, Schedule and Quality

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Impacts of Strategies to Manage Traffic During Highway Projects on Construction Methods, Productivity, Schedule, and Quality

III. RESEARCH PROBLEM STATEMENT

The aging of state and local roads and interstate highways and a higher level of funding through the Transportation Equity Act for the 21st Century have increased the number of major highway rehabilitation and reconstruction projects. Large highway reconstruction projects can cause significant disruptions to existing travel patterns and economic activity. Reducing the impacts on highway users and businesses requires that innovative and effective transportation management actions be developed and implemented. Reconstruction activities could be expedited by closing a facility, but in many situations, the remaining transportation network would not be able to accommodate the redirected traffic volumes. Traffic management plan developed during design must reach an acceptable balance between: 1) maximizing the safety and efficiency of the rehabilitation and reconstruction activity; and 2) minimizing the impacts on highway users and businesses.

Research should address the following questions:

a) What are the best practices to manage traffic during highway construction projects?
b) What are the impacts of a traffic management plan on project cost, schedule, quality, and safety?
c) How do innovative contracting methods effect existing traffic management strategies?
d) What are current methods to allocate more traffic management flexibility to the contractor? How does this increase in flexibility effect risk and responsibility for road user cost and safety? What language is effective in project specifications and contracts to accurately describe the level of flexibility and allocation of risk and responsibility for traffic management?

IV. RESEARCH OBJECTIVE

Study of best practices and guidelines to produce a synthesis of methods to manage traffic during highway construction projects.

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

Task 1: Literature Search – Conduct a review of past studies on traffic management during highway rehabilitation and reconstruction operations.
Task 2: Identify current practices and innovative methods to manage traffic during highway construction projects.
Task 3: Identify benefits, costs, and risks to highway agencies, contractors, and the traveling public.
Task 4: Study the use of innovative contracting methods (including A+B bidding, lane rental, and incentives/disincentives) and the impact on traffic management.
Task 5: Evaluate the influences of traffic management on construction cost, productivity, schedule, and quality.
Task 6: Study the impact of permitting more flexibility of traffic management methods to the contractor.
Task 7: Develop a set of strategies that recommends traffic-management best practices for highway construction projects with different characteristics.
Task 8: Final Report – Create a document that summarizes the information gathered in the review of industry best practices and presents recommended traffic-management strategies. The report should outline current traffic management practices and the effects on construction methods. Additionally, future research should also be recommended.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $250,000 Duration: 30 months

4.5.9 Recruiting, Promoting, and Retaining Qualified Personnel in Highway Construction

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Recruiting, Retaining, and Promoting Qualified Personnel in Highway Construction.

III. RESEARCH PROBLEM STATEMENT

Recruiting and retaining employees in the highway industry is a critical issue. Smart, ambitious, and highly motivated employees are difficult to keep. Attracting and retaining these people is a challenge. Qualified personnel have to be compensated well and require work that develops their skills and matches their personal interests. Since technical employees require challenging and rewarding work, a slightly different plan must be employed to successfully recruit and retain these workers. Some key factors that aid the recruiting of outstanding technical people are salary, benefits, the organization's reputation, and rewarding work.

The purpose of recruiting is to ensure a sufficient pool of applicants from which the most qualified individual may be selected. Successful recruiting can minimize the employee turnover rate. Therefore, most of the focus of previous research is on recruiting methods.

In general, state highway agencies (SHAs) are unable to offer employees the same pay scales and benefits as private companies. Also, many public agencies struggle to maintain technical career paths that reward and support the development and retention of staff with valuable specific skill areas. As a result, SHAs tend to have a low personnel retention rate as many state employees, with experience in hand, accept higher paying positions with private engineering/contracting firms. The demand of transportation construction, reconstruction, and maintenance work is increasing and thus, the demand for quality personnel throughout the industry is critical. Experts in industry indicate that many personnel have shifted from public employment to private employment and the demand for hiring and retaining new technical personnel falls more heavily on SHAs.

Research should address the following questions:

b) What are the best practices employed by SHAs and private organizations to recruit qualified employees?
c) What are the best methods to advertise for openings in different positions?
d) What are the best practices to retain qualified employees?

e) What institutional barriers exist within SHAs that limit recruiting and retaining employees?
f) What role does human resources play in the recruitment process?

IV. RESEARCH OBJECTIVE

Identify best practices and recommend strategies for recruiting and retaining qualified personnel in highway construction.

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

Task1: Literature Search – Investigate documented methods to successfully recruit and retain employees in highway construction and in other industries.
Task 2: Review of Current Practice –Identify best practices and methods used by highway agencies and private companies to recruit and retain qualified personnel in highway construction and in other industries.
Task 3: Identify Institutional Barriers –Describe barriers that exist and could be revised to enhance an agency's ability to recruit and retain valuable staff.
Task 4: Identify the Need –Investigate methods to quantify a need for human resources in state agencies to effectively recruit employees.
Task 5: Recommendations – Recommend methods, based on identified best practices, to recruit and retain personnel.
Task 6: Final Report –Document findings and recommended best practices in a final report.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $200,000 Duration: 24 months

4.5.10 Implementation and Evaluation of Performance-Related Specifications for Highway Construction

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Implementation and Evaluation of Performance-Related Specifications for Highway Construction

III. RESEARCH PROBLEM STATEMENT

Roads and bridges represent a very substantial portion of the public's investment in infrastructure. It is essential that this investment be preserved through cost-effective planning, design, and maintenance. One way of achieving this is through the use of long-term performance-related specifications (PRS).

Under quality assurance (QA) specifications, the contractor is responsible for quality control (QC) and the agency is responsible for acceptance. QA specifications have been evolving since they were first introduced in the 1960's. While the need to make QA specifications truly performance-related has always existed, only recently have research advances made the development of performance-related QA specifications possible.

Performance-related QA specifications use performance and life cycle cost models to specify the desired materials and construction quality, and measure the acceptability of the as-constructed product. A framework for performance-related specifications (PRS) has been established, and sufficient research into performance models has been completed to allow development of initial PRS for jointed plain concrete pavement (JPCP) construction/reconstruction. More research is still needed in hot mix asphalt (HMA) performance models for new construction. Virtually no research has been completed for the remaining major types of construction (continuously reinforced concrete pavement (CRCP), concrete overlays, HMA overlays, structures, soils, etc.)

Use of PRS may lower life cycle cost (LCC) of pavements and structures. PRS performance models can also be used within a warranty specification setting, or within other alternative contracting settings (such as LCC contracting). For maximum benefit to be obtained under PRS, an organized approach covering several facets is necessary – research, specification development, implementation, evaluation, education/training, and marketing.

This project will build upon past studies and will effectively evaluate the use of, and create a program to implement PRS for highway construction.

To obtain the required information the following areas should be researched:

a) What is the current use of PRS and how their use impacts a project in terms of time, cost, and quality?
b) What types of project components, i.e., pavements, bridges, etc., will benefit from the use of PRS?
c) What guidance is being provided to contractors for bidding and working under PRS so as to minimize life-cycle costs?
d) What is the current training/education needs of SHA and contractor personnel to implement PRS?
e) What performance models and criteria are available
f) What are the current methods to develop PRS and guidance to SHAs for writing effective PRS.

IV. RESEARCH OBJECTIVE

To evaluate the use of and create an implementation program for PRS in highway construction that makes use of past experience lessons learned.

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

Task 1: Survey SHAs concerning their current use of PRS.
Task 2: Perform a literature search to identify and evaluate the use of PRS within the entire construction industry.
Task 3: Determine areas where PRS are needed or are in need of updating.
Task 4: Develop an updated model PRS.
Task 5: Create a guide to aid in the development and implementation of PRS for SHAs.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $300,000 Duration: 30 months

4.5.11 Identification, Evaluation, and Implementation of Rapid Test Methods and Non-Destructive Testing to Assess Quality in Construction Process

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Identification, Evaluation, and Implementation of Rapid Test Methods and Non-Destructive Testing to Assess Quality in Construction Process

III. RESEARCH PROBLEM STATEMENT

With the need to build better highways faster, comes to need to achieve quality control and quality assurance faster. One way to accomplish this is through non-destructive testing and rapid test methods. A 'rapid' test method is one that is expected to provide a measurement in less time than the customary method used for such purposes. Such methods will allow the construction process to continue while testing is being completed or at least not stop construction for a long period of time.

According to the current research, there are many procedures under development and experimentation. SHA personnel need to have access to information such as availability and reliability of new tests, access to the equipment, costs for training personnel to conduct the tests, and methods to analyze the data collected from new testing procedures.

SHA construction engineers and managers must be able to evaluate the suitability of a test for their project, and be able to implement it within construction. At the same time, they must also be able to decrease the overall time of their project and increase the quality of the overall project.

Upon completion of this project, SHA personnel will have a comprehensive quality testing resource guide that concentrates on rapid test methods and non-destructive test methods to aid SHA personnel in ensuring quality transportation construction projects.

To obtain the required understanding, the following should be researched:

a) Current non-destructive and rapid test methods used in practice
b) Cost/time savings versus quality tradeoff of the results of the identified test methods
c) Creation of a best practices guide for SHA personnel that displays the available non-destructive and rapid test methods

d) Where the needs are for new or improved non-destructive and rapid test methods

IV. RESEARCH OBJECTIVE

Develop a comprehensive quality testing resource guide that concentrates on rapid test methods and non-destructive test methods.

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

Task 1: Survey SHAs concerning their current use of rapid test and non-destructive test methods.
Task 2: Perform a literature search to identify and evaluate the construction industry's use of rapid test and non-destructive test methods.
Task 3: Create a guide with the ability for frequent updating to advise SHA personnel on the cost and reliability of test methods for their project.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $250,000 Duration: 24 months

4.5.12 Training and Workforce Development of SHA Personnel

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Training and Workforce Development of SHA personnel

III. RESEARCH PROBLEM STATEMENT

Today's market demands efficiency, quickness, and high quality. With the retirement of the experienced SHA workforce and exodus of SHA personnel into the private sector, opportunities are available for the advancement of young, sometimes inexperienced personnel. These SHA personnel must have the necessary skills to perform their job efficiently and effectively.

At the current time, training programs are available for new SHA personnel. However, these training programs vary from SHA to SHA. A synthesis of the existing training programs may be helpful in identifying the need for additional training and education programs. This can thus allow all incoming SHA personnel the necessary training for their position.

Mentoring can be a valuable training tool if performed correctly. An effective mentoring program can pass on priceless knowledge to younger engineers that may be lost in a with the retirement of experienced personnel. Mentoring can also help each employee understand the 'big picture' and where they fit into that picture.

Training programs are typically offered throughout a SHA personnel's career. Nevertheless, project time constraints, monetary resources, and geographic location tend to limit or inhibit SHA personnel from participating in these programs. This can greatly reduce the positive professional impact a person can have at their position.

SHA personnel career paths are evolving and diversifying. Many new demands are placed on SHAs. A technical career path, along with or instead of, a managerial career path could reduce stress on SHA personnel. Certifying and training SHA personnel on the technical aspects of construction could not only improve, but also improve the industry.

The paths of private and public agencies are crossing more and more. Certain SHA responsibilities are being outsourced to the private sector; SHAs and private companies are calling upon the expertise of consultants to augment their programs. A well-developed training program can benefit all parties involved in the construction industry. Bringing together the different sectors to share knowledge can facilitate lasting partnerships between all industries.

With the age of technology comes an increasing use of computers. Computer software is being developed that can reduce the time and effort to produce design documents and can also be used to create project management tools. Personnel first need to have the knowledge to use them and then to be able to apply this knowledge.

This project will update and build on past NCHRP studies and provide an effective and efficient training and workforce development program.

To obtain the required information to develop or modify an existing program, the following areas should be researched:

b) What are the current training programs used by SHAs related to Construction Engineering and Management (CEM)
c) What are the necessary CEM skills for SHA personnel
d) What is the value of the use of mentoring programs as a training tool
e) Evaluate how the necessary CEM skills relate to the managerial career path, for example, what skills are needed at what level of career?
f) Is the use of technical career paths a possible career path for SHA CEM personnel
g) What are the available innovative model training programs which are designed to overcome traditional institutional barriers (limited time, out-of-state travel, funding)
h) What are the current opportunities and procedures used to create partnerships between SHAs, contractors, and consultants with respect to standardize training

IV. RESEARCH OBJECTIVE

Develop a comprehensive training and workforce development program that builds on the SHA programs of the past.

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

Task 1: Survey SHAs concerning their current training programs for both incoming and experienced CEM personnel.
Task 2: Identify and evaluate the past training programs for their efficiency and effectiveness.
Task 3: Determine new models and tools that should be created to aid in training and workforce development.
Task 4: Create a training and workforce development program model that can be used as a guide by all SHAs.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $250,000 Duration: 24 months

4.5.13 Constructibility Review Process Implementation Plan

I. PROBLEM NUMBER

Problem number

II. PROBLEM TITLE

Constructibility Review Process Implementation Plan

III. RESEARCH PROBLEM STATEMENT

Constructibility reviews of highway projects during the planning and design stages have the potential to minimize the number and magnitude of changes, disputes, cost overruns, and delays during construction. Cost savings determined in a study conducted by the Arizona Department of Transportation estimated that improvements made possible by a constructability review process resulted in savings of $68 million on six projects at a cost of only $1.2 million. The cost of the review effort resulted in a benefit to cost ratio of 25 to 1. Thus, for every dollar spent reviewing these projects for constructability, $25 was returned in savings.

Constructibility is defined as the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives. Constructibility is the integrating of construction knowledge, resources, technology, and experience into the engineering and design of a project. The end result should be enhanced plans and specifications for constructibility leading to increased ease and efficiency of construction, with fewer changes.

An effective constructibility review process can decrease project duration, decrease the quantity of changes, and improve the quality of the constructed facility. Despite the possible benefits of project constructibility analysis, only 23% of state highway agencies (SHAs) use a formal constructibility process. Several factors limit the implementation of a formal process including a lack of construction experience in design personnel, inadequate communication between construction and design personnel, and the absence of a record of past construction changes.

Research should address the following questions:

a) What are the benefits of a formal constructibility review?
b) What are the barriers to implement an effective constructibility review? What are successful methods to overcome these barriers?
c) What are the necessary steps to follow to conduct a successful constructibility analysis that produces a better design and facilitates the construction phase? Who should perform these analyses?
d) What is a sufficient level of analysis for different types of highway projects?

IV. RESEARCH OBJECTIVE

Identify best practices and recommend strategies for conducting a formal constructibility review and design an implementation plan for SHAs.

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

Task 1: Literature Search – Conduct a literature search to review past studies on the constructability review of highway facilities.
Task 2: Review of Current Practice – Study the results of projects, successes and failures, that have used a formalized constructability review process (CRP), document the benefits, and indicate where a CRP has not been implemented successfully.
Task 3: Identify methods to overcome implementation barriers of a CRP such as lack of time, competition between contractors, cost, and SHA resources to successfully implement a formal CRP.
Task 4: Recommendations – Develop guidelines for highway agencies to implement a formal constructability review. The implementation plan must consider the barriers identified by the review of current practice. The plan should include the following: a) Identify different levels of constructability analysis and application for each; b) Determine what constitutes a sufficient level of constructability analysis; c) Outline the steps to follow (possibly a checklist format) to implement a CRP; and d) Provide examples based on different levels of analysis for various types of work.
Task 5: Conduct workshops to train agency staff to use the implementation plan and a formal CRP.
Task 6: Final Report

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $250,000 Duration: 24 months

4.5.14 Determination of Strategies to Manage the Reduced Staff Size and Increased Workload of SHA Personnel

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Determination of Strategies to Manage the Reduced Staff Size and Increased Workload of SHA Personnel

III. RESEARCH PROBLEM STATEMENT

Experienced SHA personnel are retiring. The private sector is competing for college graduates and experienced personnel. At the same time, highways are in need of maintenance and reconstruction and new highways are being built.

These facts bring the question –how are the SHAs supposed to manage and execute with an ever-increasing workload with their reduced staff size?

There are at least three possible answers to this question: (1) hire more SHA personnel; (2) create more efficiency in the workplace; and (3) contract out functions once performed by SHA personnel.

In order to hire more personnel, funding needs to be allocated for competitive salaries and benefits. Once the funding is available, recruitment of employees must begin. Finally, once new employees are hired, training programs need to be in place to adequately train the new personnel.

Contracting out functions such as design and inspection creates administrative tasks. This approach also raises questions such as: (1) will the quality of the projects be reduced; (2) will SHA personnel be willing to give up the control they once had; and (3) will the cost of a project increase due to third party design and inspection?

Several projects have been performed by NCHRP that concern the use of out-sourcing as an alternative. This research project will build upon those studies and add additional alternative methods to create a comprehensive program that will aid SHA personnel.

To obtain the required information, the following areas should be researched:

a. What are the current ways SHAs and others are approaching the problem of increased workload with reduced CEM staff size?

b. What is the value of the use of outsourcing versus more efficient use of in-house resources?
c. What decision support tools are currently available for SHA personnel use to assess outsourcing of CEM processes versus work retained in-house versus other alternatives?
d. What are new strategies to address reduced staff size with increased workload and what is their effectiveness?

IV. RESEARCH OBJECTIVE

Determine strategies to offset the reduced staff size with the increased workload of SHA personnel.

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

Task 1: Survey SHAs to identify current practices used to manage reduced staff size and increased workload.
Task 2: Perform a literature search to identify and evaluate the methods SHAs and others within the construction industry are utilizing to handle this problem.
Task 3: Identify and evaluate new techniques that may be employed by SHA CEM personnel.
Task 4: Develop a decision support tool to assist SHA in determining which strategy to use.
Task 5: Create a comprehensive best practices guide that includes all strategies that can be exercised by SHA CEM personnel for the purpose of managing the increased workload with a reduced staff size.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $200,000 Duration: 24 months

4.5.15 Identification, Evaluation, and Implementation of Performance-Related Acceptance Tests

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Identification, Evaluation, and Implementation of Performance-Related Acceptance Tests

III. RESEARCH PROBLEM STATEMENT

To predict performance, suitable acceptance tests need to be identified and developed. These tests should provide adequate evidence that a construction product will or will not meet its design needs. Some currently used acceptance tests are performance-related and suitable. Other acceptance tests need to be revised and improved to better correlate with performance. In some cases, new acceptance tests will need to be developed.

Acceptance tests should, where possible, be rapid, timely (performed soon after construction), be insitu, nondestructive, provide full coverage (as opposed to testing a small sample), measure fundamental engineering properties, and have low sampling and testing error. To insure reliable test results, improvements to equipment, sampling, testing and analysis methods need to be considered.

In some cases, a test correlation to performance may not be adequate when the test is performed immediately after construction. The test may be more suitable (more indicative of performance) when conducted years after construction, as part of warranty specifications. Such tests also need to be identified and developed.

With the reduction of available SHA personnel, more responsibility of testing a construction product is being transferred to the contracting agencies. At this time many people do not believe the contractors have the resources and experience to test the products. Some are also concerned about placing the contractor in a position of compromise if their test results do not meet the acceptable criteria.

This project will build on past studies to provide a comprehensive summary of the evaluation and implementation of performance-related acceptance tests.

To obtain the required information, the following areas should be researched:

b) What is the current use of performance-related acceptance tests?
c) What properties are needed to predict performance?
d) What are the performance-related tests that need to be developed?
e) Are there uniform testing procedures for those determined from above?
f) What is the cost-effectiveness and needed level of acceptance testing?
g) What are the institutional barriers to implementation?

IV. RESEARCH OBJECTIVE

Evaluate performance-related acceptance tests and create an implementation program to increase their use.

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

Task 1: Survey SHAs to assess their current use of performance-related acceptance tests.
Task 2: Perform a literature search to identify and evaluate the current use of performance-related acceptance tests within the entire construction industry.
Task 3: Identify areas in which new performance-related acceptance tests need to be developed.
Task 4: Create a best practices guide to aid SHA personnel on how to use and implement performance-related acceptance tests for their specific projects.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: \$200,000 Duration: 24 months

4.5.16 Best Practices for Community Outreach During Construction

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Best Practices for Community Outreach and Involvement During Construction

III. RESEARCH PROBLEM STATEMENT

Any construction project, no matter the size, will affect a community in some way. Projects that SHAs develop, design, and construct affect the people in surrounding communities. People not only travel on roads built by SHAs, but they also pay for the roads through their taxes. Because of this, community residents and leaders desire to have a say or, at the very least, be kept informed about how the physical attributes of their community are going to be affected.

There is a need to identify different ways in which SHA personnel can obtain and utilize community input to help coordinate construction. However, obtaining public acceptance and support for construction projects can present difficult challenges.

Programs to facilitate cooperation between the community and the SHA could be very beneficial and help create more successful construction projects. Various states have enacted public relation programs to help keep the community informed about the current and future construction projects. However, not every state has a program. Also, states may not be aware of the other states' programs.

This project will build on previous NCHRP projects and present a comprehensive best practices guide to assist SHA personnel in community outreach throughout construction projects.

To obtain the required information, the following areas should be researched:

b) Public perceptions regarding impact of construction on motorists and businesses.
c) Current community involvement programs
d) Benefits of having a public involvement program versus the cost of the program.
e) Uniform methods for SHAs to use to obtain public feedback on agency construction programs on a regular basis.
f) Best practices for community outreach and involvement during construction.

IV. RESEARCH OBJECTIVE

Develop a best practices guide for community outreach and involvement during construction.

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

Task 1: Survey SHAs concerning present practices of community involvement and outreach.
Task 2: Survey a statistically sound sampling of the public regarding perceptions on construction and the current SHA community outreach programs.
Task 3: Perform a literature search to identify and evaluate community involvement and outreach programs used by the entire construction industry.
Task 4: Develop new community outreach and involvement programs that integrate public perception.
Task 5: Perform case studies to evaluate the different programs.
Task 6: Create a best practices guide to be used by SHA personnel to facilitate useful community outreach and involvement.

V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: $300,000 Duration: 30 months

4.5.17 Best Practices for Managing Environmental Restrictions and Requirements

I. PROBLEM NUMBER

Problem Number

II. PROBLEM TITLE

Best Practices for Managing Environmental Restrictions and Requirements

III. RESEARCH PROBLEM STATEMENT

Today, now more than ever, the environment plays a key role in everyday activities. Some cities have smog warnings, some have water pollution warnings, and others focus on vehicle emissions. In order to reduce these and other warnings and increase the health of the general public, regulatory agencies are enacting limitations.

Along with warnings, there are environmental practices in place that prevent other harms to the environment. These practices employ restrictions and regulations on activities carried out in a particular location. Construction is one practice that now requires many different permits for any given location.

Construction project managers are willing to comply with environmental restrictions. However, it can be difficult at times. The rules and types of permits required seem to change frequently. The costs to comply are also increasing, which in turn increases the cost of the project.

Construction engineers and managers need to have an effective way to manage all the different permitting requirements and restrictive regulations. The management should include cost saving compliance options.

This research project will build on previous NCHRP projects and provide a comprehensive best practices guide to assist SHA construction engineers and managers in managing environmental restrictions and requirements.

To obtain the required information, the following areas should be researched:

a) What is the impact on SHA CEMs with respect to the current and impending regulations of noise, air, storm water management?
b) What are the current programs available to SHA CEMS that focus on compliance of environmental regulations?
c) Are there programs to facilitate the communication of environmental decisions that were made in pre-construction planning/permitting stage to the construction team?

d) What other programs or areas of study are needed that will aid the SHA CEMs in compliance of environmental regulation?

IV. RESEARCH OBJECTIVE

Develop a best practices guide for managing environmental restrictions and requirements.

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

Task 1: Survey SHAs concerning present plans for compliance with environmental restrictions and regulations.
Task 2: Perform a literature search to identify and evaluate how the entire construction industry is managing environmental restrictions and regulations.
Task 3: Identify and create compliance programs in areas in which they are needed.
Task 4: Create a best practices guide, with the ability for regular updating, that facilitates the management of environmental regulations and restrictions with respect to construction.

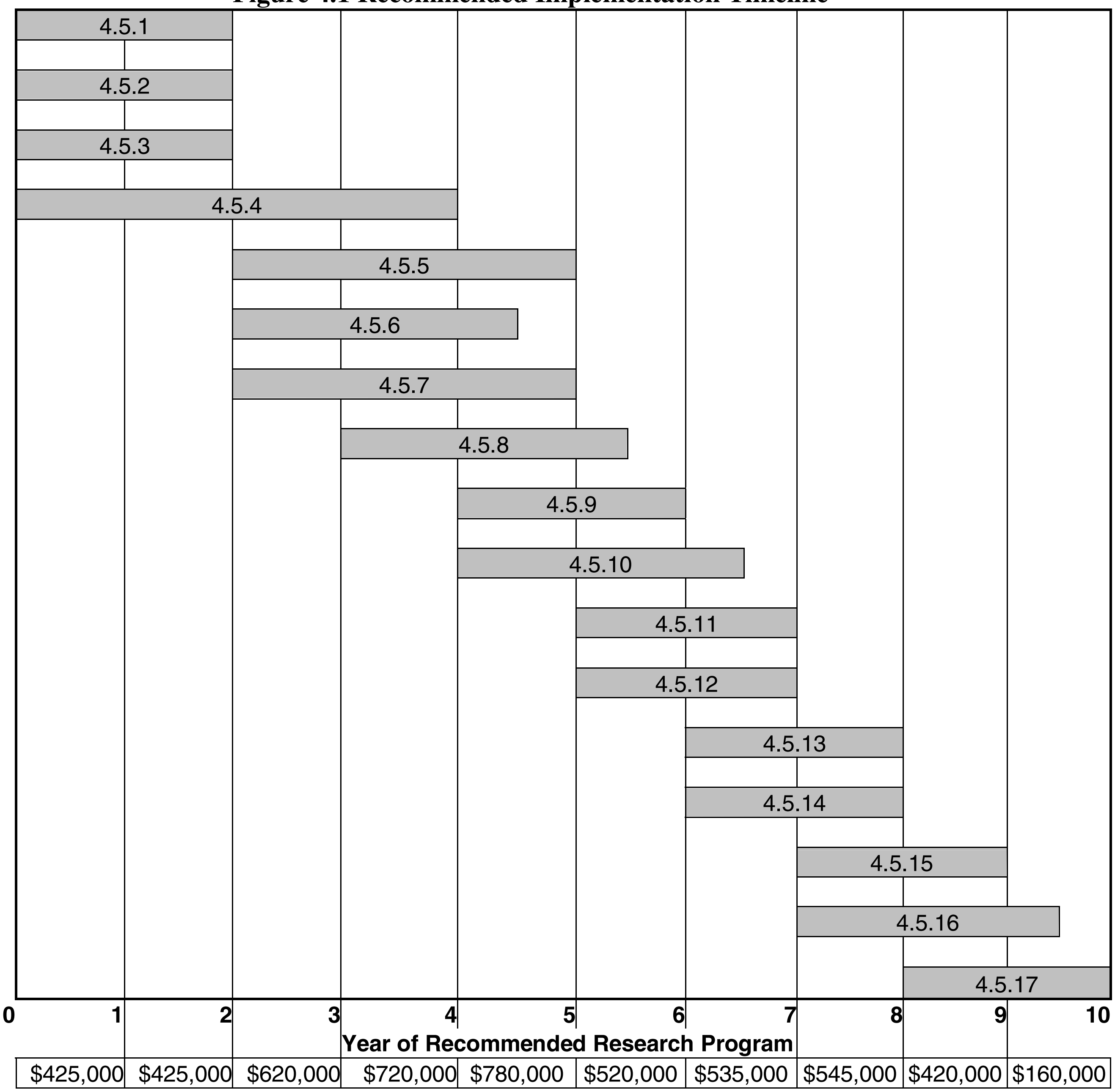
V. ESTIMATE OF PROBLEM FUNDING AND RESEARCH PERIOD

Cost: \$200,000 Duration: 24 months

4.6 Implementation Timeline

Figure 4.1 illustrates a timeline for the recommended research program. It was developed based upon the estimated duration and cost of each project and the final priority based on Table 4.1. The timeline values correspond to the research project section number (e.g. section 4.5.1, Evaluation of the Use of I/Ds to Reduce Time to Complete Highway Projects). The cost per year is displayed at the bottom of the figure. The recommended research program will span approximately 10 years.

Figure 4.1 Recommended Implementation Timeline



4.7 Chapter Summary

This chapter summarized the approach to develop the recommended research program and the implementation plan. A detailed recommended research program was then presented.

References

Improve safety of public and workers during highway reconstruction and maintenance

"Caltrans Fact Sheet: Highway Worker Safety" (http://www.dot.ca.gov/hq/paffairs/about/safety.htm)

"Construction Safety Enhanced by Quick-Change Barrier Blades." (1998). *Engineering News Record*, 240(26), H-16.

"Keeping Traffic Moving – and Workers Safe." (1996). *Public Works*, 127(9), 44-45.

"MDOT – Give 'em a Brake!!" (http://www.mdot.state.mi.us/more/brake.htm)

"NDOT Motorist Information: Give' Em A Brake" (http://www.nevadadot.com/motorist/roads/gbrake.html)

"New Work Zone Safety Campaign Unveiled." (http://www.ink.org/public/kdot/pubinfo/98-098.html)

"Speed bumps can control work-zone speed." (2000). *Better Roads*, 70(2), 18.

"The 11 best ways to improve work zone safety." (1990). *Better Roads*, 60(7), 20-23.

"Washington State Department of Transportation 'Give 'em a Brake' – Bulletins" (http://www.wsdot.gov/brake/content/bulletin/htm.)

"Water-filled barrier provides work-zone safety." (1993). *Better Roads*, 63(1), 13-14.

"Work Site Safety Procedures Review – Report to the Legislature." (1991). California Department of Transportation, Sacramento, CA.

"Work zone programs make road work safer." (1993). *Engineering News Record*, 231(10), 22.

"Work Zone Safety ~ Give 'Em a Brake." (http://www.odot.state.us/region1/f_safety/october.htm)

Andrew, L.B , Bryden, J.E. (1997). "Managing Construction Safety and Health – Experience of New York State Department of Transportation." *Transportation Research Record*, 1585, 9-18.

Benekohal, R.H. (1997). *Traffic Congestion and Traffic Safety in the 21st Century*. ASCE, New York, NY.

Brackett, Q., Stuart, M., Carnahan, T., Stealy, S. (1985). "Protection of Personnel in Maintenance and Construction Zones." Report No. FHWA/TX-86/01+330-1, Texas Transportation Institute, College Station, TX.

Bryden, J.E., Andrew, L.B. (1999). "Serious and Fatal Injuries to Workers on Highway Construction Projects." *Transportation Research Record*, 1657, 42-47.

Ellison, B.F. (1988). "Give Us A Brake! – Highway Maintenance And Construction Can Be High Risk Occupations." *Drive*, Spring, 8-10.

Evans, M.H. (1990). "Highway construction site safety." *Highways and Transportation*, 37(11), 26-30.

Gent, S. (1998). "Iowa DOT uses 'smart work zone' to increase safety." *APWA Reporter*, 65(7), 4-5.

Ha, T., Nemeth, Z.A. (1995). "Detailed Study of Accident Experience in Construction and Maintenance Zones." *Transportation Research Record*, 1509, 38-45.

Hall, J.W., Lorenz, V.M. (1989). "Characteristics of Construction-Zone Accidents." *Transportation Research Record*, 1230, 20-27.

Hombuger, W.S. (1989). "Traffic Control in Construction Zones with Nighttime Activities." Research Report UCB-ITS-RR-89-10, Institute of Transportation Studies, University of California, Berkeley.

Ingram, J. (1993). "Construction Zones: Give Them a Brake." *Overdrive*, 33(12), 24-25.

Ivey, D.L., Mak, K.K., Cooner, H.D., Marek, M.A. (1988). "Safety in Construction Zones Where Pavement Edges and Dropoffs Exist." *Transportation Research Record*, 1163, 43-59.

Krizan, W.G. (2000). "Construction Declares War on Highway Work Zone Carnage." *Engineering News Record*, 244(23), 36-41.

Lasek, J.J. (1993). "Major FHWA initiatives underway for safety." *Roads & Bridges*, 31(7), 34-35.

MacCollum, D.V. (1995). *Construction Safety Planning*. Van Nostrand Reinhold, New York, NY.

McKain (1996). "A Tough Place to Work." *Focus on Hot Mix Asphalt Technology*, 1(4), 18-19.

Migletz, J., Graham, J.L., Anderson, I.B., Harwood, D.W., Bauer, K.M. (1999). "Work Zone Speed Limit Procedure." *Transportation Research Record*, 1657, 24-30.

Noel, E.C., Dudek, C.L., Pendleton, O.J., Sabra, Z.A. (1988). "Speed Control Through Freeway Work Zones: Techniques Evaluation, *Transportation Research Record*, 1163, 31-42.

Pietrucha, M.T. (1995). "Human Factor Issues Related to Work Zone Safety." *Transportation Builder*, 7(5), 40-42.

Trujillo, E., Allison, B.T., and Frank, B. (1995). "Effectiveness of Accelerating Highway Rehabilitation in Urban Areas." *Report No. SWUTC/95/60058-1*, Southwest Region University Transportation Center, College Station, TX.

Ward, W.V., and McCullough, B.F. (1993). "Mitigating the Effects of Urban Highway Construction." *Research No. FHWA/TX-95+1227-1*, Texas Department of Transportation, Austin, TX.

Develop and evaluate new construction methods, processes, and materials to facilitate faster construction

Baumgartner, C.A., Ishmael, K.D. (1993). "Hassel-Free Bridge Rehab." *Civil Engineering*, 63(9), 44-47.

Bemanian, S., Sebaaly, P. (1999). "Cost-Effective Rehabilitation of Portland Cement Concrete Pavement in Nevada." *Transportation Research Record*, 1684, 156-164.

Civil Engineering Research Foundation (CERF) (1994). "Materials for Tomorrow's Infrastructure: Executive Report: A Ten Year Plan for Deploying High Performance Construction Materials and Systems." *Report No. 94-5011E*, Washington DC.

Federal Highway Administration (FHWA) (1998). "Assessing the Results of the Strategic Highway Research Program." *Report Number FHWA-SA-98-008*. Washington, DC.

Grippo, G.J. (1995). "Bridge Repair on the Fast Track." *Civil Engineering*, 65(2), 64-66.

Hakim, B.A., Jennison, C.W. (1999). "Concrete Pavement Strengthening Using Crack and Seat." *Highways and Transportation*, 46(10), 20-22.

Illingworth, J.R. (2000). *Construction Methods and Planning*. E & FN Spon, New York.

"Innovative Contracting Practices." *Transportation Research Circular*, 386, Transportation Research Board, National Research Council, Washington, DC.

Issa, M.A., Yousif, A.A., Issa, M.A. (1995). "Construction Procedures for Rapid Replacement of Bridge Decks." *Concrete International*, 17(2), 49-52.

Kearney, E.J., Huffman, J.E. (1999). "Full-Depth Reclamation Process." *Transportation Research Record*, 1684, 203-209.

Krammes, R.A. (1990). "Travel Impact Evaluation for Major Highway Reconstruction Projects." *Journal of Transportation Engineering*, 116(1), 64-80.

Lane, S., Munley, E., Wright, W., Simon, M., Cooper, J.D., (1996). "High-Performance Materials: A Step Toward Sustainable Transportation." US-European Workshop, July 1996, Barcelona, Spain.

"Life Cycle Costing to Select Longer Lasting Materials and Products." (2000). <http://www.fhwa.dot.gov//////quality/HP-OH5.htm> (Dec. 13, 2000).

Muller, J.M. (1993). "Bridge to the Future." *Civil Engineering*, 63(1), 40-43.

National Institute of Standards and Technology Building and Fire Research Laboratory (2000). Introduction to High-Performance Construction Materials and Systems, <http://www.nist.gov> (Nov. 2000).

O'Connor, J.T., El-Diraby, T.E. (2000). "Urban Freeway Bridge Reconstruction Planning: Case of Mockingbird Bridge." *Journal of Construction Engineering and Management*, 126(1), 61-67.

Parks, D.M., Reis, R. (1997). "In-Service Performance of Epoxy Coated Steel Reinforcement in Bridge Decks." Report No. FHWA/CA/TL-96/01-MINOR, California Department of Transportation, Sacramento.

Risser, B., Johnston, M. (1996). "Tips for Reconstructing Concrete Intersections." *Aberdeen's Concrete Construction*, 41(2), 160-164.

Sharp, K.G., Johnson-Clarke, J.R., Fossey, D.W., Chitty, M.C., Shackel, B. (1998). "ALF Trials on Alternative Modular Paving Arrangements." *Road and Transport Research*, 7(4), 75-76.

Thirumali, K., (1998). "Transportation Infrastructure Needs and Opportunities." Workshop on Materials for the Infrastructure, Report No. 98-1, Institute for Mechanics and Materials, La Jolla, CA, April 1-3, 1998.

"Train Method of Construction." (2000). <http://www.fhwa.dot.gov//////quality/HP-FL2.htm> (Dec. 13, 2000).

Weyers, R.E., Sprinkel, M.M., Pyc, W., Zemajtis, J., Liu, Y., and Mokarem, D. (1997). "Field Investigation of the Corrosion Protection Performance of Bridge Decks and Piles Constructed with Epoxy-Coated Reinforcing Steel in Virginia." *Report No. VTRC 98-R4*, Virginia Research Council, Charlottesville.

Recruiting, Promoting, and Retaining of Qualified Personnel in Highway Construction (including supervisors to staff projects

Berg, T.F. (1991). "Quality Personnel: To Have and To Hold." *Public Utilities Fortnightly*, 128(5), 18-22.

Berggren, E.G., (1999). "Using Money to Attract, Develop, and Retain Staff." *Journal of Management Consulting*, 10(4).

Bowes, L., (1987). *No One Need Apply: Getting and Keeping the Best Workers*. Harvard Business School Press, Boston, MA.

Breaugh, J.A. (1981). "Relationships between Recruiting Sources and Employee Performance, Absenteeism, and Work Attitudes." *Academy of Management Journal*, 24(1), 142-147.

Bredwell, J. (1981). "The use of broadcast advertising for recruitment." *Personnel Administrator*, February, 45-49.

Brendan, C. (1996). "Tech wars: Recruiting and retaining IT personnel on Wall Street." *Wall Street & Technology*, 14(2), 42-48.

Caruth, D.L., Noe, R.M., Mondy, R. W. (1988). *Staffing the Contemporary Organization*. Quorum Books, New York, NY.

Cronin, R.J. (1981). "Executive recruiters: are they necessary?" *Personnel Administrator*, February, 31-34.

Fyock, C.D. (1990). *America's Work Force is Coming of Age*. Lexington Books, Lexington, MA.

Mason, J.M. (1994). "Expanding the Civil Engineering Pool." National Cooperative Highway Research Program, *Project 20-24 (03)*, Washington, DC.

Murray, J.P. (1999). "Successfully Hiring and Retaining IT Personnel." *Information Systems Management*, 16(2), 18-24.

Phillips, J.J., (1987). *Recruiting, Training, and Retaining New Employees*. Jossey-Bass Publishers, San Francisco, CA.

Rosenbaum, D.B. (2000). "Concern about Talent Shortage Leads Industry into Classrooms." *Engineering News Record*, 245(17), 44-51.

Schreier, J.W. (1983). "Deciphering messages in recruitment ads." *Personnel Administrator*, March, 35-39.

Soat, D.M., (1996). *Managing Engineers and Technical Employees*. Artech House, Inc., Norwood, MA.

Overall improvement of the construction process – particularly alternative construction methods and techniques, contracting methods and delivery systems to facilitate faster construction/reconstruction

"A+B, and Incentive/Disincentive Clauses." (2000a). <http://www.its.fhwa.dot.gov/quality/HP-MI3.htr> (Oct. 31, 2000).

"A+B Bidding Clauses in North Carolina DOT Contracts." (2000b). <http://www.its.fhwa.dot.gov/quality/HP-NC11.htr> (Oct. 31, 2000).

"A+B Bidding (Time Based Bidding)." (2000c). <http://www.its.fhwa.dot.gov/quality/HP-OK8.htr> (Oct. 31, 2000).

"A+B Contracts." (2000d). <http://www.its.fhwa.dot.gov/quality/HP-NY1.htr> (Oct. 31, 2000).

"A+B, I/D and Lane Rental in Reducing Contract Time." (2000e). <http://www.its.fhwa.dot.gov/quality/HP-IN13.htr> (Oct. 31, 2000).

"A+B with I/D for Reducing Contract Time." (2000f). <http://www.its.fhwa.dot.gov/quality/HP-MO2.htr> (Oct. 31, 2000).

"Alternative Contracting Practices." (2000). <http://www.its.fhwa.dot.gov/quality/HP-FL3.htr> (Oct. 31, 2000).

American Association of State Highway Transportation Officials (AASHTO) Highway Subcommittee on Construction (1998). *Primer on Contracting 2000*, Second Edition, Washington, DC.

Anderson, S.D., Russell, J.S. (1999a). "Improved Contracting Methods for Highway Construction Projects." National Cooperative Highway Research Program, Project 10-49, Washington, DC.

Anderson, S.D., Russell, J.S. (1999b). "Implementation Guidelines for Warranty, Multi-Parameter, and Best Value Contracting." National Cooperative Highway Research Program, Project 10-49, Washington, DC.

Anderson, S.D., Ullman, G.D. (2000). "Reducing and Mitigating Impacts of Lane Occupancy during Construction and Maintenance." National Cooperative Highway Research Program, *Synthesis 293*, Washington, DC.

Christiansen, D.L. (1987). "An Analysis of the Use of Incentive/Disincentive Contracting Provisions for Early Project Completion." *Transportation Research Board, Special Report 212*, 69-76.

Cole, L.W., Voigt, G.F. (1995). "Roadway Rehabilitation with Fast-Track Concrete Paving." *Transportation Congress, Proceedings 1, October 22-26, 1995*, 517-528.

"Construction Lane-mile Rentals." (2000). <http://www.its.fhwa.dot.gov/quality/HP-OK10.htr> (Oct. 31, 2000).

Florida Department of Transportation (FDOT) (1999). "Alternative Contracting Program Preliminary Evaluation." Tallahassee, FL.

Florida Department of Transportation (FDOT) (1997). "Alternative Contracting User's Guide." Tallahassee, FL.

"Frequent Use of Innovative Contracting Procedures." (2000). <http://www.its.fhwa.dot.gov/quality/HP-UT13.htr> (Oct. 31, 2000).

Gaj, S.J. (1992). "Lane Rental – An Innovative Contracting Practice." *Transportation Research News*, 162, 7-9.

Groton, J.P., Smith, G.A. (1997). "Selecting the Most Appropriate Project Delivery Methodology." *Construction Congress Proceedings, October 4-8, 1997*, S.D. Anderson, ed., ASCE, Reston, Virginia.

Harp, D.W. (1991). "Historical Background – Low Bid Concept." *Transportation Research Circular*, 386, 43-47.

Herbsman, Z.J., Chen, W.T., Epstein, W.C. (1995). "Time is Money: Innovative Contracting Methods in Highway Construction." *Journal of Construction Engineering and Management*, 121(3), 273-281.

Herbsman, Z., Ellis, R. (1992). "Multiparameter Bidding System – Innovation in Contracting Administration." *Journal of Construction Engineering and Management*, 118(1), 142-150.

"Innovative Contracting Practices." *Transportation Research Circular*, 386, Transportation Research Board, National Research Council.

Kudelka, B. (2000). "Fast-Track Funding." *Civil Engineering*, 70(3), 54-57.

"Lane Rental Specification." (2000). <http://www.its.fhwa.dot.gov/quality/HP-OR8.htr> (Oct. 31, 2000).

"New Jersey's Modified Design-Build Program." (1998). <http://www.fhwa.dot.gov///////infrastructure/progadmin/contracts/NJ_rpt4a.htm> (Nov. 9, 2000).

"Pre-qualification to Restrict the Bidding Capacity of Contractors." (2000). <http://www.its.fhwa.dot.gov/quality/HP-OH4.htr> (Oct. 31, 2000).

Reseigh, C. (1997). "Price and Schedule Bidding." *Construction Congress Proceedings, October 4-8, 1997,* S.D. Anderson, ed., ASCE, Reston, Virginia.

Ridings, R.L., Quinn, S.B. (1992). "Life in the Fast Track." *Civil Engineering*, 62(4), 46-49.

Scott, S. (1997). "Contract Management Techniques for Improving Construction Quality." Federal Highway Administration, *FHWA-RD-97-067*, Washington, DC.

Scott, S. (1999). "Guidebook to Highway Contracting for Innovation: The Role of Procurement and Contracting Approaches in Facilitating the Implementation of Research Findings." National Cooperative Highway Research Program, *Report 428*, Washington, DC.

Tadros, M.K., Baishya, M.C. (1998). "Rapid Replacement of Bridge Decks." National Cooperative Highway Research Program, Report 407. National Academy Press, Washington, D.C.

"Time Based Bidding (A+B, I/D and Lane Rental)." (2000). <http://www.its.fhwa.dot.gov/quality/HP-MS5.htr> (Oct. 31, 2000).

Evaluation of the Use of Incentives/Disincentives (I/Ds) to Reduce Time to Complete Highway Projects

Anderson (2000). "Improved Contracting Methods for Highway Construction Projects" NCHRP 10-49 *Transportation Research Board* Washington, DC.

Anon (1987). "Transportation management for major highway reconstruction proceedings of the national conference on corridor traffic management for major highway reconstruction" *Special Report - National Research Council, Transportation Research Board 212*. Publ by Transportation Research Board, Washington, DC, USA 128p.

Bauer (2000). "Alternative Contracting Practices" *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-FL3.htm)

Bertram (2000) *"A+B, I/D and Lane Rental in Reducing Contract Time"* FHWA Quality Journey - Best Practices *U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-IN13.htm).*

Christiansen (1987). *"Analysis of the use of incentive/disincentive contracting provisions for early project completion"* Special Report - National Research Council, Transportation Research Board 212*. Publ by Transportation Research Board, Washington, DC, USA p 69-76.*

El Itr; Kangari (1994). "Improving effectiveness of equal business opportunity programs" *Journal of Professional Issues in Engineering Education and Practice*. v 120 n 3 Jul 1994, p 295-312

Fort (2000). *"A+B, and Incentive/Disincentive clauses"* FHWA Quality Journey - Best Practices *U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-IN13.htm).*

Gordon (1994). "Choosing appropriate construction contracting method" *Journal of Construction Engineering and Management*. v 120 n 1 Mar 1994, p 196-210

Haswell (1986). *" Contract element in tunneling"* Tunnels-and-Tunnelling. *v 18 n 4 Apr 1986, p 81-82.*

Ibbs; Ashley (1987). *"Impact of various construction contract clauses"* Journal of Construction Engineering and Management. *v 113 n 3 Sep 1987, p 501-521.*

Jaraiedi; Plummer; Aber-Mary-S (1995). "Incentive/disincentive guidelines for highway construction contracts" *Journal of Construction Engineering and Management.* v 121 n 1 Mar 1995, p 112-120.

Kay (1983). "Arizona's experience with a construction noise-abatement incentive" *Transportation Research Record* -937. 1983, p 30-35 .

Ksaibati; Staigle; Adkins (1995). "Pavement construction smoothness specifications in the United States" *Transportation Research Record*. n 1491, Jul 1995. p 27-32.

Neil (1991) "Incentives. Powerful tools for owners." *Cost Engineering* (Morgantown-WVa). v 33 n 1 Jan 1991, p 19-23

Newman; Hejl (1984). *"Contracting practices and payment procedures" NCHRP 20-7 Task 23* Transportation Research Record*. 1984. p 50-59.*

O' Connor; Colwell (1980) "Cost plus incentive fee for construction contracts" *Technical RepConstruction Engineering Research Lab*. n P-118 Dec 1980, 21 p.

Pond (1996) "Underground contracts for the 21st century" *Civil Engineering* (New-York). v 66 n 12 Dec 1996, p 54-57.

Pozdena (2000). "Development of an Update to the 1977 AASHTO Redbook" NCHRP 2-23 *Transportation Research Board* Washington, DC.

Shilstone (1990). "Concrete pavement. Specification by modeling." *Service Durability Construction Material Processes* First Material Engineering Congress. Publ by ASCE, Boston Society of Civil Engineers Sect, Boston, MA, USA. p 943-952

Shilstone (1997) "Concrete quality assurance - changing the paradigm" *Quality Assurance A National Commitment ASCE Annual Convention on Innovative Civil Engineering for Sustainable Development*. 1997, ASCE, New York, NY, USA. p 81-89.

Simmons; Matthews; Multari (1994). "Preparation of bid documents for dredging/excavating contaminated sediments, soils and marsh deposits at the Marathon Battery Superfund Site, Cold Spring, NY" *International-Conference-on-Dredging-and-Dredged-Material-Placement*. v 2 1994, ASCE, New York, NY, USA. p 1201-1209

Smith (1996). "Smoothness Specifications for Pavements" NCHRP 1-31 *Transportation Research Board* Washington, DC.

Smith (1999). "Use of incentives in alliancing" *Nuclear Engineer*. v 40 n 6 1999, p 236-239.

Willett (2000*) "Technical Advisory – Incentive/Disincentive (I/D) for early completion" (http://www.its.fhwa.dot.gov/legsregs/directives/techadvs/t508010.htm)*

Innovative strategies to manage traffic during highway construction projects – as specifically related to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction

Anderson, S.D., Russell, J.S. (1999). "Improved Contracting Methods for Highway Construction Projects." National Cooperative Highway Research Program, Project 10-49.

Anderson, S.D., Ullman, G.L. (2000). "Reducing and Mitigating Impacts of Lane Occupancy During Construction and Maintenance." National Cooperative Highway Research Program, Project 20-5, Topic 30-12.

Benz, R.J., Fenno, D.W., Voigt, A.P. (1998). "Accelerating Major Freeway Reconstruction Projects." *Transportation Research Record*, 1632, 59-67.

"Caltrans Traffic Management Plan." (2000). <http://www.its.fhwa.dot.gov/quality/HP-CA11.htr> (Nov. 2, 2000).

Cutler, M.R. (1993). "Use of Traffic Forecasting Models in the Development of Traffic Management Plans for Construction of the Central Artery/Tunnel Project." *Transportation Research Record*, 1404, 8-14.

Ellis, R.D., Herbsman, Z.J., Kumar, A., Chheda, P.N. (1991). "Developing Night Operations in Florida." Department of Civil Engineering, University of Florida, Gainesville, Florida.

Elrahman, O.A., Perry, R.J. (1998). "Guidelines for night-time maintenance and construction operations." Road & Transportation Research, 7(3), 3-16.

"Get In Get Out Stay Out." *Proceedings of the Workshop on Pavement Renewal for Urban Freeways*, February 16-19, 1998, Irvine, California.

Graham, J.L., Migletz, J. (1994). "Development and Implementation of Traffic Control Plans for Highway Work Zones." National Cooperative Highway Research Program, Synthesis of Highway Practice 208. National Academy Press, Washington, D.C.

Hess, T.G. (2000). "Avoiding Delays in Constructing Highway Projects." National Cooperative Highway Research Program, Project 10-60 – Anticipated Project.

Higgins, T.J. (1993). "Monitoring and Evaluating Highway Reconstruction Strategies." *Transportation Quarterly*, 47(4), 525-544.

Homburger, W.S. (1989). "Traffic Control in Construction Zones with Nighttime Activities." Research Report UCB-ITS-RR-89-10, Institute of Transportation Studies, University of California, Berkeley.

Janson, B.N., Anderson, R.B., Sterne, R.B. (1989). "Managing transportation during highway reconstruction: A recommended process." *Transportation*, 16(1), 47-79.

Krammes, R.A. (1990). "Travel Impact Evaluation for Major Highway Reconstruction Projects." *Journal of Transportation Engineering*, 116(1), 64-80.

"Lane Closure Policy." (2000). <http://www.its.fhwa.dot.gov/quality/HP-FL5.htr> (Nov. 2, 2000).

"Limited Length of Lane Closure Within a Project." (2000). <http://www.its.fhwa.dot.gov/quality/HP-NC5.htr> (Nov. 2, 2000).

Neveu, A.J., Maynus, L. (1985). "How to Manage Traffic During Highway Reconstruction." New York State Department of Transportation, Albany, New York.

"Performance Plan Objective to Reduce the Public's Exposure to Highway Construction Activities." (2000). <http://www.its.fhwa.dot.gov/quality/HP-R91.htr> (Nov. 2, 2000).

"Removal of Traffic Control Pattern if not working multiple shifts." (2000). <http://www.its.fhwa.dot.gov/quality/HP-PAT1.htr> (Nov. 2, 2000).

"Road Closure Program." (2000). <http://www.its.fhwa.dot.gov/quality/HP-MC3.htr> (Nov. 2, 2000).

Saag, J.B. (1999). "Project Development Methodologies for Reconstruction of Urban Freeways and Expressways." National Cooperative Highway Research Program, Synthesis of Highway Practice 273. National Academy Press, Washington, D.C.

"Twelve Minute Delay Rule." (2000). <http://www.its.fhwa.dot.gov/quality/HP-MA1.htr> (Nov. 2, 2000).

Ullman, G.L. (1996). "Traffic Management System Considerations in Freeway Design and Redesign." Research Report 1467-2. Texas Transportation Institute, College Stations, TX.

Wisconsin Department of Transportation (1997). "Freeway Work Zone Traffic Control Method Selection Process." Division of Transportation Infrastructure Development and Division of Transportation Districts.

Training and Workforce Development of SHA personnel

"Access and Opportunity: Strengthening Workforce Development in the Washington Metropolitan Region. Conference Summary and Proceedings" *Metropolitan Washington Council of Governments. 131p, 1999*

Anon (1987). "How DOTs Improve Equipment Management and Maintenance" *Better Roads*. v 57 n 10 Oct 1987, p 22-31.

Blaschke (1989). "Specifications and Constructability." *Proc Construction Congress I Excellence in Construction Projects*. Publ by ASCE, New York, NY, USA. p 87-92.

Carbajal (1989). "Training for Highway Construction Personnel" *National Cooperative Highway Research Program* Project 20-25(2), FY 1989

Carter (1990) "Training for Highway Construction Personnel" *National Cooperative Highway Research Program* Project 20-25(2), FY 1989

Cassidy; Conner (1999). "Asphalt technician certification: The Rocky Mountain way" *ASTM-Special-Technical-Publication*. n 1378, 1999. p 11-22

Dowd (2000) "Inspector certification and training. Preparing the construction team to build projects better" *Transportation Congress*, Proceedings. v 1 1995, ASCE, New York, NY, USA. P 1023-1032

Etmanczyk (1995). "Wisconsin DOT measures quality from top to bottom" *Journal of Management in Engineering*. v 11 n 4 Jul-Aug 1995, p 19-23.

Foy; Iwaszek (1996) "Workforce development - building the public education pipeline to meet manufacturing technician hiring needs" *IEEE SEMI Advanced Semiconductor Manufacturing Conference and Workshop*. 1996, IEEE, Piscataway, NJ, USA,96CH35953. p 451-454

Hall; Pylant (1999). "First-year summary of the Arkansas hot-mix asphalt technician certification program" *ASTM Special Technical Publication*. n 1378, 1999. p 60-69.

Hinerman (1995) “Unique needs drive innovative industry-education partnerships for workforce development and retraining” *Investing in the Future ASEE Annual Conference Proceedings*. v 1 1995, ASEE - American Society for Engineering Education, Washington, DC, USA. p 358 -362
Huff (1998). “Transportation technician qualification program” *ASEE Annual Conference Proceedings.* 1998, ASEE, Washington, DC, USA. 4pp.
Jenkins (1996) “Technology transfer in Western Rural Areas” *Transportation Research Record*. n 1565, Nov 1996. p 10-15.
Nelson; Sinha; Michael (1988). “Graduate education and highway research needs in the 21st century.” *Engineering the 21st Century Highway*. Publ by ASCE, New York, NY, USA. p 202-207.
Paniati (1990). “Application of interactive videodisc for work zone traffic control training.” *Microcomputer Application Transportation III* Proc International Conference of Microcomputer Transportation. Published by ASCE, New York, NY, USA. p 89-99.
Pope (2000). *Workforce Development Branch*. (http://www.faa.gov/region/aso/hrmd/workforc.htm)
Ramey; Wolff; Wright (1997). “DOT management actions to enhance bridge durability/longevity” *Practice Periodical on Structural Design and Construction*. v 2 n 3 Aug 1997, p 125-130.
Stukhart (1985). “Construction QA/QC Systems that Work: Case Studies” *1985 ASCE*, New York, NY, USA. 44p .
West; Lynn (1999). “Certification and accreditation programs: A contractor's perspective” *ASTM Special Technical Publication*. n 1378, 1999. p 70-75.
Wilmot (1994). “Reforms in the road industry. Changing responsibilities in the construction industry” *Road and Transportation Research*. v 3 n 3 Sept 1994, p 36-40.

Implementation and Evaluation of Performance Related Specifications for Highway Construction

Al Abdul; Wahhab; Asi; Al Dubabe; Ali (1997). “Development of performance-based bitumen specifications for the Gulf countries.” *Construction-and-Building-Materials*. v 11 n 1 Feb 1997, p 15-22
Anon (1984). *TRNews*. n 113 Jul-Aug 1984, p 9-12
Anon (1990). “Asphalt cost control without quality loss.” *Better Roads*. v 60 n 2 Feb 1990, p 36-38
Anon (1997) “Performance-based documentation system.” *Elevator World*. v 45 n 9 Sep 1997, p 104, 106
Balog (1995). “Paratransit Vehicle Specifications and Related Special Maintenance Requirements.” *Transit Cooperative Research Program*. The Bionetics Corp, KETRON Division, Project C-09, FY 1995.
Cominsky (1993). “Early field experience with SUPERPAVE.” *Pacific-Rim-TransTech-Conference*. 1993, Publ by ASCE, New York, NY, USA. p 534-540
Connor; Dexter (1999). “Fatigue design of modular bridge expansion joints.” *Transportation Research Record*. n 1688, Nov 1999. p 124-130

Cunningham; Gaughan "Some NSW experiences in specifying rubber modified and high non-volatile emulsified bituminous binders." *Pavements and Materials Proceedings - Conference of the Australian Road Research Board pt 2*. Publ by Australian Road Research Board, Nunawading, Aust. p 303-325.

Curtis (1995). "Performance-based road specifications" *Quarry-Management*. v 22 n 1 Jan 1995, 3pp

Dexter (1994). "Fatigue Criteria for Modular Bridge Expansion Joints". *National Cooperative Highway Research Program.* Lehigh University, Project 12-40, FY 1994.

Dhir; Hewlett; Byars; Bai (1994). "Estimating the durability of concrete in structures" *Concrete* (London). v 28 n 6 Nov-Dec 1994, p 25-30.

Emmons; Vaysburd; Thomas (1998). "Strengthening concrete structures, Part II" *Concrete International*. v 20 n 4 Apr 1998, p 56-60.

Epps; Kari (1983). "Factors to be Considered in Developing Performance Based Specifications." *Asphalt Paving Technology: Proceedings Association of Asphalt Paving Technologists Technical Sessions*. v 52 1983, Publ by Univ of Minnesota.

Ferragut (2000). "Performance Related Specifications Workshop." *Florida Department of Transportation.* National Quality Initiative, June 26, 2000.

Fleckenstein; Allen (2000). "Development of a performance-based specification (QC/QA) for highway edge drains in Kentucky" *ASTM Special Technical Publication*. n 1390, 2000. p 64-71.

Goodwin; Gellings; McMillan; Chow; Sarvi; Stude (1997). "Specifications that ensure sliplining success." *Practical Applications Proceedings of the Conference on Trenchless Pipeline Projects*. 1997, ASCE, New York, NY, USA. p 390-397

Hoerner; Darter; Khazanovich; Titus (2000) "Improved Prediction Models for PCC Pavement Performance-Related Specifications" *FHWA-RD-00-130* Federal Highway Administration, December 2000.

Hoerner; Darter; Kopac (1999) "Summary of the 1996 portland cement concrete performance-related specification shadow field trial: Iowa State Route 23" *Transportation Research Record*. n 1654, 1999. p 12-23.

Huber; Zhang; Fontaine (1996). "Superpave models: predicting performance during design and construction" *Transportation Research Record*. n 1545, Nov 1996. p 105-112.

Hudson; Haas. "Research and innovation toward standardized pavement management." *ASTM Special Technical Publication*. n 1121, Publ by ASTM, Philadelphia, PA, USA. p 132-147

Kashiwagi; Halmrast (1996). "*Construction regulated by performance information*" Computing in Civil Engineering (New York). 1996, p 551-558.

Kennedy, Cominsky, Harrigan (1983). "Development of performance-based specifications and AAMAS." *Asphalt Paving Technology: Proceedings Association of Asphalt Paving Technologists Technical Sessions.* v 60. Publ by Assoc of Asphalt Paving Technologists, 1983, Sloan Place, Suite 10, St. Paul, MN, USA. p 647-677

King; King; Harders; Chavenot; Planche (1983). "Influence of asphalt grade and polymer concentration on the high temperature performance of polymer modified asphalt." *Asphalt Paving Technology: Proceeding Association of Asphalt Paving*

Technologists Technical Sessions. v 61 1992, Publ by Assoc of Asphalt Paving Technologists, 1983 Sloan Place, Suite 10, St. Paul, MN, USA. p 29-66
Kuzyk; Haas; Cockfield (1991). "Performance-based specifications for pavements." *Canada Journal of Civil Engineering*. v 18 n 6 Dec 1991, p 1054-1061
Litman (1999). "Memo - Performance Based Service Contracting (PBSC)." http://www.dot.gov/ost/m60/pbsc/pbscagenda.htm
Minneapolis, Minn, USA p 271-291
Masson; Lacasse (1999). "Considerations for a performance-based specification for bituminous crack sealants" *ASTM Special Technical Publication*. n 1348, 1999. p 168-181.
Mokashi (1999). "Creating performance specifications for coating and lining concrete." *Journal of Protective Coatings and Linings*. v 16 n 12 1999, p 38-46
Richardson (1994). "Determining degrees of combustibility of building materials-National Building Code of Canada." *Fire and Materials*. v 18 n 2 Mar-Apr 1994, p 99-106
Smith; Minchin (1997). "Quality-Based Performance Rating of Contractors for Prequalification and Bidding Purposes." *National Cooperative Highway Research Program.* Pennsylvania Transportation Institute, Project 10-54, FY 1997.
Sousa; Harvey; Bouldin; Azevedo (1994). " Application of SHRP mix performance-based specifications". *Transportation Research Record*. n 1454, Dec 1994. p 154-162
The Construction Specifications Institute. (http://www.csinet.org/)
Youdale (1992) "Facing the challenges road rehabilitation and recycling" *Proceedings Conference of the Australian Road Research Board*. v 16 pt 1 1992, Publ by Australian Road Research Board Ltd, Nunawading, Aust. p 159-177.
Zaghloul; Saeed; Jassim; Rafi (1998). "End-result specifications for warranted asphalt pavements." *Transportation Research Record*. n 1632, Sep 1998. p 1-12
Zogg (2000). "Specifications." *Quality Control/Quality Assurance for Highway Construction.* University of Wisconsin – Madison Civil and Environmental Engineering 698, June 2000.

Identification, evaluation, and implementation of performance-related acceptance tests

"AASHTO Quality Assurance Guide Specifications" (http://www.fhwa.dot.gov///////infrastructure/pavement/matrac/aashto.htm)
"Strategies for Coping with Construction Project Staffing Demands" (http://www.fhwa.dot.gov//////infrastructure/progadmin/contracts/cope_sum.htm#Summary)
Brown; Taylor (1996). *"From `compliance-based' to `performance-based' quality: A trend in and evolution of U.S. quality standards"* Proceedings of the ASME JSME International Conference on Nuclear Engineering, *ICONE. v 5 1996, ASME, New York, NY, USA. p 317-324.*
Buttlar; Roque; Reid (1998*) "Automated procedure for generation of creep compliance master curve for asphalt mixtures"* Transportation Research Record*. n 1630, Sep 1998. p 28-36.*

Chin (1985). *"Highway Construction Inspection Management using a Microcomputer."* Publ by ASCE*, New York, NY, USA p 739-748.*

Curtis (1994). "Performance based specifications for asphalt" *Mine and Quarry*. v 23 n 12 Dec 1994, p 25-26.

Dexter (1998) "Performance Tests for Modular Bridge Joints" NCHRP 10-52 *Transportation Research Board* 1998.

Dhir; Hewlett; Byars; Bai (1994). "Estimating the durability of concrete in structures" *Concrete* (London). v 28 n 6 Nov-Dec 1994, p 25-30.

Farrand; Emery (1995). *"Recent improvements in quality of steel slag aggregate"* Transportation Research Record*. n 1486, Jul 1995. p 137-141.*

Fleckenstein; Allen (2000). "Development of a performance-based specification (QC/QA) for highway edge drains in Kentucky" *ASTM Special Technical Publication*. n 1390, 2000. p 64-71.

Guirguis (1993). *"New cement standard in Australia - its implication and further development"* Cement, Concrete and Aggregates*. v 15 n 2 Winter 1993, p 170-173.*

Huber (1993). "Steps to a mix design solution for better asphalt" *Pacific Rim TransTech Conference*. 1993, Publ by ASCE, New York, NY, USA. p 263-269.

Huber; Zhang; Fontaine (1996) "Superpave models: predicting performance during design and construction" *Transportation Research Record*. n 1545, Nov 1996. p 105-112.

Lewis (1991). "Construction inspection in South Carolina." *Preparing for Construction in the 21st Century Constr Congr* 91. Publ by ASCE, New York, NY, USA. p 543-547.

Lieberman; Lieberman (1992) "Inadequate inspection cause of flawed vacuum tower revamp" *Oil and Gas Journal*. v 90 n 50 Dec 14 1992, p 33-35.

Nazarian; Yuan; Tandon (1999). "Structural field testing of flexible pavement layers with seismic methods for quality control" *Transportation Research Record*. n 1654, 1999. p 50-60.

Newman; Adam; LaHue (1994) "Construction Testing and Inspection Levels" NCHRP 10-39 *Transportation Research Board* 1994.

Pradhan; Armijo (1994) "Montana experience with polymer modified asphalt" Infrastructure: *New Materials and Methods of Repair Proceedings of the Materials Engineering Conference 804*. Oct 1994, ASCE, New York, NY, USA. p 311-318.

Quinn (1985). "Construction Management: Dallas North Tollway Project" *1985ASCE*, New York, NY, USA. p 26-37 .

Ramey; Wright (1997). *"Results of bridge durability/longevity survey"* Practice Periodical on Structural Design and Construction*. v 2 n 3 Aug 1997, p 105-117.*

Rausche; Likins; Hussein (1994) *"Formalized procedure for quality assessment of cast-in-place shafts using sonic pulse echo methods"* Transportation Research Record*. n 1447, Oct 1994. p 30-38.*

Russell (1984). "Role of the Professional Engineer in Construction Inspection" *1984ASCE*, New York, NY, USA. p 4-10 .

Russell (1998) "Testing and Inspection Levels for Hot-Mix Asphaltic Concrete" NCHRP 10-39A *Transportation Research Board* 1998

Sanborn (1992) "Examination of randomized inspection schedules with respect to two detection criteria." *Journal of the Institute of Nuclear Materials Management.* v 20 n 4 Jul 1992, p 12-16.

Schell (1986). "Cutting the Costs of Corrosion in Highway Structures – Ontario's Approach." *Publ by NACE,* Houston, TX, USA p 27-39.

Udo; Uzoije (1997). "HICIMS: An integrated GIS and DBMS application" *Computing in Civil Engineering (New-York).* 1997, ASCE, New York, NY, USA. p 240-247.

Volkman (199) "Aspects of blast resistant masonry design." *ASTM Special Technical Publication.* n 1063, Publ by ASTM, Philadelphia, PA, USA. p 413-422.

Williams (1991). *"Hypertext system for asphalt paving construction"* Artificial Intelligence and Civil Engineering Second Int Conf Appl Artif Intell Civ Struct Eng. *Publ by Civil Comp Limited, Edinburgh, Scotl. p 235-239.*

Williams; Parks; LiMarzi (1990). "Expert system for asphalt-paving construction inspection." *Journal of Computer and Civil Engineering.* v 4 n 4 Oct 1990, p 370-380.

Determination of strategies to offset reduced staff size with increased workload of the SHA personnel

"Outsourcing of State Highway Facilities and Services" *National Research Council* 1997

"Strategies for Coping with Construction Project Staffing Demands" 1998 AASHTO Subcommittee on Construction, Contract Administration Task Force (http://www.its.fhwa.dot.gov/infrastructure/progadmin/contracts/cope_sum.htm)

Calderon; West; Jurkofsky; Crockett; Alexander (2000) "Contracting Out; Bench Marking Study" *Federal Lands Highway* Sept 2000

Dvorak (2000) "Kansas - Cities and Counties Letting Exempt, Non-NHS Projects Using Local Procedures" *FWHA Best Practices Policy* (http://www.fhwa.dot.gov/////modiv/letting.htm)

Godwin; Menzies (1996) "Approaches for Increasing Private-Sector Involvement in Highway Innovation Process" NCHRP 20-41 *Transportation Research Board* Washington, DC

Godwin (2000) "TRB Study on Future Surface Transportation Agency Human Resource Needs: Strategies for Recruiting, Training, and Retaining Personnel" Project 20-55, FY 2001, *Transportation Research Board,* Washington, D.C.

Henk (1998) "Privatization and the public/private partnership" *Journal of Management in Engineering.* v 14 n 4 July-Aug 1998, p 28-29.

Lewis (1991) "Construction inspection in South Carolina." *Preparing for Construction in the 21st Century Construction Congress 91.* Publ by ASCE, New York, NY, USA. p 543-547.

Mikkola; Fridel (1996) "Crossing conflict: The in-service lowering of a 34 inches crude oil pipeline for the construction of the Owen flood diversion channel" *Proceedings of the International Pipeline Conference, IPC.* v 2 1996, ASME,New York, NY, USA. p 717-734

Nicholson (1991) "A G.I.S. for cross country pipelines." *Second National Spec. Conference in Civil Engineering Appl.Remote Sensor Geographic Information Systems.* Publ by ASCE, New York, NY, USA. p 48-55.

Sanborn (1992) "Examination of randomized inspection schedules with respect to two detection criteria. *Journal of the Institute of Nuclear Materials Management.*. v 20 n 4 Jul 1992, p 12-16

Wilmot; Deis; Schneider; Coates (1999) "In-House versus Consultant Design Costs in State Departments of Transportation" *Transportation Research Board, 78th Annual Meeting*, Jan 1999 Washington, D.C.

Identification, evaluation, and implementation of rapid test methods and non-destructive testing to assess quality in the construction process

Almesberger (2000) "Diagnosis, control and monitoring of buildings and construction" *Insight: Non-Destructive Testing and Condition Monitoring*. v 42 n 9 Sep 2000, p 612-613.

Behr (1989) "Rapid test method for quality assurance in asphalt road construction." *Bitumen*. v 51 n 2 1989, p 57-64.

Berube (1993). "Canadian experience with testing for alkali-aggregate reactivity in concrete" *Cement and Concrete Composites*. v 15 n 1-2 1993, p 27-47.

Buckley; Read (1992) "Simulated field trials of non-destructive concrete test methods for highway structures." *Nondestructive Testing of Concrete Elements and Structures Proc. Nondestructive Tests for Concrete Element Structures*. Publ by ASCE, New York, NY,USA. p 162-170.

Ellway (1987) "Practical guidance on the use of integrity tests for the quality control of cast in situ piles" *Ground Engineering*. v 20 n 7 Oct 1987, p 8-10, 12-13.

Guram; Marienfeld; Hayes (1994) "Evaluation of nonwoven geotextile versus lime-treated subgrade in Atoka County, Oklahoma" Transportation Research Record. 1439, 1994. p 7-11.

Hayhoe (2000) "Airport Nondestructive Pavement Testing" *Project 13, Airport Technology Research and Development Branch* (http://www.airtech.tc.faa.gov/pavement/28perform.htm)

Hoerner; Darter; Kopac (1999) "Summary of the 1996 portland cement concrete performance-related specification shadow field trial: Iowa State Route 23" *Transportation Research Record*. n 1654, 1999. p 12-23.

Isecke (1988) "Corrision and Non-Destructive Testing in Reinforced Concrete Structures." *Technical Mess. TM*. v 55 n 4 1988, p 152-156.

Mayrbaurl (2000) "Structural Safety Evaluation Guidelines for Suspension Bridge Parallel Wire Cables" NCHRP 10-57 *Transportation Research Record* Washington, DC.

Mebarki; Sellier (1995) "Importance zone and importance sampling in reliability analysis of civil structures" *International Journal of Pressure Vessels and Piping*. v 61 n 2-3 1995, p 513-526.

Olson (2000) "Unknown Subsurface Bridge Foundation Testing" NCHRP 21-05(2) *Transportation Research Record* Washington, DC.

Roper; Baweja; Kirkby G (1984) "Towards a quantitative measure of durability of concrete structural members" *Publ. SP. American Concrete Institute.* 1984. American Concrete Inst, p 639-658.

Saleh (2000) "NDEVC Research & Development - Nuclear Non-Destructive Testing Laboratory" (http://www.tfhrc.gov///////hnr20/nde/nuclear.htm)
Shayan; Ivanusec; Diggins (1994) "Suitability of two rapid test methods for determining the alkali reactivity of sands" *Cement and Concrete Composites 16-3*. 1994, p 177-188.
Soutsos; Bungey; Long (2000) "Henderson In-situ strength assessment of concrete - the European Concrete Frame Building Project" *Insight: Non-Destructive Testing and Condition Monitoring*. v 42 n 7 Jul 2000, p 432-435.
Von Quintus (1997) "Nondestructive Testing to Determine Insitu Material Properties of Pavement Layers" NCHRP 10-44 *Transportation Research Record* Washington, DC.
Weed (1985) "Computer Assisted Random Sampling" *Transportation Research Record*. 1985. p 140-152.

Develop best practices for community outreach and involvement during construction

"Community Involvement" Report No. FAA-EE-96-05 U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy, May 1996
Arrigone (1983) "Core Housing – A research and development project using locally manufactured building components" 1983, *National Swedish Institute for Building Research*, Gavle, Swed. p 281-292
Bleyl (2000) "Involvement of Affected Communities and Businesses in the Project Development Process" *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-MC2.htm)
Borg (1976) "Social and Environmental Concerns in Construction" *ASCE Journal of Construction* Div. v 102 n 1 Mar 1976, p 1-20
Chorlton (1990) "Burnthouse Lane traffic calming scheme." *Highway Transportation*. v 37 n 8 Aug 1990, p 7-8, 10-11
Clark; Anderson (1990) "Changing roles in providing the ACT's roads infrastructure." *Traffic Data and Analysis Proceedings - Conference of the Australian Road Research Board pt 6*. Publ by Australian Road Research Board, Nunawading, Aust. p 101-113
Conner; Hale; Deering; Metts (1998) "Balancing environment and reliability: East Mission Gorge Trunk Sewer rehabilitation project case study" *Pipelines in the Constructed Environment Proceedings of the Pipeline Division Conference*. 1998, ASCE, Reston, VA, USA. p 298-307
Dickinsin (2000) "Public Information Campaign" *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-IA3.htm)
Edson (1993) "Public Outreach in Transportation Management" NCHRP 20-24(5) *Transportation Research Board*
Forkenbrock (2000) "Evaluation of Methods, Tools, and Techniques to Assess the Social and Economic Effects of Transportation Projects" NCHRP 25-19 *Transportation Research Record,* Washington, D.C.
Gallagher (2000) "Community Advisory Councils" *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-COC4.htm)

Hale (1995) “What SDG&E learned about urban pipeline construction” *Gas Industries (Park Ridge, Illinois).* v 40 n 1 Nov 1995, p 15-18.

Hedges (2000) “Using Customer Needs to Drive Transportation Decisions” NCHRP 20-53 Problem Statement *Transportation Research Record*, Washington, D.C.

Henley (1994) “Community partnering in accelerated construction program” *Journal of Urban Planning and Development*. v 120 n 2 Jun 1994, p 74-86

Hilsdon (1976) “Total Community Involvement wins fight to upgrade facilities” *Water Sewage Works*. v 123 n 9 Sep 1976, p 90-91

Hopkins (2000) “Constructing Your Image--A Public Relations Handbook for Contractors” *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-CO3.htm)

Kitchener; Mizon (1997) “Second Severn crossing - management of construction” *Proceedings of the Institution of Civil Engineers, Civil Engineering*. v 120 n Special Issu 1997, p 64-72.

Koehn; Winkleman (1981) “Public Reaction to Construction Project” *ASCE Journal of Construction* Div. v 107 n 2 Jun 1981, p 209-217

Matthews; Serruto (1998) “Traffic calming with the use of decorative concrete” *Transport Proceedings Conference of the Australian Road Research Board*. 1998, ARRB Transport Research Ltd, Vermont,Australia. p 152-191.

Mudge (1989) “Using Market Research to Improve the Management of Transportation Systems” NCHRP 20-24(01) *Transportation Research Record*, Washington, D.C.

O'-Brien (1997) “West side highway reconstruction story” *Public Works*. v 128 n 1 Jan 1997, p 28-30

Oost; Thomas; Jones “Paris-Lexington Road: integration of intrinsic qualities, civics of design, and computer technology” *Transportation Research Record*. n 1549, Nov 1996. p 85-92.

Wallace (1997) “Iowa DOT and communities become partners in design” *Public Works*. v 128 n 10 Sep 1997, p 66, 68 70

Walsh; Schock; Jimenez (1996) “Riddle of the riverbed” *Civil Engineering (New York).* v 66 n 6 Jun 1996, p 64-67.

Weinberger (1998) “City of San Diego Mid-City pipeline project integrating a public outreach program into the planning and alignment selection process” *Pipelines in the Constructed Environment Proceedings of the Pipeline Division Conference*. 1998, ASCE, Reston, VA, USA. p 232-240

White; Smalls; Bek (1994) “Carcoar wetland - A wetland system for river nutrient removal” *Water Science and Technology*. v 29 n 4 1994, p 169-176

Wielinga (1998) “Planning for the Ten Year Pacific Highway Upgrading Program” *Transport Proceedings Conference of the Australian Road Research Board*. 1998, ARRB Transport Research Ltd, Vermont, Australia. p 465-482.

Best practices for managing environmental restrictions and requirements

Blair; Houser (1992) “Soil conservation innovations. Construction equipment modifications to satisfy environmental concerns.” *Pipeline Technology Proceedings of the International Offshore Mechanics and Arctic Engineering Symposium*. v 5 pt A. Publ by ASME, New York, NY, USA. p 187-193

Carper (1990) “Environmental permitting a major expressway facility in Florida.” *Optimum Resource for Water Management Proc ASCE 17th Annual National Conference* Publ by ASCE, Boston Society of Civil Engineers Sect, Boston, MA, USA. p 144-148.

Esselman; Sobajic; Maulbetsch (1999) “Hybrid discrete and continuous control for power systems *Discrete Event Dynamic Systems: Theory and Applications*. v 9 n 4 1999, p 297-318

Fong; Lundin; Pappas (1995) “Environmental impact of groundwater discharge during tunnel construction” *Proceedings Rapid Excavation and Tunneling Conference*. 1995, Soc for Mining, Metallurgy & Exploration Inc, Littleton, CO, USA. p 319-331

Hoover (1990). “Cost/benefit or survival.” *Pit Quarry*. v 82 n 12 Jun 1990, p 38,40,42

Joskow; Rose (1985) “Effects of technological change, experience and environmental regulation on the construction cost of coal-burning generating units” *Rand Journal of Economics*. v 16 n 1 Spring 1985, p 1-27

Kibert; Coble (1995) “Integrating safety and environmental regulation of construction industry” *Journal of Construction Engineering and Management.* v 121 n 1 Mar 1995, p 95-99

McCready (2000). “Consideration of Environmental Factors in Transportation Systems Planning” NCHRP 8-38 *Transportation Research Board.* Washington, DC

McCready (2001). “Effective Methods for Environmental Justice Assessment” NCHRP 8-41 *Transportation Research Board.* Washington, DC

Przepiora; Hesterberg; Parsons; Gilliam; Cassel; Faircloth (1997) “Calcium sulfate as a flocculant to reduce sedimentation basin water turbidity” *Journal of Environmental Quality*. v 26 n 6 Nov-Dec 1997, p 1605-1611.

Rosenberg (1995) “Insurance and the environmental engineer” *Civil Engineering (New York).* v 65 n 3 Mar 1995, p 69-71.

Smith; Von Haefen; Zhu; (1999) “Do Environmental Regulations Increase Construction Costs for Federal-Aid Highways? A Statistical Experiment” *Journal of Transportation and Statistics*. May 1999.

Thompson (1994) “Transportation & the Environment - Description and Review of Alternative Policies for Departmental Consideration - Wisconsin TransLinks 21” (http://www.bts.gov/ntl/DOCS/tte.html)

Whipple (1996). “Integration of water resources planning and environmental regulation” *Journal of Water Resources Planning and Management*. v 122 n 3 May-Jun 1996, p 189-196

Zelenko; Perry (1995) “Meeting environmental requirements for new tunnels in Washington, D.C.” *Proceedings Rapid Excavation and Tunneling Conference*. 1995, Soc for Mining, Metallurgy & Exploration Inc, Littleton, CO, USA. p 361-373

Review of the constructability of transportation facilities in the planning and design phases – specifically deficiencies in quality and clarity of construction plans

American Association of State Highway Transportation Officials (AASHTO) Subcommittee on Construction (2000). “Constructibility Review Best Practices Guide.” *Final Draft*, July 31, 2000, Washington, DC.

Anderson, S.D., Fisher, D.J. (1997a). “Constructibility Review Process for Transportation Facilities.” National Cooperative Highway Research Program, Report 390. National Academy Press, Washington, D.C.
Anderson, S.D., Fisher, D.J. (1997b). “Constructibility Review Process for Transportation Facilities-Workbook.” National Cooperative Highway Research Program, Report 391. National Academy Press, Washington, D.C.
“Contractor Participation in Constructibility Reviews.” (2000a). <http://www.its.fhwa.dot.gov/quality/HP-OK2.htr> (Oct. 26, 2000).
“Contractor Hired by Design Consultant to do Constructibility Review on James River Bridge.” (2000b). <http://www.its.fhwa.dot.gov/quality/HP-VA13.htr> (Oct. 26, 2000).
“Constructibility Reviews by Construction Industry Representatives During Project Design.” (2000a). <http://www.its.fhwa.dot.gov/quality/HP-CO1.htr> (Oct. 26, 2000).
“Constructibility Reviews on High Visibility Projects in Design Phase.” (2000b). <http://www.its.fhwa.dot.gov/quality/HP-IN8.htr> (Oct. 26, 2000).
DeWitt, S.D. (1999). “Subcommittee Constructibility Survey.” Presentation to the AASHTO Subcommittee on Construction, August 1-5, 1999.
Ellis, R.D., Kumar, A., Ahmed, Q.A. (1992). “Life Cycle Reconstructibility.” University of Florida, Engineering and Industrial Experimental Station, Gainsville, Florida.
Fisher, D.J., Rajan, N. (1996). “Automated Constructibility Analysis of Work-Zone Traffic-Control Planning.” *Journal of Construction Engineering and Management*, 122(1), 36-43.
“Formal Constructibility Review Process (CRP).” (2000). <http://www.its.fhwa.dot.gov/quality/HP-CA8.htr> (Oct. 26, 2000).
Hugo, F., O’Connor, J.T., Ward, W.V. (1990). “Highway Construct*Ability Guite.” Investigation of Highway Project Constructibility, Research Project 3-6-88-1149, The Center for Transportation Research, The University of Texas at Austin.
Laguros, J.G., Miller, G.A. (1997). “Stabilization of Existing Subgrades to Improve Constructibility During Interstate Pavement Reconstruction.” National Cooperative Highway Research Program, Synthesis 247. National Academy Press, Washington, D.C.
Liman, M. (1995). “Constructibility Review Process Framework for Transportation Facilities.” MS thesis, Department of Civil Engineering, Texas A&M University, College Station, Texas.
Mendelsohn, R. (1999). “Constructibility Review Process: A Constructor’s Perspective.” <http://www.transportationusa.net/Article/fullarticle.asp?ID=145> (Oct. 26, 2000).
“North Carolina Contractor’s Association Participation in Constructibility Reviews.” (2000). <http://www.its.fhwa.dot.gov/quality/HP-NC12.htr> (Oct. 26, 2000).
O’Connor, J.T., Hugo, F., Stamm, E.M. (1991). “Improving Highway Specifications for Constructibility.” *Journal of Construction Engineering and Management*, 117(2), 242-258.

Expanded Use of Contractor-Performed Quality Control Processes for Acceptance of Highway Projects

Bleyl (2000). “City Organized Consultant and Contractor Quality Improvement Team to Recommend Ways to Build Projects Quicker, Better, Cheaper, and Safer--Peer Review by Other Cities” *FHWA Quality Journey - Best Practices* U.S. Department of Transportation (http://www.its.fhwa.dot.gov/quality/HP-COP1.htm)

Dobrowolski; Bressette (1998) “Development of quality control/quality assurance specifications by using statistical quality assurance for asphalt concrete pavements in California” *Transportation Research Record*. n 1632, Sep 1998. p 13-21

Fleckenstein; Allen (2000) “Development of a performance-based specification (QC/QA) for highway edge drains in Kentucky” *ASTM Special Technical Publication*. n 1390, 2000. p 64-71

Graper (1994) “Wireline data quality control: from wellsite to evaluated final product” *Log Analyst*. v 35 n 5 Sept-Oct 1994, p 39-42.

Hall; Pylant (1999) “First-year summary of the Arkansas hot-mix asphalt technician certification program” *ASTM Special Technical Publication*. n 1378, 1999. p 60-69

Parker; Hossain (1994) “Hot-mix asphalt mix properties measured for construction quality control and assurance” *Transportation Research Record*. n 1469, Dec 1994. p 9-17

Sanders; Rath; Parker (1994) “Comparison of nuclear and core pavement density measurements” *Journal of Transportation Engineering*-120-6. Nov-Dec 1994, p 953-966

Schmitt; Russell; Hanna; Bahia; Jung (1998) “Summary of current quality control/quality assurance practices for hot-mix asphalt construction” *Transportation Research Record*. n 1632, Sep 1998. p 22-31

Torres; McCullough (1991) “Dynamic quality control of flexible pavements.” *Journal of Transportation Engineering*. v 117 n 1 Jan-Feb 1991, p 23-32.

Appendix A.
Initial Questionnaire

To: District and Central Office Management, Design and Construction Engineers, Materials and Testing Engineers, Regional and District Engineers, Planners

From: Jeffrey S. Russell

Date: May 15, 2000

Re: Input for NCHRP 10-58, "Construction Engineering and Management Research Program"

The University of Wisconsin – Madison (UW-M) and the Texas Transportation Institute (TTI) are working on a research project, NCHRP 10-58, to determine problems affecting state highway agencies (SHAs). The research project is titled "Construction Engineering and Management Research Program."

The objective of our research project is to identify and rank the top 15 issues facing the SHAs in the construction engineering and management area, and then to create research programs to address those issues. The first phase of this process is an initial questionnaire, which is enclosed. We are using this questionnaire to identify current and future issues important to the SHAs. The second phase to this project will be additional data collection using the Delphi process where we will take these issues and narrow them down to 15 ranked priority issues. Once the issues are identified, we will perform the third phase, a comprehensive literature search on the 15 issues. This search will be used to identify issues such as prior research success and failures, implementation barriers, and gaps in existing states of knowledge. The fourth phase of this project consists of a 2-½ day workshop to discuss and revise the 15 issues. The final product of this research project will be 15 complete research problem statements that will include scope, purpose, and plans for implementation.

Enclosed you will find a short questionnaire. First it asks you to identify the top 5 present and future issues you believe are important to construction engineering and management. Second, it asks you to rank the issues currently important to state highway agencies. The issues are categorized into seven groups. They are: (1) State Highway Agency (SHA) staffing; (2) Innovative Contract Methods; (3) Quality Assurance/Quality Control (QA/QC); (4) Performance-Based Specifications; (5) Innovation in Construction Equipment; (6) Innovation in Rapid Test Methods and Procedures; and (7) Reconstruction Issues. Keep in mind that it is acceptable to overlap the issues in Part 1 and Part 2.

Please copy and distribute this questionnaire to other SHA personnel you feel would aid us in this research project. Personnel can include district and central office management, design and construction engineers, materials engineers, region/district engineers, and planners. We ask that all engaged fill out the questionnaire and fax it back to us at (608) 265-9860 by **June 2, 2000**.

We thank you for your time and look forward to receiving your input. Should you have any questions, please contact us at russell@engr.wisc.edu or (608) 262-7244.

cc: Stuart D. Anderson, Awad S. Hanna, David Trejo, Corey Hessen, State TRB Representatives

Enclosure

Initial Questionnaire for NCHRP 10-58
'Construction Engineering and Management Research Program''

Name: ____
Title: ______________________ **Organization:** ____________________
Number of years experience in transportation field: _____
Primary area of expertise in transportation field ________________________
Address: ____
Phone number: ______________ **Fax number:** ____________________
Email address: ____

Part 1: Present and Future Issues

Please list and rank the construction engineering and management issues that affect the state highway agencies today or will affect them up to 10 years in the future (1 being most important, 5 being least important).

Rank

____ A.) ____

____

____ B.) ____

____

____ C.) ____

____

____ D.) ____

____

____ E.) ____

____

Part 2: Past and Present Issues

The following is a list of issues that have affected the state highway agencies as identified from previous studies. Please place a check mark under the Issue column if you think the issue still affects the SHAs today.

If you have any issues in the groups that are not listed, please add them on the blank lines. Please note that if you would like to add additional issues than there are lines provided, do so on a separate page.

Once you have added your issues, please rank them from most important to least important in that category (1 being most important, 5 being least important).

Issue **Rank** ***1) State Highway Agency (SHA) Staffing***

____ ____ a.) Recruiting, testing, promoting, and retaining qualified personnel in highway construction.
____ ____ b.) Adequate/Existence of certification programs for construction engineering technicians.
____ c.) ____

____

____ d.) ____

____

2) Innovative Contract Methods

____ ____ a.) Development of feasible incentive and disincentive contract provisions covering contract time for assuring timely completion of projects.
____ ____ b.) Identification of causes of contract claims.
____ c.) ____

____

____ d.) ____

Issue **Rank** ***3) Quality Assurance/Quality Control (QA/QC)***

____ ____ a.) Development of cost effective sampling and testing process.

____ ____ b.) Implementation and evaluation of sampling and testing procedures in regard to quality as related to performance of the end product.

____ ____ c.) Training certification and retention of non-engineering personnel for quality assurance.

____ ____ d.) Contractor performed QA and QC testing.

____ e.) ____________________

____ f.) ____________________

4) Performance-Based Specifications

____ ____ a.) Development, implementation and evaluation of performance-based specifications for highway construction.

____ b.) ____________________

____ c.) ____________________

5) Innovation in Construction Equipment

____ ____ a.) Alternative construction methods and techniques to facilitate timely reconstruction.

____ ____ b.) Constructability and operability of transportation facilities.

____ c.) ____________________

____ d.) ____________________

6) Innovation in Rapid Test Methods and Procedures

____ ____ a.) Development of more effective rapid test methods and procedures.

____ b.) ____________________

____ c.) ____________________

7) Reconstruction Issues

____ ____ a.) Construction-zone traffic and safety problems.

____ ____ b.) Development of a preconstruction-activity planning and scheduling system.

____ ____ c.) Constructibility review.

____ d.) ____________________

____ e.) ____________________

Thank you for your time.

Please fax your completed questionnaire by **June 2** to:

Jeffrey S. Russell
University of Wisconsin –Madison
fax: (608) 265-9860
Email: russell@engr.wisc.edu

Phone: (608) 262-7244

Appendix B.
Results from Initial Questionnaire

Part 1 –Present and Future Issues –Write-In

Issue Statement	Frequency
Staffing	
Recruitment and Retention of qualified personnel	56
Reduced staffing with increased workload	8
Regain previous quality of plans	8
Competing for College graduates and/or Experienced Personnel with Private Sector	5
Adequate state inspectors and supervisors in the right place to staff projects	5
Staff and Contractor Expertise	4
Retirement Impact	3
SHA staffing levels and staffing requirements to enforce current specifications	1
Implementation of site manager	1
Use of in-house staff versus consultants for contract administration and construction inspection	1
Use of consultant provided services	1
Risk	
Claim Management	14
Safety	13
Contractor Quality Control	11
Contractor Warranties	10
Level of inspection (how much, privatization, etc.)	5
Recognition of risk - the cost of allocating risk to the contractor and developing ways to fairly allocate risk.	5
Increased Litigation/ Claims from Contractors	2
Insuring quality construction by using QC/QA (inspection by statistics)	2
Alternate methods for construction claims, mitigation, and dispute claims	1
Consultant Construction Inspection	1
Reduction of and quicker resolution of contract claims	1
Shifting of liability and insurance climate	1
Performance Based Specifications	
Development of performance based specifications for all aspects of highway construction	20
Performance Based Quality Control/ Quality Assurance tests	13
Specifications for innovative construction materials such as fiber reinforced plastics	2
Specs that allow innovative construction techniques without change orders	1
Materials	
Innovation in Construction Materials - Use of composites/ longer lasting materials	5
Use of Recycled Materials	5
Best practices for pavement construction	3
Specifications for innovative construction materials	3
Test methods representative of performance and rapid	3
Availability of material resources	2
Pavement Life	2
Materials sources	1
Non destruction testing	1
Quality of Materials	1

Part 1 Continued

Issue Statement	Frequency
Manage Traffic	
Traffic Management	9
Reconstruction of highways with high traffic volumes	7
Night and Weekend Construction	5
Development of strategies to minimize construction delays once construction starts	5
Constructibility & Maintaining Traffic of Rehabilitation Projects	5
Environmental	
Compliance with current and future environmental restrictions/requirements	23
Streamline the environmental permitting processes	2
Storm-water	1
Multi-Modal	
Design more multi-modal access into our highway systems (pedestrians, bicycles, transit)	4
ITS implementation and increased appropriate uses of mass transit	2
Funding	
Funding	22
Federally mandated/ recognized, but unresourced work	5
Raise pay for personnel in highway industry	2
Resources	2
Development and Implementation of life cycle cost procedures for reconstruction projects	2
Improved coordination with local agencies for locally funded projects on the state highway system	1
Adequate funding for non-transportation expenses - archeology, historic preservation, environmental stewardship projects, landscaping, etc.	1
Capitol Budgets (programs size, privatization, etc.)	1
Delivery Systems	
Innovative delivery systems and appropriate QA/QC	16
Privatization and Use of Consultants	8
Training	
Ability to train staff	7
Keeping all staff abreast of new technology and practice	4
Certification of personnel	3
Adequate trained staff	3
Update of construction manual/ procedures/ contract documents	3
Educate construction engineers in financial aspects of projects as related to funding for all projects	1

Part 1 Continued

Issue Statement	Frequency
Technology	
New technology - its use, impact and skills required	15
Information management - Cost effective system for collecting/sharing construction data/information, electronic documentation	14
Rapid construction methods that reduce traffic delay	5
Implementation of AASHTO transport site manager to assist in construction administration	2
Superpave implementation	2
NPDES - retrofitting existing facilities	1
ITS implementation and increased appropriate uses of mass transit	1
New mixing, placing, and other techniques to reduce the cost of concrete pavement	1
DOT Organization	
FWHA Controls	2
Implementation of new organization structures within DOT	2
Planning/ Marketing	
Public relations/impact on communities/ marketing	12
Timely Completion of projects	6
Optimize highway systems operations - utilize existing facilities to their fullest extent	5
Project Scheduling	5
Constructibility and quality plan development	4
Political Reaction to and interface with what can normally be expected with construction projects	3
Satisfying public expectations regarding impacts of construction projects	1
Construction Industry Capacity	1
Strategic Planning for Guidance	1
Utilities	
Utility agreements/RR agreements	3
Means to speed up third party interference, utilities, railroads, other government agencies	1
Integrating ADA compliance into SHA construction	
Integrating ADA compliance into SHA construction	1
Innovative Contracting	
Innovative Contracting	7
Realistic and consistent method of calculating user costs for ID contracts	1
Resource Agency Permit Monitoring	
Resource Agency Permit Monitoring	1

Part 2 –Past and Present Issues

Issue Statement	Frequency
1) SHA Staffing	
a) Recruiting, testing, promoting, and retaining qualified personnel in highway construction	106
b) Adequate/Existence of certification programs for construction engineering technicians	74
SHA Staffing - Write-Ins	
Training and workforce development	10
Dealing with Reduced Staffing Levels	8
Development of technical training for new employees	4
Decline in engineering graduates from US Universities	4
Adequate/existence of certification programs for construction inspectors	4
Adequate recognition (pay) for PE's all highway personnel	4
Control and coordination of use of consultant engineering firms	4
Keeping morals high in the work force	2
Development of specifications to minimize SHA staffing requirements	1
Training in contract management and oversight	1
Soft Skills such as dealing with other agencies	1
Summer work program for college students	1
Maintaining a continual balance of lower level and upper level inspection force	1
Adequate support from upper management in contract administration	1
Forecasting staffing needs	1
2) Innovative Contract Methods	
a) Development of feasible incentive and disincentive contract provisions covering contract time for assuring timely completion of projects	85
b) Identification of causes of contract claims	82
Innovative Contract Methods - Write-Ins	
Development of standardized design/build contracting procedures for highway and bridge construction	15
Warranties	12
Appropriate partnering and value engineering activities	7
Alternative construction methods/ Delivery systems	7
Dispute Resolution Process	5
Development of contract provisions that reward contractors for quality	5
On line Bidding	3
Liability issues related to design and construction of innovative financed projects	2
Development of Innovative Bidding Process	2
Identification of methods to avoid construction delays caused by utility conflicts	1
Develop/implement a "best bid/best value" method to replace the "lowest responsible" bid method	1
Develop innovative contractor and SHA insurance coverage for OCIPS and new technology	1
Selection of project time	1
Need to have a "large pool" of qualified contractors to bid on.	1

Part 2 Continued

Issue Statement	Frequency
3) Quality Assurance/Quality Control	
a) Development of cost effective sampling and testing problem	80
b) Implementation and evaluation of sampling and testing procedures in regard to quality as related to performance of the end product	97
c) Training certification and retention of non-engineering personnel for quality assurance	85
d) Contractor performed QC and QA testing	87
Quality Assurance/Quality Control - Write-Ins	
QC/QA testing that is better linked to performance	8
Development of reasonable "percent within limits" statistical specifications	3
Quality Construction	2
Clear penalties and/ or repair or replacement criteria for failures or non-compliance	2
Value Engineering	2
Contractors managing other contractors	1
Comprehensive geotechnical QAR including construction, design & materials	1
4) Performance Based Specifications	
a) Development, implementation and evaluation of performance - based specifications for highway construction	98
Performance Based Specifications - Write-Ins	
Warranties	10
Development of performance criteria related to service life	3
Development of strategies for implementation of above	3
Simplify control and approval of materials	1
Maintaining some expertise in house.	1
Overcoming fear of product liability	1
5) Innovation in Construction Equipment	
a) Alternative construction methods and techniques to facilitate timely reconstruction	89
b) Constructibility and operability of transportation facilities	71
Innovation in Construction Equipment - Write-Ins	
Equipment that reduces environmental impacts	6
Integrating new technology and equipment to facilitate the documentation of location/quantity of work performed (GPS, bar readers, etc)	3
Development of new materials that provide faster construction/less manpower	3
Safety Issues	2
Use of automated equipment for construction	1
Mobil equipment allowing shorter set up and take down due to shorter construction windows	1
Improved Equipment for placement of higher quality pavement mixes	1
Drilled Shaft Construction Equipment and Materials	1
Adopt innovative equipment & techniques used outside the USA	1
Illumination for night work	1
Noise reducing equipment	1
Smart Compaction technology equipment	1

Part 2 Continued

Issue Statement	Frequency
6) Innovation in Rapid Test Methods and Procedures	
a) Development of more effective rapid test methods and procedures	77
Innovation in Rapid Test Methods and Procedures - Write-Ins	
Development of NDT methods	5
End product/non destructive testing for lifetime performance, durability	3
Replacement of sodium sulfate soundness test	1
Replacement of nuclear based non-destructive test procedures with simpler non-nuclear based techniques	1
Development of test methods which are performance based and related to service life	1
Develop aggregate moisture sensitivity test	1
Development of above that are applicable to field use by contractor	1
7) Reconstruction Issues	
a) Construction-zone traffic and safety problems	103
b) Development of a preconstruction - activity planning and scheduling system	79
c) Constructibility review	85
Reconstruction Issues - Write-Ins	
Traffic handling during construction	6
Rapid Construction Techniques	5
Value Engineering	4
Past construction reviews	3
Night time work zones and their relationship to safety	2
Incident management in work zones	2
Safety auditing of reconstruction projects	2
Utility & RR agreements	1
Development of quality plans	1
ADA Compliance	1
Perform Market Research to determine customer's view point on how reconstruction projects should be built	1
Methods to allow contractors to get legally involved in constructibility	1

Appendix C.
Delphi Invitation Package

June 12, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

The University of Wisconsin-Madison and the Texas Transportation Institute (TTI) are teamed in a research project funded by the National Cooperative Highway Research Program (NCHRP), Project 10-58 entitled, *Construction Engineering and Management Research Program.* The objective of this research is to identify and prioritize approximately 15 key issues and opportunities for improving construction engineering and management (CEM) of transportation projects.

The purpose of this letter is to invite you to participate in a study to assess important transportation CEM issues. This is your opportunity to influence future research in the CEM area. Other participants will include experts and leaders in all aspects of highway construction including state highway agencies, general contractors, material suppliers, engineering consultants, and academics.

Phase I of the 10-58 research identified a large number of CEM issues through a two-page survey of state highway agencies. Over 100 responses were received from professionals involved in different areas of transportation projects. These responses represented almost all 50 states and experience of the respondents ranged from over 40 years to less than 1 year. Data analysis will reduce the number of issues based on frequency of citation and rank order.

In Phase II, the prioritization of these key issues affecting highway construction engineering and management will be assessed using the Delphi technique. A questionnaire will be sent to you and other expert panelists to evaluate level of importance and to prioritize the key issues identified from the Phase I survey. Additional issues can be suggested. The research team will analyze the Delphi survey data and will return your response with a summary of responses of all participants along with a second survey. The intent of the second survey is to clarify issues and rank new issues assessed in the first round. A third and final round *may be necessary* to move closer to a consensus. A more complete description of the Delphi process is attached for your information.

The information gathered and the summary group response should be of interest to you and your organization. Unlike most questionnaires, the group results will be sent to you in the package with the next survey. You will have the opportunity to revise your answers from the first-round questionnaire and prioritize new issues. It should be interesting for you to see where you stand, relative to your colleagues, on important issues in the area of CEM within the transportation construction industry.

We understand that your time is important. Each round of the Delphi process will take approximately 30 to 45 minutes to complete. The questionnaires can be submitted in one of two ways for your convenience, by mail, or e-mail.

If you agree to participate in this research project, the first-round questionnaire will be sent (by mail, or e-mail) in mid July 2000. The project team will analyze the results and send out the second-round questionnaire in late August 2000. If a third and final-round questionnaire is necessary to achieve a consensus on the 15 key issues, this questionnaire will be sent in late October 2000 and final results will be available to you in November 2000.

Please complete the attached form if you are interested in participating in this study and return by **June 30, 2000**. Since TTI is coordinating the Delphi study, please return your participation form to:

Dr Stuart D. Anderson, Ph.D.
Department of Civil Engineering or Fax: (979) 845-6554
Texas A&M University
College Station, TX 77843-3136

Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Dr. Stuart D. Anderson at (979) 845-2407 or s-anderson5@tamu.edu.

Sincerely,

Jeffrey S. Russell, Ph.D., P.E.
Professor

Stuart D. Anderson, Ph.D.
Associate Professor

Attachments (2)

BACKGROUND INFORMATION
Delphi Method and Application to this Study

The Delphi Method

The Delphi method is a process to collect data and information to solve nonanalytical problems. Used as a research tool, the process gathers knowledge from individuals, analyzes and combines the information to obtain a group consensus.

The Process

The information is gathered in a series of questionnaires or surveys called rounds. The first round is exploratory in nature and presents the participant with a standard questionnaire. The second round will present the participant with the group response with his or her response from the first round. The member has the opportunity to alter his or her answer or to voice his or her opinion about new issues collected in the previous survey. The third round, if necessary, will finalize the statistical response of the group to form a consensus.

The Advantages of Delphi

Delphi has three features over other data collection methods: (1) *anonymity*, (2*) controlled feedback* of results, and (3) *statistical group response* or consensus.

Anonymity –The members of the process are unknown to other members. This feature will help minimize the 'bandwagon effect." In public group meetings, one participant, possibly less knowledgeable, may be more vocal during discussion, potentially persuading more knowledgeable panelists. Also by keeping the participants unknown, one participant may change his or her answer to one question without publicly admitting that he or she has done so.

Controlled Feedback –The benefit to the participant of Delphi is gained by feedback of results collected in earlier rounds. The participant will be sent the group response of colleagues and other experts in the industry.

Statistical Group Response –The goal of Delphi is to move towards a group consensus. However, the end result, undoubtedly will display a range of opinions. The statistical group response is created to assure that the opinions of all participants in the surveys are represented.

The Application of Delphi

You have been asked to participate in the Delphi process for NCHRP Project 10-58 to help assess and prioritize engineering and management issues in the transportation construction industry. The goal of this project is to identify the most critical 15 issues or problem areas in need of future research investigation. If you agree to participate, you will be sent the first round questionnaire. The first questionnaire will ask you, in your opinion, to evaluate the importance and to rank issues affecting the industry. The second questionnaire will follow and will display the group response of the first questionnaire and new issues collected. You will be able to compare your response with the opinions displayed by the rest of the participants. The third questionnaire will be used, only if *necessary*, to eliminate gaps in the information collected in earlier rounds and to finalize the group response.

Time Commitment

The time commitment is minimal. Each round or questionnaire should take approximately 30 minutes to complete and submit.

Schedule

If you agree to participate in this research project, the first-round questionnaire will be sent (by mail, or e-mail) in mid July 2000. The project team will analyze the results and send out the second-round questionnaire in late August 2000. If a third and final-round questionnaire is necessary to achieve a consensus on the 15 key issues, this questionnaire will be sent in late October 2000 and final results will be available to you in November 2000.

NCHRP PROJECT 10-58
CONSTRUCTION ENGINEERING AND MANAGEMENT RESEARCH PROGRAM

Delphi Process Study –Participation Response Form

Name: ____

Organization: ____

Address: ____

____

Telephone: ____________________________

YES I will serve as a member of the panel of experts for this study. I understand that I will be providing input to a minimum of two and a maximum of three rounds of questionnaires.

If you prefer that the questionnaires be sent to an address other than the one used above, please provide the address here:

Address: ____

____

If you prefer that the questionnaires be sent to an e-mail address to view and submit electronically, please provide the e-mail address here:

E-mail: ____________________________

NO I will not be able to serve on the panel for this study.

If you know another individual involved in transportation construction engineering and management who may be interested in participating in this study, we would appreciate his or her name and address.

Name: ____

Organization: ____

Address: ____

____

Telephone: ____________________ E-mail: ______________________

Please send your response to: Dr. Stuart D. Anderson, Ph.D., Department of Civil Engineering, Texas A&M University, College Station, TX 77843-3136. Or Fax: (979) 845-6554.

Appendix D.
Delphi Invitation Follow-Up Letter

July 5, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Two weeks ago a letter was sent inviting you to participate in a study to assess and identify important transportation construction engineering and management (CEM) issues. This is your opportunity to influence future research in the CEM area. To date, 36 responses have been received from state highway agency officials, contractors, consultants, academics, and association representatives.

The University of Wisconsin-Madison and the Texas Transportation Institute (TTI) are teamed in a research project funded by the National Cooperative Highway Research Program (NCHRP), Project 10-58 entitled, *Construction Engineering and Management Research Program*. The objective of this research is to identify and prioritize approximately 15 key issues and opportunities for improving CEM of transportation projects.

The prioritization of these key issues affecting highway construction engineering and management will be assessed using the Delphi technique. A questionnaire will be sent to you and other expert panelists to evaluate level of importance and to prioritize the key issues. The research team will analyze the Delphi survey data and will return your response with a summary of responses of all participants along with a second survey. The intent of the second survey is to clarify issues and rank new issues assessed in the first round. A third and final round *may be necessary* to move closer to a consensus.

We know there are numerous demands on your time. Each round of the Delphi process will take approximately 30 to 45 minutes to complete. The questionnaires can be submitted in one of two ways for your convenience, by mail or e-mail. Please complete the attached form if you are interested in participating in this study and return by **July 12, 2000**. Since TTI is coordinating the Delphi study, please fax your participation form to Dr. Stuart D. Anderson, Ph.D. at Fax: (979) 845-6554.

Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Dr. Stuart D. Anderson at s-anderson5@tamu.edu or (979) 845-2407.

Sincerely,

Jeffrey S. Russell, Ph.D., P.E.
Professor

Stuart D. Anderson, Ph.D.
Associate Professor

Appendix E.
Delphi Survey Round One

July 20, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Thank you for agreeing to be one of our expert panelists for NCHRP 10-58, *Construction Engineering and Management Research Program*. Your participation in this study is sincerely appreciated.

The prioritization of key issues affecting highway construction engineering and management will be evaluated using the Delphi technique. The Delphi process is composed of a series of surveys sent to knowledgeable participants in which the goal is a combined group response. The research team will analyze the survey data collected from the first questionnaire and will return a summary of responses to you with the second round survey. The intent of the second round is to clarify issues and rank new issues identified in the first round. A third and final round may be necessary to reach group consensus. The first round Delphi questionnaire is attached and contains five sections.

In the first section, general background information about you and your organization is requested. In the following sections, you are asked to enter your assessment of the importance and priority of critical issues in need of future research and development in the highway construction industry in the area of construction engineering and management. The issues presented are those ranked as most important by state highway agencies through a Phase I survey conducted in May 2000 for this project.

Please complete the attached questionnaire and return it by **August 4, 2000**. If possible, please fax your completed questionnaire to us and then mail the hard copy. Our fax number is (409) 845-6554.

Additional background, project, and contact information are available at the NCHRP Project 10-58 website (http://welcome.to/nchrp10-58).

The second questionnaire with the summary of initial responses will be provided approximately two to three weeks after the due date of the first survey. Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Dr. Stuart Anderson at s-anderson5@tamu.edu or (409) 845-2407.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Attachments (1)

National Cooperative Highway Research Program
Project 10-58
Construction Engineering and Management Research Program

FIRST-ROUND QUESTIONNAIRE

A Study by

The University of Wisconsin –Madison
And
The Texas Transportation Institute

July 20, 2000

BACKGROUND

The University of Wisconsin-Madison and the Texas Transportation Institute are teamed in research funded by the National Cooperative Highway Research Program (NCHRP), Project 10-58 entitled, *Construction Engineering and Management Research Program*. The objective of this research is to identify and prioritize approximately 15 key issues and opportunities for improving construction engineering and management (CEM) of transportation projects. This research is sponsored by the AASHTO Highway Subcommittee on Construction.

The Federal Highway Administration (FHWA) has funded two similar projects in the past to assess critical issues and areas requiring additional research. Issues collected during the studies (FHWA-HO-79-1, FHWA-RD-90-034) were combined into a Phase I survey for this research project to validate their relevance to the highway construction industry today.

The Phase I survey was mailed in May 2000 to over 750 professionals including State Highway Agencies (SHAs), consultants, contractors, and associations. The respondents included district and central office management, design and construction engineers, materials engineers, district engineers, and planners. Responding professionals ranked the importance of the issues collected from the past studies and identified new issues that they viewed as critical to the industry today and in the next 10 years.

Approximately 120 Phase I surveys were returned and analyzed and the results were used to prepare the first-round Delphi questionnaire that is attached. Each issue that appears on the attached questionnaire was either a critical issue from a past FHWA study (validated by SHAs) or a critical issue identified as a new issue in a majority of surveys received from SHAs.

INSTRUCTIONS

The attached questionnaire consists of five (5) parts.

Part I requests contact information and details about your experience in the highway construction industry. The set of questions in Part I, *and only Part I*, has been tailored specifically to your business area (SHA, Contractor, Consultant, Material/Equipment Supplier, FHWA, Association, or Academic). Part I questions for other business areas are not included in your survey. Questions for experts representing other business areas also inquire about experience in construction engineering and management in the highway industry. The information gathered in Part I will enable the research team to separate data and validate the Phase I survey results.

Part II requests that you evaluate issues, identified in the Phase I survey, facing the highway construction industry. Indicate the importance of the following issues according to the need for **future research**. "Extremely Important (5)" would specify that you believe that the issue is very critical to highway construction engineering and management necessitating future research. "Not Important (1)" would specify that the issue is not a significant problem in the industry and is not in need of future research. The mid-range values (2,3,4) imply different degrees of importance.

Part III requests that you rank **only the 15 most important issues** from the Part II list. You should enter the issue number from Part II. A rank of "1" indicates that you believe that the issue has the highest priority of all the issues assessed.

Part IV is divided into two sections. Part IV (A) will give you an opportunity to enter other issues that you feel have been omitted from the list provided in Part II. Part IV (B) will allow you to rephrase issue statements from the list in Part II to improve clarity and/or enhance understanding of the importance of future research and development for the issue.

Part V will allow you to enter any general comments about the issues assessed under this research project.

FIRST-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((DOTs)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ____ Date: ________________

Position / Job Title: ____

State Highway Agency: ____

E-mail: ______________________________ Phone: _______________________

1. What is the total number of years you have worked in the transportation industry?

   Number of years: Public _______ Private _______ Total _______

2. Indicate the jurisdiction of the state highway agency office where you *currently* work.

   - ❑ Central / State Office
   - ❑ District Office
   - ❑ Field Office
   - ❑ Other : ____

3. Please specify your area(s) of work within the transportation industry *during the last 15 years* by indicating how many years you have worked in each area. If you use 'Other" please specify.

Description of Responsibility	**No. of years**
Agency Management	
Project Management and Engineering	
Pavement / Bridge Design	
Construction Engineering / Administration	
Materials	
Traffic Engineering	
Other:	
Total	15

4. Which of the *Descriptions of Responsibility* listed above would you characterize as your primary "Area of Expertise?"

   ____

FIRST-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((Contractors)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ________________________________ Date: ______________

Position / Job Title: ________________________________

Organization: ________________________________

E-mail: ______________________ Phone: ________________

1. What is the total number of years you have worked in the transportation construction industry?

   Number of years: Public _______

   Private _______

   Total _______

2. Please specify your area(s) of work within the transportation industry *during the last 15 years* by indicating how many years you have worked in each area. If you use "Other" please specify.

Description of Responsibility	**No. of years**
Executive Management	
Project Management	
Field Supervision	
Construction Engineering	
Other:	
Total	15

3. Which of the *Descriptions of Responsibility* listed above would you characterize as your primary "Area of Expertise?"

   ____

FIRST-ROUND QUESTIONNAIRE
NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((Suppliers)))
RESPONDENT INFORMATION QUESTIONNAIRE

Name: ________________________________ Date: ______________

Position / Job Title: ________________________________

Organization: ________________________________

E-mail: ______________________ Phone: ________________

1. What is the total number of years you have worked in the transportation industry?

   Number of years: Public _______

   Private _______

   Total _______

2. Please specify your area(s) of work within the transportation industry *during the last 15 years* by indicating how many years you have worked in each area. If you use "Other" please specify.

Description of Responsibility	**No. of years**
Executive Management	
Project Management	
Product Development / Product Research	
Manufacturing	
Sales and Marketing	
Other:	
Total	15

3. Which of the *Descriptions of Responsibility* listed above would you characterize as your primary "Area of Expertise?"

   ____

FIRST-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((Consultants)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ______________________________ Date: ____________

Position / Job Title: ______________________________

Organization: ______________________________

E-mail: ____________________ Phone: ________________

1. What is the total number of years you have worked in the transportation industry?

   Number of years: Public _______

   Private _______

   Total _______

2. Please specify your area(s) of work within the transportation industry *during the last 15 years* by indicating how many years you have worked in each area. If you use "Other" please specify.

Description of Responsibility	**No. of years**
Executive Management	
Project Management	
Design Engineering	
Other:	
Total	15

3. Which of the *Descriptions of Responsibility* listed above would you characterize as your primary "Area of Expertise?"

   ____

FIRST-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((FHWAs)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ________________________________ Date: ______________

Position / Job Title: ________________________________

Organization: ________________________________

E-mail: ______________________ Phone: __________________

1. What is the total number of years you have worked in the transportation-related industry?

   Number of years: Public _______

   Private _______

   Total _______

2. Please specify your area(s) of expertise within the transportation industry by indicating how many years you have worked in each area *during the last 15 years*. If you use 'Other" please specify.

Area of Expertise	**No. of years**
Pavement	
Bridges	
Research	
Other:	
Total	15

3. Which of the *Areas of Expertise* listed above would you characterize as your primary Area of Expertise?

   ____

FIRST-ROUND QUESTIONNAIRE
NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((Associations)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ______________________________ Date: ____________

Position / Job Title: ______________________________

Organization: ______________________________

E-mail: ______________________ Phone: __________________

1. What is the total number of years you have worked in the transportation industry?

   Number of years: Public _______

   Private _______

   Total _______

2. Please specify your area(s) of expertise within the transportation industry by indicating how many years you have worked in each area *during the last 15 years*. If you use "Other" please specify.

Area of Expertise	**No. of years**
Design	
Construction	
Management	
Research	
Materials	
Other:	
Total	15

3. Which of the *Areas of Expertise* listed above would you characterize as your primary Area of Expertise?

   ____

FIRST-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART I (((Academics)))

RESPONDENT INFORMATION QUESTIONNAIRE

Name: ____________________ Date: ____________

Position / Job Title: ______________________________

Organization: ______________________________

E-mail: ____________________ Phone: ____________________

1. What is the total number of years you have worked in the transportation construction industry?

   Number of years: Industry _______

   Education _______

   Total _______

2. Please specify your area(s) of research within the transportation industry. Check the appropriate box(es). If you use 'Other" please specify.

Area of Research
❑ Contract Administration
❑ Construction Administration
❑ Construction
❑ Pavement Design
❑ Bridge Design
❑ Project Management
❑ Materials
❑ Other:

PART II

ASSESS IMPORTANCE OF ISSUES

Indicate the importance of the following issues according to the need for **future research**. Evaluate each issue using the scale provided. 'Extremely Important (5)" would specify that you believe that the issue is very critical and necessitates future research. 'Not Important (1)" would specify that the issue is not a significant problem to highway construction engineering and management and is not in need of future research.

Each issue that appears in the list below was either a critical issue from a past FHWA study (validated by SHAs in the Phase I survey) or a critical issue identified as a new issue in the majority of Phase I surveys received from SHAs.

Please circle your choice for each issue.

There is no significance in the order of the issues listed below.

1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
2. Integration of contractor warranties into project contracts				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
3. Compliance with current and future environmental restrictions/requirements				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
4. Contractor performed QC and QA testing				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
5. Alternative construction methods and techniques to facilitate faster reconstruction				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

6. Deficiencies in quality and clarity of construction plans				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
7. Night and weekend construction to reduce traffic implications				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
8. Allocation of financial risk between the agency and contractor				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
9. Impact of construction projects on communities and necessary communication between agency/contractor and general public				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
12. Training and workforce development of personnel				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
13. Safety of public and workers during highway reconstruction and maintenance				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
14. Appropriate partnering and value engineering activities				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
16. Use of pre-construction/pre-project planning and project scheduling systems				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
17. Operability of construction equipment in relation to constructibility of transportation facilities				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
18. Training certification and retention of non-engineering personnel for quality assurance				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
19. Development, implementation, and evaluation of performance based specifications for highway construction				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
20. Management of contract claims (including identification of causes of claims)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
22. System for electronically collecting and distributing construction information				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
24. Construction equipment that reduces environmental impacts				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
25. Use of recycled materials in highway construction				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
26. Availability and adequacy of certification programs for construction engineering technicians				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
27. Strategies to minimize construction delays once construction starts				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
28. Use of more durable materials in highway construction				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
29. Review of the constructibility of transportation facilities in the planning and design phases				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
32. Development of standardized design-build contracting procedures for highway and bridge construction				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
33. Management of traffic during highway construction projects –Project staging of highway projects				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

PART III

RANK ISSUES

Please rank only the **top 15** construction engineering and management issues from the list assessed in Part II, in order of importance. A rank value of "1" being most critical and in need of future research and "15" being not as critical as "14". In the spaces provided, please enter the "issue number" from Part II. **Please enter one, and only one, issue-number per space**.

For example: If you believe that the *most critical* issues is "Compliance with current and future environmental restrictions/requirements" (Number 3 from the list of issues in Part II), then you should place a "3" in the space under the "ISSUE (Number)" column next to the RANK of "1."

RANK	ISSUE (Number)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

PART IV - A

IDENTIFY ADDITIONAL ISSUES

Please identify any critical issues affecting highway construction engineering and management that have been omitted from the list assessed in Part II.

A. ____

____

B. ____

____

C. ____

____

D. ____

____

E. ____

____

PART IV - B

REPHRASE ISSUES FROM PART II

Please edit and reword any issues from the list assessed in Part II if you feel that an issue(s) has been phrased incorrectly or unclearly. If you believe that a current issue statement(s) from Part II is not a critical issue but can be rephrased in a way to emphasize an important research need, please indicate below.

Write the issue number from Part II in the space provided on the left and the rephrased issue statement on the adjacent sets of lines provided.

____. ____

____

____. ____

____

____. ____

____

____. ____

____

____. ____

____

PART V

COMMENTS

If you would like to provide any general comments, please provide those in the space provided on this page (use additional sheets if necessary). Please note that such comments will greatly help us better understand and incorporate your perspectives. Thank you.

Thank you for your participation in the first-round survey.

Please fax your completed survey to:

Dr. Stuart Anderson Fax: (409) 845-6554

Then mail the hard copy to:

Dr. Stuart D. Anderson, Ph.D.
Department of Civil Engineering
Texas A&M University
College Station, TX 77843-3136

Questions contact

Dr. Stuart Anderson at:
Email: s-anderson5@tamu.edu
Phone: (409) 845-2407

or

Andrew J. Damron at:
damron@tamu.edu
(409) 845-9300

Please return by: August 4, 2000

Thank you.

Appendix F.
First Round Delphi Follow-Up Letter

August 4, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Two weeks ago the First-Round Delphi Questionnaire for the project, NCHRP 10-58 *Construction Engineering and Management Research Program*, was sent to you. This is your opportunity to influence future research in the highway construction engineering and management (CEM) area. To-date, 38 completed questionnaires have been received from state highway agency officials, contractors, consultants, academics, and association representatives. If you have already completed and returned the questionnaire, please accept our sincere thanks.

If you did not receive the questionnaire, or it has been misplaced, please contact Andrew J. Damron at damron@tamu.edu or (409) 845-9300 and another copy will be sent to you. The second-round questionnaire will report a summary of the responses on the highway CEM issues assessed and prioritized in the first-round questionnaire. It is very important that your view be represented. We know there are numerous demands on your time. The first-round questionnaire should take approximately 30-45 minutes to complete.

If possible, please return the first-round questionnaire by **August 11, 2000**. Please fax your complete questionnaire to Dr. Stuart Anderson at (409) 845-6554.

Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Andrew J. Damron at damron@tamu.edu or (409) 845-9300.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Appendix G.
Experience of the Delphi Participants

ATTACHMENT 1

STATE HIGHWAY AGENCY

RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	**Private**	**Total**
Average (years)	25.6	1.4	27.0
High (years)			43
Low (years)			8

2. Jurisdiction of the state highway agency office where respondents *currently* work

	Number of Respondents
Central / State Office	32
District Office	7
Field Office	0
Other	1

3. Primary "Area of Expertise"

Area of Expertise	**Number of Respondents**	**Years Per Respondent (During last 15) spent in Area**
Agency Management	4	11.8
Project Management and Engineering	7	8.9
Pavement / Bridge Design	1	3.0
Construction Engineering / Administration	21	8.9
Materials	5	7.4
Traffic Engineering	2	11.5
Other	--	--
Total	40	9.0

"Years Per Respondent (During last 15) spent in Area" was calculated as an average of the years spent in the Primary "Area of Expertise" during the last 15 years for the respondents that indicated that specific area.

For example: the 4 SHA professionals that indicated Agency Management as their "Area of Expertise" have spent an average of 11.8 years in Agency Management during the last 15 years.

CONTRACTOR
RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	Private	Total
Average (years)	8.0	21.8	29.8
High (years)			42
Low (years)			20

2. Primary "Area of Expertise"

Area of Expertise	Number of Respondents	Years Per Respondent (During last 15) spent in Area
Executive Management	3	12.3
Project Management	1	7.0
Field Supervision	1	10.0
Construction Engineering	--	--
Other	--	--
Total	5	10.8

MATERIAL/EQUIPMENT SUPPLIER
RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	Private	Total
Average (years)	0.0	42.0	42.0
High (years)			42
Low (years)			42

2. Primary "Area of Expertise"

Area of Expertise	Number of Respondents	Years Per Respondent (During last 15) spent in Area
Executive Management	--	--
Project Management	--	--
Product Development / Product Research	1	6.0
Manufacturing	--	--
Sales and Marketing	--	--
Other	--	--
Total	1	6.0

CONSULTANT

RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	**Private**	**Total**
Average (years)	12.2	14.4	26.6
High (years)			49
Low (years)			13

2. Primary "Area of Expertise"

Area of Expertise	**Number of Respondents**	**Years Per Respondent (During last 15) spent in Area**
Executive Management	1	15.0
Project Management	3	7.3
Design Engineering	1	5.0
Other	--	--
Total	5	8.4

FHWA

RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	**Private**	**Total**
Average (years)	24.0	4.5	28.5
High (years)			40
Low (years)			14

2. Primary "Area of Expertise"

Area of Expertise	**Number of Respondents**	**Years Per Respondent (During last 15) spent in Area**
Pavement	1	9.0
Bridges	--	--
Research	2	12.5
Other (Traffic management)	1	14.0
Total	4	12.0

ASSOCIATION

RESPONDENT INFORMATION

1. Total number of years respondents have worked in the transportation industry

	Public	**Private**	**Total**
Average (years)	11.5	11.5	23.0
High (years)			25
Low (years)			21

2. Primary "Area of Expertise"

Area of Expertise	**Number of Respondents**	**Years Per Respondent (During last 15) spent in Area**
Design	--	--
Construction	--	--
Management	--	--
Research	1	15.0
Materials	--	--
Other (Pavement design)	1	10.0
Total	2	12.5

ACADEMIC

RESPONDENT INFORMATION

1. Total number of years you have worked in the transportation industry

	Industry	**Education**	**Total**
Average (years)	20.0	13.0	33.0
High (years)			33
Low (years)			33

2. "Areas of Research"

Area of Research	**Conducted by panelists**
Contract Administration	Yes
Construction Administration	Yes
Construction	Yes
Pavement Design	
Bridge Design	
Project Management	Yes
Materials	Yes

ATTACHMENT 2

New Issues Identified from the First-Round Delphi Questionnaire

The numbers in parentheses following each comment indicate respondent identification numbers for internal reference purposes only.

The following is a complete list of new issues identified by respondents of the First-Round Delphi Questionnaire:

Staffing
- Development of personnel skilled in planning and scheduling (#217)
- I believe an effort must be made at the high school level to begin educating potential employees about the benefits of pursuing a career in the highway industry. Discuss all areas that are available. It's impossible to train them if you don't first attract them. (#33)
- Impact of fluctuations in program values on industry capacity, ability to recruit and retain personnel, and quality of work. (#121)

Performance Based Specifications
- Contractor mix design to meet performance tests specified. (#73)

Materials
- Development of validated performance prediction models for pavements (#177)
- Materials and construction variability and its effect on construction performance (#20)
- There is a push to move to a higher specification such as the superpave, we need to make sure that this push does not reduce the availability of the resource "sand and rock" (#83)
- Pavement smoothness-incentive and disincentives. (#73)
- Impact of less material sources in regions/areas of US –what alternative materials are there? (#194)

Traffic Management
- Uniformed law enforcement on all high profile projects (Night/Day) (#57)
- Development of standard road user costs (being done NCHRP 2-23) (#141)
- Use of Motorist Assistance Patrol (MAP) during construction (Paid for in Contract) (#188)
- Ability to effectively manage multiple construction and multiple lane closures to minimize the impact to the public, contractor and maintenance focus (#16)
- Integration of the consideration of operational performance of the facility and impact on traffic into all phases of project planning, design, implementation, and maintenance (#7)
- Development of the recommended guidance and best practices to support real time management of travel and traffic operations into the appropriate types of highway improvement projects (#7)
- Development of the recommended procedures, specifications, legislation or policies, training, and best practices to allow all phases of real time travel management and traffic control to be provided by a contractor or sub-contractor on a roadway improvement project. This is different from the normal traffic control plan, it could involve real time traveler information, incident management, traffic surveillance, and coordination of traffic conditions and various events with appropriate local agencies and service providers (e.g. enforcement, EMS, towing) (#7)

Environmental
- Constructing roads in federal land agencies right-of-way, federal, environmental requirements (#194)

Technology

- Reduce gap between computer-literate staff and construction supervisors, craftsmen and workers (#217)
- Restructuring construction engineering staffing requirement to new electronic technology (#155)
- Finding new and improved methods for documenting and paying for quantities (#155)
- Changing current laws and regulations to match new technology (#155)
- Electronic bidding (#150)
- Using improved automation technology to support the seamless transfer of data from design through construction. (#137)
- Implementing systems to integrate bid estimating, project management and construction management. (#137)
- Need a better "tool"/"program" to gather data in the field to fulfill requirements of new DBE regulations (monitor eligibility of DBE, subcontractor payments, DBE qualifications, etc) and to compile statewide data (#16)

Planning/Marketing

- A new look at "Life Cycle Costing,"–Does our current practice reflect what is actually is happening in the field (#39)
- Prediction of construction performance and life cycle costs (#20)
- Consider reconstructability in initial design. (#73)
- Methodology for developing contract time (#175)
- Methodology to accurately determine the extent of deterioration of existing facilities (#175)
- Development or integration of the measures of effectiveness to account for transportation operations into existing and future methodologies and tools used by practitioners throughout the project development process (#7)
- Development of the recommended guidance and best practices of the analysis, tools, and level of effort appropriate to assess the impact of different improvement alternatives, construction staging, and traffic control plans on operation of facility (#7)
- Development of standard model specifications, contracts, procedures which minimize time and variation in individual state implementation (#213)

Innovative Contracting/Delivery Systems

- Creating a climate to foster partnering between government and industry (#29)
- Applying disciplines to contractors –Requires conformance with contract requirements (#217)
- Getting quality into the prequalification process (#143)
- Design build (#150)
- Investigate arbitration (#150)
- Cost effectiveness of various specifications criteria (#20)
- Statistical evaluation of QC/QA and statistical acceptance (#152)
- Customer forced design and construction (#152)
- Impact of delivery models (eg. In-house inspection, TPM, D/R) on quality of work and costs (including claims. (#121)

Testing

- Non-destructive density testing method for bituminous-non-nuclear (#150)

Other

- More flexibility of Federal Funding given to states so that projects can be advertised when appropriate. (#187)
- Relationship with regulatory agencies (D.E.P.) needs to be addressed to allow for more practicality. (#187)
- Effects of "Anti-Highway" groups (#42)
- Changes in Nationwide Permit 3 and impact on pipe/culvert maintenance activities (#204)
- Determination of construction program performance measures which are consistent across state boundaries (#205)

ATTACHMENT 3

Restated Issues from the First-Round Delphi Questionnaire

The numbers in parentheses following each comment indicate respondent identification numbers for internal reference purposes only.

The following is a complete list of restated issues from the First-Round Delphi Questionnaire:

(1) Feasible incentive and disincentive contract provisions which assure . . (#39)

(4) Contractor quality control (QC) and quality assurance (QA) are separate form "acceptance." If you are asking "contractor performed acceptance testing," then I would rank this a (1) "Not important." If you are voting the importance of contractor owning QC and taking responsibility for QC, then this would get a (5) "Extremely Important." (#152)

(5) Alternative construction methods and technologies to facilitate better (faster, higher quality, longer life, more cost effective) reconstruction (#86)

(6) Deficiencies in quality and clarity of construction contract documents (drawings, bid documents, specifications) (#20)
(6) Appropriate accuracy in quality and clarity of construction plans. (#172)

(7) Identifying problems brought on by nighttime construction (#219)

(8) Fair allocation of financial risk between the agency and contractor (#143)

(11) Performance based QC/QA tests –validated for environmental and load associated stresses (#177)

(12)&(18) Combine: Training and certification of construction and inspection workforce (#213)

(14) "Partnering" and "value engineering" are two different animals; partnering is a "5" for me and value engineering is a "2". (#42)

(17) ??? (#39)
(17) Construction equipment designed for reconstruction work. (#172)

(22) System for seamless collection and distribution of design and construction information. (#137)
(22) Evaluation of DOT's contract information systems and identification of "shadow: systems. (#172)

(27) Cost avoidance strategies to mitigate delays during construction. (#172)

(30) Develop and implement reputable testing that will measure the quality and durability of a product such as concrete or asphalt pavement after the product is installed and ready for use (#155)

ATTACHMENT 4

Comments from the First-Round Delphi Questionnaire

The numbers in parentheses following each comment indicate respondent identification numbers for internal reference purposes only.

The following is a complete list of comments from the First-Round Delphi Questionnaire:

We must continually try to solve problems, not treat symptoms. All efforts should be expanded towards a better project, even if it does not match the specification in all cases. We must remember what we are trying to accomplish in the end, and why, and be less concerned with how we can get there –the product is more important than the process. (#86)

Safety and public concerns should be highly rated in any survey. However the vast majority of the economic resources are devoted to maintaining and improving the infrastructure. Reliable performance prediction models and testing would open the process to innovation and reduce owner's risks of accepting such innovation. Incremental extensions in infrastructure life would yield huge cost benefits. (#177)

I am very interested in the results of the survey. Can you break it down between the public and private respondents? (#39)

People issues are by far the most critical facing the entire construction industry. We must do much more to recruit, train, and retain personnel. Everything from equipment design to pay and benefits needs to be reevaluated. (#209)

The world is moving into a new age of information and electronic technology. Transportation, especially construction engineering needs to read the change and take advantage of this technology. (#155)

This was an excellent questionnaire to fill out. Easy to read and didn't take much time to complete. User friendly. (#150)

To meet public demands we must be innovative in delivering quality finished projects. This clearly points out the need to become more open minded to new and better ideas. (Changes) The ranking of issues supports the above statement. (#57)

The major issues seem to be in quicker construction, less motorist interference, need of quality and addressing shortage of educated and trained technical personnel. (#141)

Many delays and claims are caused by the inflexibility of regulatory agencies, such as Dept. of Environmental Protection, regarding minute changes that occur due to field conditions being slightly different from the plans and permit plates. (#187)

A speedier method to evaluate new methods, materials and machinery is needed so that new technology can find its way into use more quickly. (#73)

My background is heavy in design and light in construction. My ranking of issues will probably reflect this and should be weighed accordingly. (#189)

Issues which are similar eg 10, 12, and 15 and 4, 11, and 19. They need to be combined. There is a risk that several related issues would be ranked low, whereas a single issue would not split the vote and be ranked high. (#121)

In ranking the issues I reviewed my top issues and arranged them based on, 1. Safety, 2. Environment and Community, 3. Constuctability/Timeliness, 4. Traffic delay avoidance, 5.QC/QA (#172)

The construction management issues that I feel are critical can be categorized into three groups. 1.Quality of plans, constructability errors omissions etc which all lead to potential claims and time delays construct extensions ect. 2. Fast-tracking construction –New construction methods, innovations, new technologies. 3.Performance specs-warranties-QC/QA. These all impact training, recruiting, agency resources, consultant resources. (#212)

Many of the issues have a common theme and could be grouped to define a comprehensive research project. It will be helpful to maintain these specific issues for development of problem statements. (#118)

Improvement in the quality of plans and specifications and reducing of impacts to the traveling public will help resolve many issues. Training and recruiting of youth to enter the transportation area –both at the technical and craft levels –is extremely important. (#175)

Some of the issues identified are important construction issues but they do not lend themselves very well to research (i.e. issue 6, 15, 18). The management of contract claims has always been difficult to apply research to. (#216)

My priorities are 1 – People, 2 – Responsibility-contractor warranties, 3 – Materials and technology. (#199)

After reviewing my rankings I wonder if I have ranked #8 high enough. There is increasing pressure to reduce design time, bid document preparation time, advertising time and working days; restrict weather day allowances, QC/QA, increase liquidated damages, add warranties, require specialty type certification (QP1, QP2, QP3 for painting contractors), pre job audit and qualification for steel fabricators, welding certification, night-time construction, traffic czar to approve lane closures, storm water pollution control, etc.) How are these cumulatively affecting the relative risk between the owner and contractor and the public? (#16)

List is incomplete, because you have basically focused on traditional roadway and design construction issues. Industry has a major gap that needs to be overcome by integrating the actual operation of the facility and MOE's used to make decisions need to account for impact on users. To date most of the focus has been provided on soil, materials, pavements, structures, design elements and techniques. Recent advances have expanded focus on environment but the discipline and consideration of traffic operations continues to be ignored and omitted throughout most of the project planning and development process. This is due to the focus of most DOT's on only building the roadway infrastructure, versus expanding their role and responsibility to also safely manage and operate travel on this facility. As such the appropriate electronic infrastructure required to manage and operate various traffic management strategies and monitor conditions is also needed. There is a disproportionate amount of staff allocated and funding spent on research and roadway construction on all phases of project planning and development except traffic operations and necessary supporting electronic infrastructure. Need to make sure you have a balanced number of people on this panel to ensure appropriate representation of interests across all disciplines. In final report, research needs to be clarified to include long term research, operational tests, technical guidance and recommended practices, training, outreach and awareness. In most cases, resources need to be allocated on raising the state-of-the-practice, versus long range research to extend the state-of-the-art. (#7)

In many cases there must be a progression in the development of the 33 issues listed, since several of the more simplistic ones are needed to implement other, more complex ones. For example, contractor QC is needed to effectively implement performance based specifications. Some current ??? exist now including better materials, less delays, and night work. The current state of design build is a disaster. Utah is currently the only state with a true DB approach. (#213)

ATTACHMENT 5

SHA vs. Other results from the First-Round Delphi Questionnaire

The table below displays the State Highway Agency (SHA) responses (n=35) compared to all other responses (contractors, consultants, suppliers, FHWA, academics, and association professionals) (n=18).

No.	Issue Statement	SHA Rank	Other Rank
13	Safety of public and workers during highway reconstruction and maintenance	1	3
5	Alternative construction methods and techniques to facilitate faster reconstruction	4	1
15	Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	2	9
23	Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	6	2
33	Management of traffic during highway construction projects –Project staging of highway projects	5	6
12	Training and workforce development of personnel	7	10
19	Development, implementation, and evaluation of performance based specifications for highway construction	11	5
11	Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	12	4
27	Strategies to minimize construction delays once construction starts	13	7
10	Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	3	28
30	Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	14	11
28	Use of more durable materials in highway construction	15	8
21	Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	10	19
9	Impact of construction projects on communities and necessary communication between agency/contractor and general public	8	26
1	Feasible incentive and disincentive contract provisions assuring more timely completion of projects	16	17
29	Review of the constructibility of transportation facilities in the planning and design phases	17	15
3	Compliance with current and future environmental restrictions/requirements	9	33
6	Deficiencies in quality and clarity of construction plans	18	16
4	Contractor performed QC and QA testing	21	13
7	Night and weekend construction to reduce traffic implications	23	12
31	Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	26	14

No.	Issue Statement	SHA Rank	Other Rank
32	Development of standardized design-build contracting procedures for highway and bridge construction	25	18
2	Integration of contractor warranties into project contracts	22	22
18	Training certification and retention of non-engineering personnel for quality assurance	19	25
20	Management of contract claims (including identification of causes of claims)	20	30
22	System for electronically collecting and distributing construction information	24	27
8	Allocation of financial risk between the agency and contractor	27	21
16	Use of pre-construction/pre-project planning and project scheduling systems	28	24
14	Appropriate partnering and value engineering activities	30	20
26	Availability and adequacy of certification programs for construction engineering technicians	29	29
25	Use of recycled materials in highway construction	32	23
24	Construction equipment that reduces environmental impacts	31	31
17	Operability of construction equipment in relation to constructibility of transportation facilities	33	32

Appendix H.
Delphi Survey Round Two

August 21, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Thank you for completing the First-Round Delphi Questionnaire for the research project NCHRP 10-58*, Construction Engineering and Management Research Program*. We appreciate the valuable time you have given us.

The response from the first-round questionnaire was excellent. To-date, we have received 53 completed questionnaires. The Delphi panelists include 35 from state highway agencies and 18 from other organizations (contractors, consultants, FHWA, associations, academics) involved in the highway construction industry.

Please complete the attached, second-round, questionnaire and return it by **August 31, 2000**. If possible, please fax your completed questionnaire to us and then mail the hard copy. Our fax number is (979) 845-6554.

Additional results from the first round are covered in an attachment to the Second-Round Delphi Questionnaire. You may refer to this information as you deem necessary to help you complete the Second-Round Delphi Questionnaire. However, reviewing this information is not required to complete the questionnaire.

The third questionnaire, if necessary, and the summary of responses will be provided approximately two to three weeks after the due date of the second survey. Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Dr. Stuart D. Anderson at s-anderson5@tamu.edu or (979) 845-2407.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Attachments (2)

National Cooperative Highway Research Program
Project 10-58
Construction Engineering and Management Research Program

SECOND-ROUND QUESTIONNAIRE

A Study by

The University of Wisconsin –Madison
And
The Texas Transportation Institute

August 21, 2000

KEY RESULTS –FIRST ROUND

The First-Round Delphi Survey was sent to 67 professionals in the highway construction industry. Of the professionals that received the questionnaire, 53 (79%) have responded.

Based on the results from Part I of the First-Round Delphi Questionnaire, the 53 respondents represent the following areas:

Area	**Number of Respondents**
State Highway Agency	35
Contractor	5
Material/Equipment Supplier	1
Consultant	4
FHWA	4
Association	2
Academic	2
Total	**53**

The characteristics of the panel, including *level of experience* and *areas of expertise*, are available in Attachment 1. Attachment 1 is summarized by the areas listed in the table above.

Part II of the First-Round Delphi Survey requested your assessment of thirty-three key issues on a five-point scale. The scale was defined as Extremely Important (5), Important (4), Moderately Important (3), Slightly Important (2), and Not Important (1).

The **Top 5** issue statements are as follows:

Issue No.	Statement	Average
13	Safety of public and workers during highway reconstruction and maintenance	4.4
5	Alternative construction methods and techniques to facilitate faster reconstruction	4.3
12	Training and workforce development of personnel	4.2
23	Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	4.2
33	Management of traffic during highway projects – Project staging of highway projects	4.2

The **Bottom 5** issue statements are as follows:

Issue No.	Statement	Average[1]
26	Availability and adequacy of certification programs for construction engineering technicians	3.3
14	Appropriate partnering and value engineering activities	3.2
32	Development of standardized design-build contracting procedures for highway and bridge construction	3.1
24	Construction equipment that reduces environmental impacts	3.0
17	Operability of construction equipment in relation to constructibility of transportation facilities	2.9

1 –The average values, approximately 3 on the 5-point scale, for the Bottom 5 indicate that the issues are important, however, not as critical and in need of research as the other 28 issues on the complete list.

Part III of the First-Round Delphi Survey requested you to prioritize and rank the key issues by ranking the top 15 research and development needs listed in Part II.

The **Top 5** ranked issue statements are as follows:

Issue No.	Statement	Rank
13	Safety of public and workers during highway reconstruction and maintenance	1
5	Alternative construction methods and techniques to facilitate faster reconstruction	2
15	Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	3
23	Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	4
33	Management of traffic during highway construction projects –Project staging of highway projects	5

Part IV-A of the First-Round Delphi Survey requested additional issue statements affecting highway construction engineering and management. A total of 48 new issue statements were identified in the first-round survey. Only four of the new issues were identified from multiple first-round responses. These issue statements are displayed in Part B-1 of this survey. A complete list of all additional issues identified is available in Attachment 2.

Part IV-B of the First-Round Delphi Survey requested clarification of issue statements. Multiple respondents identified several issue statements as unclear. These statements are displayed in Part B-2 of this survey. A complete list of suggested re-phrased issues is available in Attachment 3.

Part V of the First-Round Delphi Survey requested general comments about the survey or the research project. A total of 21 comments were made on the first-round surveys. Most of these comments emphasized the respondents' primary area of concern or area of needed research. Further, several respondents indicated that similar issues could be combined. The combination of issue statements will not be done at this point, but may be necessary in the future to create comprehensive research topics. A summary of the comments is available in Part D of this survey. A complete list of all comments is available in Attachment 4.

INSTRUCTIONS

The attached questionnaire consists of four (4) parts.

Part A requests that you re-evaluate the issues facing highway construction engineering and management, identified in the Phase I survey, given your previous assessment of the issue and information on the group response.

Part B-1 requests that you evaluate the importance of the new issues identified by multiple respondents in the First-Round Delphi Questionnaire. Please assess the importance and need for future research of the issues on a five-point scale. If you believe that any of the new issue statements belongs on the prioritized list of the Top 15, please include them in your new ranked list in Part C of this survey.

Part B-2 requests that you evaluate the importance of the issues rephrased by multiple respondents in the First-Round Delphi Questionnaire. Please assess the importance and need for future research of the issues on a five-point scale. If you believe that any of the re-phrased issue statements belongs on the prioritized list of the Top 15, please include them in your new ranked list in Part C of this survey.

Part C requests that you re-rank **only the 15 most important issues** from Part A and Part B. You should enter the issue numbers from Part A and/or Part B based on your original ranking and the group response.

The analysis of the group response was accomplished using a method called Relative Index Rating (RIR). RIR is a means to report the respondent's rankings on a 0 to 1 scale. A value of 15 points was assigned for a rank of '1", 14 points for a rank of '2",...1 point for a rank of "15", and 0 points for an unranked issue. The sum of points for each issue is divided by the total number of points possible (15 points x total number of respondents).

For example: Issue statement number 3 'Compliance with current and future environmental restrictions/requirements" received 197 points, out of 795 (15 x 53) points possible. Therefore its RIR is 197 / 795 = 0.248 (See Table below).

Rank	**No. Respondents**	**Points per Rank**	**Total Points**
1	3	15	45
2	3	14	42
3	1	13	13
4	1	12	12
5	2	11	22
6	2	10	20
7	0	9	0
8	0	8	0
9	2	7	14
10	0	6	0
11	0	5	0
12	3	4	12
13	2	3	6
14	5	2	10
15	1	1	1
Unranked	28	0	0
Total	**53**	**--**	**197**

The RIR for the issue statements prioritized in the first-round questionnaire are displayed in Table 1 in Part C.

Please re-evaluate and, if necessary, re-rank the issue statements based on your original ranking and the group response displayed in the RIR table.

Part D displays a summary of general comments from the first-round questionnaire. Please indicate any response you might have to these comments.

SECOND-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART A

RE-EVALUATE IMPORTANCE OF ISSUES

Under each issue statement, your original assessment is provided in the left-hand column. The second column contains a space for your new answer if you wish to change your previous response after reviewing the group response. The group response is displayed as a median value and as percentages of respondents that selected each degree of importance on the five-point scale.

If you **do not** want to change your assessment of an issue statement you may leave the space under ‘New Response” blank.

Indicate the importance of the following issues according to the need for **future research**. Evaluate each issue using the scale provided. ‘Extremely Important (5)” would specify that you believe that the issue is very critical and necessitates future research. ‘Not Important (1)” would specify that the issue is not a significant problem to highway construction engineering and management and is not in need of future research.

Previous Response	***New Response***	***Median Group Response***	***1 Not Important***	***2 Slightly Important***	***3 Moderately Important***	***4 Important***	***5 Extremely Important***
1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects							
<#>		4	0%	11%	17%	51%	21%
2. Integration of contractor warranties into project contracts							
<#>		4	6%	13%	30%	42%	9%
3. Compliance with current and future environmental restrictions/requirements							
<#>		4	0%	4%	34%	34%	28%
4. Contractor performed QC and QA testing							
<#>		4	2%	2%	30%	45%	21%
5. Alternative construction methods and techniques to facilitate faster reconstruction							
<#>		4	0%	6%	4%	43%	47%

Previous Response	*New Response*	*Median Group Response*	*1 Not Important*	*2 Slightly Important*	*3 Moderately Important*	*4 Important*	*5 Extremely Important*
6. Deficiencies in quality and clarity of construction plans							
<#>		3	0%	15%	34%	26%	25%
7. Night and weekend construction to reduce traffic implications							
<#>		4	4%	9%	19%	43%	25%
8. Allocation of financial risk between the agency and contractor							
<#>		4	0%	28%	19%	40%	13%
9. Impact of construction projects on communities and necessary communication between agency/contractor and general public							
<#>		4	2%	11%	21%	38%	28%
10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel							
<#>		4	4%	13%	13%	36%	34%
11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)							
<#>		4	0%	2%	21%	38%	40%
12. Training and workforce development of personnel							
<#>		4	0%	4%	11%	45%	40%
13. Safety of public and workers during highway reconstruction and maintenance							
<#>		5	2%	0%	9%	30%	58%
14. Appropriate partnering and value engineering activities							
<#>		3	6%	17%	38%	28%	11%
15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)							
<#>		4	0%	8%	13%	36%	43%

Previous Response	*New Response*	*Median Group Response*	*1 Not Important*	*2 Slightly Important*	*3 Moderately Important*	*4 Important*	*5 Extremely Important*
16. Use of pre-construction/pre-project planning and project scheduling systems							
<#>		3	0%	17%	38%	36%	9%
17. Operability of construction equipment in relation to constructibility of transportation facilities							
<#>		3	2%	34%	38%	25%	2%
18. Training certification and retention of non-engineering personnel for quality assurance							
<#>		4	0%	8%	42%	36%	15%
19. Development, implementation, and evaluation of performance based specifications for highway construction							
<#>		4	0%	6%	21%	38%	36%
20. Management of contract claims (including identification of causes of claims)							
<#>		4	0%	13%	32%	40%	15%
21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)							
<#>		4	0%	9%	19%	34%	38%
22. System for electronically collecting and distributing construction information							
<#>		4	2%	13%	34%	32%	19%
23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility							
<#>		4	0%	4%	13%	43%	40%
24. Construction equipment that reduces environmental impacts							
<#>		3	6%	25%	40%	21%	9%

Previous Response	*New Response*	*Median Group Response*	*1 Not Important*	*2 Slightly Important*	*3 Moderately Important*	*4 Important*	*5 Extremely Important*
25. Use of recycled materials in highway construction							
<#>		4	2%	28%	19%	32%	19%
26. Availability and adequacy of certification programs for construction engineering technicians							
<#>		3	0%	25%	32%	30%	13%
27. Strategies to minimize construction delays once construction starts							
<#>		4	0%	8%	13%	45%	34%
28. Use of more durable materials in highway construction							
<#>		4	0%	4%	17%	40%	40%
29. Review of the constructibility of transportation facilities in the planning and design phases							
<#>		4	0%	8%	21%	47%	25%
30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)							
<#>		4	0%	4%	23%	32%	42%
31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)							
<#>		4	2%	4%	23%	53%	19%
32. Development of standardized design-build contracting procedures for highway and bridge construction							
<#>		3	9%	21%	34%	21%	15%
33. Management of traffic during highway construction projects –Project staging of highway projects							
<#>		4	0%	6%	13%	38%	43%

PART B-1

EVALUATE IDENTIFIED ISSUES

Please evaluate the new issues identified from the First-Round Delphi Questionnaire by multiple respondents on the same five-point scale used in Part A.

Please circle your response.

34. Use of Motorist Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway work-zones				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
35. Assessment and verification of current life cycle cost methodologies				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
36. Implementing electronic information systems to integrate bid estimating, project management, and construction management				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

PART B-2

EVALUATE RESTATED ISSUES

Please evaluate the restated/re-worded issue statements from the First-Round Delphi Questionnaire by multiple respondents on the same five-point scale used in Part A.

Please circle your response.

4-R1. Contractor performed QC				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
4-R2. Contractor performed QA				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
14-R1. Appropriate partnering activities				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
14-R2. Appropriate value engineering activities				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important
22-R. Using automation technology in a system for collection and distribution of design and construction information				
1 Not Important	2 Slightly Important	3 Moderately Important	4 Important	5 Extremely Important

PART C

RANK ISSUES

Please review your original ranking of the issue statements and the group ranking displayed in Table A, Relative Index Rating (RIR) on the following page. In the spaces provided in the column entitled New Ranking, you may edit your prioritized list of issue statements.

If you believe that one or more of the new/restated issue statements evaluated in Part B are among the Top 15 construction engineering and management issues you may include them in your new ranked list below.

For your information, Attachment 5 contains the ranking results divided into two groups (SHAs versus all other respondents). If you deem necessary, you may reference the information in Attachment 5 to help you complete your new ranking.

A rank value of “1” being most critical and “15” being not as critical as “14”. In the spaces provided, please enter the “issue number” from Part A and/or Part B.

RANK	**Original** Ranking Issue (No.)	**New** Ranking Issue (No.)	**Group** Ranking Issue (No.)
1	<#>		13
2	<#>		5
3	<#>		15
4	<#>		23
5	<#>		33
6	<#>		12
7	<#>		19
8	<#>		11
9	<#>		27
10	<#>		10
11	<#>		30
12	<#>		28
13	<#>		21
14	<#>		9
15	<#>		1

Table A. RIR for the issue statements prioritized in the First-Round Delphi Survey

No.	Issue Statement	RIR
13	Safety of public and workers during highway reconstruction and maintenance	0.512
5	Alternative construction methods and techniques to facilitate faster reconstruction	0.450
15	Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	0.423
23	Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	0.421
33	Management of traffic during highway construction projects –Project staging of highway projects	0.397
12	Training and workforce development of personnel	0.372
19	Development, implementation, and evaluation of performance based specifications for highway construction	0.357
11	Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	0.346
27	Strategies to minimize construction delays once construction starts	0.331
10	Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	0.331
30	Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	0.316
28	Use of more durable materials in highway construction	0.314
21	Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	0.298
9	Impact of construction projects on communities and necessary communication between agency/contractor and general public	0.289
1	Feasible incentive and disincentive contract provisions assuring more timely completion of projects	0.262
29	Review of the constructibility of transportation facilities in the planning/design phases	0.249
3	Compliance with current and future environmental restrictions/requirements	0.248
6	Deficiencies in quality and clarity of construction plans	0.224
4	Contractor performed QC and QA testing	0.201
7	Night and weekend construction to reduce traffic implications	0.196
31	Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	0.166
32	Development of standardized design-build contracting procedures for highway and bridge construction	0.157
2	Integration of contractor warranties into project contracts	0.155
18	Training certification and retention of non-engineering personnel for quality assurance	0.151
20	Management of contract claims (including identification of causes of claims)	0.136
22	System for electronically collecting and distributing construction information	0.126
8	Allocation of financial risk between the agency and contractor	0.126
16	Use of pre-construction/pre-project planning and project scheduling systems	0.108
14	Appropriate partnering and value engineering activities	0.107
26	Availability and adequacy of certification programs for construction engineering technicians	0.088
25	Use of recycled materials in highway construction	0.074
24	Construction equipment that reduces environmental impacts	0.060
17	Operability of construction equipment in relation to constructibility of transportation facilities	0.020

PART D

SUMMARY OF COMMENTS

Of the 53 completed questionnaires received, 21 respondents added general comments about the survey or the research project. Of the 21 general comments, 11 respondents emphasized an area of concern or most critical problem in the industry. These 11 comments have been generalized as follows:

Critical Area	No. Respondents
Electronic technology	1
Performance prediction	1
Providing quality finished products	2
Quality of plans	2
Quicker construction	2
Safety	1
Staffing / Training	2
Total	**11**

Two (2) respondents suggested the combination of similar issues; 'Many issues have a common theme and should be grouped to define a comprehensive research project."

If you have any views on the general comments, please provide them on the lines below:

Thank you for your participation in the second-round survey.

Please fax your completed survey to:
Dr. Stuart Anderson Fax: (979) 845-6554

Then mail the hard copy to:
Dr. Stuart D. Anderson, Ph.D.
Department of Civil Engineering
Texas A&M University
College Station, TX 77843-3136

Please return by: **August 31, 2000**

Thank you.

Questions contact

Dr. Stuart Anderson at:
Email: s-anderson5@tamu.edu
Phone: (979) 845-2407

or

Andrew J. Damron at:
damron@tamu.edu
(979) 845-9300

Appendix I.
Second Round Delphi Follow-Up Letter

September 1, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Ten days ago the Second-Round Delphi Questionnaire for the project, NCHRP 10-58 *Construction Engineering and Management Research Program*, was sent to you. To-date, 29 completed second-round questionnaires have been received. If you have already completed and returned the questionnaire, please accept our sincere thanks.

If possible, please return the second-round questionnaire by **September 8, 2000**. Please fax your complete questionnaire to Dr. Stuart Anderson at (979) 845-6554.

The third-round questionnaire, if necessary, will include a summary of responses of the issues assessed and prioritized in the second-round questionnaire. It is very important that your view be represented. We know there are numerous demands on your time. The second-round questionnaire should take approximately 30-45 minutes to complete.

Thank you for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Andrew J. Damron at damron@tamu.edu or (979) 845-9300.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Appendix J
Results from Delphi Survey Round Two

ATTACHMENT A

Second-Round Questionnaire –Part A Results

Part A of the second-round Delphi survey requested your assessment of thirty-three key issues on a five-point scale. The scale was defined as Extremely Important (5), Important (4), Moderately Important (3), Slightly Important (2), and Not Important (1).

The **Top 5** issue statements from the second-round are as follows (standard deviation and first-round average are also displayed):

Issue No.	Statement	2nd-Round Average	2nd-Round Std. Dev.	1st-Round Average	1st-Round Std. Dev.
13	Safety of public and workers during highway reconstruction and maintenance	4.6	0.6	4.4	0.8
5	Alternative construction methods and techniques to facilitate faster reconstruction	4.5	0.6	4.3	0.8
33	Management of traffic during highway projects – Project staging of highway projects	4.3	0.7	4.1	1.0
12	Training and workforce development of personnel	4.3	0.7	4.2	0.8
15	Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	4.3	1.0	4.1	1.0

The **Bottom 5** issue statements from the second-round are as follows (standard deviation and first-round average are also displayed):

Issue No.	Statement	2nd-Round Average[1]	2nd-Round Std. Dev.	1st-Round Average	1st-Round Std. Dev.
16	Use of pre-construction/pre-project planning and project scheduling systems	3.3	0.8	3.3	0.9
14	Appropriate partnering and value engineering activities	3.0	1.0	3.2	1.1
24	Construction equipment that reduces environmental impacts	3.0	0.9	3.0	1.0
32	System for electronically collecting and distributing construction information	3.0	1.0	3.1	1.2
17	Operability of construction equipment in relation to constructibility of transportation facilities	2.7	0.7	2.9	0.9

1 –The average values, approximately 3 on the 5-point scale, for the Bottom 5 indicate that the issues are important, however, not as critical and in need of research as the other 28 issues on the complete list.

ATTACHMENT B

Second-Round Questionnaire –Part B Results

Part B-1 of the Second-Round Delphi Survey requested your assessment of four issues identified from the First-Round Delphi Questionnaire.

The issue statements and average ratings are as follows:

Issue No.	Statement	Average
34	Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway work-zones	3.3
35	Assessment and verification of current life cycle cost methodologies	3.6
36	Implementing electronic information systems to integrate bid estimating, project management, and construction management	3.4
37	Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	3.9

Part B-2 of the Second-Round Delphi Survey requested your assessment of five issues rephrased since the First-Round Delphi Questionnaire.

The issue statements and average ratings are as follows:

Issue No.	Statement	Average
4-R1	Contractor performed QC	3.7
4-R2	Contractor performed QA	3.1
14-R1	Appropriate partnering activities	3.0
14-R2	Appropriate value engineering activities	3.0
22-R	Using automation technology in a system for collection and distribution of design and construction information	3.4

ATTACHMENT C

SHA vs. Other results from the Second-Round Delphi Questionnaire

The table below displays the State Highway Agency (SHA) responses (n=36) compared to all other responses (contractors, consultants, suppliers, FHWA, academics, and association professionals) (n=17) for the first-round and the second-round surveys.

Aggregate Ranking	Issue Statement	2nd-rnd RIR	1st-rnd RIR	2nd-Round SHA Rank	2nd-Round Other Rank	1st-Round SHA Rank	1st-Round Other Rank
1	13. Safety of public and workers during highway reconstruction and maintenance	0.742	0.476	1	2	1	3
2	5. Alternative construction methods and techniques to facilitate faster reconstruction	0.581	0.442	3	1	4	1
3	15. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)	0.513	0.431	2	8	2	9
4	23. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility	0.459	0.411	7	3	6	2
5	33. Management of traffic during highway construction projects –Project staging of highway projects	0.434	0.380	6	4	5	6
6	12. Training and workforce development of personnel	0.428	0.372	4	9	7	10
7	19. Development, implementation, and evaluation of performance based specifications for highway construction	0.371	0.371	8	6	11	5
8	11. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)	0.360	0.325	10	7	12	4
9	10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel	0.341	0.330	5	25	3	28

Aggregate Ranking	Issue Statement	2nd-rnd RIR	1st-rnd RIR	2nd-Round SHA Rank	2nd-Round Other Rank	1st-Round SHA Rank	1st-Round Other Rank
10	27. Strategies to minimize construction delays once construction starts	0.331	0.323	14	5	13	7
11	21. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)	0.316	0.298	9	15	10	19
12	30. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)	0.296	0.328	12	12	14	11
13	9. Impact of construction projects on communities and necessary communication between agency/contractor and general public	0.282	0.275	13	14	8	26
14	28. Use of more durable materials in highway construction	0.272	0.325	15	11	15	8
15	7. Night and weekend construction to reduce traffic implications	0.242	0.197	17	10	23	12
16	3. Compliance with current and future environmental restrictions/requirements	0.228	0.228	11	37	9	33
17	1. Feasible incentive and disincentive contract provisions assuring more timely completion of projects	0.214	0.251	16	13	16	17
18	6. Deficiencies in quality and clarity of construction plans	0.165	0.228	18	21	18	16
19	4. Contractor performed QC and QA testing	0.164	0.220	20	16	21	13
20	29. Review of the constructibility of transportation facilities in the planning and design phases	0.162	0.260	19	18	17	15
21	2. Integration of contractor warranties into project contracts	0.125	0.163	22	22	22	22
22	37. Development of real-time traffic management of highway reconstruction projects (including traveler information, incident management, and traffic surveillance)	0.118	--	21	24	--	--

Aggregate Ranking	Issue Statement	2nd-rnd RIR	1st-rnd RIR	2nd-Round SHA Rank	2nd-Round Other Rank	1st-Round SHA Rank	1st-Round Other Rank
23	8. Allocation of financial risk between the agency and contractor	0.107	0.144	23	20	27	21
24	31. Impact and implementation of new construction technologies (including the training of personnel to use new technologies)	0.103	0.171	27	17	26	14
25	32. Development of standardized design-build contracting procedures for highway and bridge construction	0.091	0.153	24	23	25	18
26	25. Use of recycled materials in highway construction	0.074	0.079	32	19	32	23
27	18. Training certification and retention of non-engineering personnel for quality assurance	0.074	0.141	26	26	19	25
28	20. Management of contract claims (including identification of causes of claims)	0.073	0.155	25	27	20	30
29	22. System for electronically collecting and distributing construction information	0.055	0.148	28	29	24	27
30	24. Construction equipment that reduces environmental impacts	0.052	0.068	29	31	31	31
31	26. Availability and adequacy of certification programs for construction engineering technicians	0.047	0.096	30	32	29	29
32	16. Use of pre-construction/pre-project planning and project scheduling systems	0.043	0.097	35	28	28	24
33	14. Appropriate partnering and value engineering activities	0.040	0.098	33	30	30	20
34	36. Implementing electronic information systems to integrate bid estimating, project management, and construction management	0.024	--	31	38	--	--
35	4-R1. Contractor performed QC	0.018	--	39	33	--	--
36	35. Assessment and verification of current life cycle cost methodologies	0.015	--	40	34	--	--

J6

Aggregate Ranking	Issue Statement	2nd-rnd RIR	1st-rnd RIR	2nd-Round SHA Rank	2nd-Round Other Rank	1st-Round SHA Rank	1st-Round Other Rank
37	22-R. Using automation technology in a system for collection and distribution of design and construction information	0.015	--	34	40	--	--
38	14-R1. Appropriate partnering activities work-zones	0.014	--	41	35	--	--
39	34. Use of Motor Assisted Patrol (MAP) during construction to enforce the speed of traffic and traffic safety in highway	0.010	--	37	36	--	--
40	14-R2. Appropriate value engineering activities	0.004	--	36	41	--	--
41	17. Operability of construction equipment in relation to constructibility of transportation facilities	0.001	0.017	38	39	33	32
42	4-R2. Contractor performed QA	0.000	--	42	42	--	--

J7

ATTACHMENT D

Comments from the Second-Round Delphi Questionnaire

The numbers in parentheses following each comment indicate respondent identification numbers for internal reference purposes only.

Issues 15&10 could be combined –possibly also adding 12
Issues 11, 4 and 30 should be combined
Issues 23 and 1 could be combined –possibly also adding 2
Issue 26 could be combined with issue 12
The information provided in the attachments was very enlightening and informative, including similar information with future surveys/questionnaires would be helpful (#175).

I agree that similar issues should be grouped together (#219).

Many issues are symptoms rather than causes. The need is to focus on treating causes. If we can accurately predict performance and build longer-lasting products, less time is spent constructing and maintaining the facility over its life, so speed and duration are less of an issue (#86).

1. I agree that several issues should be grouped.
2. All of the testing by trained folks and life cycle cost analyses are not worth much if they don't predict of reflect performance of the pavement. Hence the need for validated performance-prediction tests/models (#177).

We do agree the above emphasized concern are most critical (#57).

One can recognize the differing views between SHAs and others. This survey is heavily loaded with SHA respondents. Therefore the weightings will be SHA influenced. Probably no way to avoid this except get more non-SHA respondents (#217).
I was surprised that safety was ranked #1 but respect this was more a politically correct response than actual opinion. It is like being in favor of motherhood. The Top 5 priorities reflect the preponderance of SHA respondents. The primary requirement is still the need for thorough planning and provision of quality documents in the design phase. Our continuous constructibility work book is lying dormant, largely ignored. Before we head into more research we need to find a way to ensure results of previous research are implemented. Perhaps a benign dictator (#217).

Many issues do have a common theme. The ones I listed as the top 15 could probably be grouped as the top ten (#210).

- I agree with the comments that some issues should be combined.
- Restating issue 4 into issues (4R1 and 4R2) did more to confuse me than to clarify.

- It takes more than a title to evaluate research need. Can 1-3 sentences of explanation go with the title for round 3? (#20).

I agree with the grouping of "common theme" issues (#97).

Items 11 & 19, Items 1 & 23, would be good candidates for combination. There are other items that deal with the same subject but different aspects (#172).

Always ask the question: "Is it researchable?" (#216)

Issue #35 – Life-cycle costs need to include the impact on the users (e.g. traveling public) (#7).

I have two comments:

1. The instructions state that the issues are to be ranked according to the need for future research. The elaboration states that a 5 indicates an issues is very critical and necessitates future research; a 1 indicates an issue is not a significant problem and not in need of future research. The elaboration is not the same as the instruction because there are two criteria to be satisfied, not the single criterion given in the instruction. This is important because there are cases where an issue is important, but not researchable. Under the basic instruction, such an issue would be rated low.
2. In attempting to clarify issues, some things have become more confusing. Without knowing the scope of Issue 4, 4-R1 and 4-R2, it is difficult to rank them (#121).

My priorities are based on where I feel new research needs to occur. Safety is important but issue #13 is too broad. Reduce work zone speeds (very basic) and you significantly reduce potential for accidents. There are ways to do this without need for research but they are not popular with public. Most agencies refuse to implement for that reason. Issues 23, 5, and 1 address a common theme – Time & Money. My revised rankings are based on what I feel are critical areas: Time/Money, Safety, Specifications, Staffing (#212).

I agree that several issues have a common theme and could be grouped together to provide a more meaningful ranking (#199).

I agree with the comments that these are the general critical areas and that most of the important issues could be grouped into one of these areas. I placed my ranking next to each critical area even though you did not ask for it.

1. Safety
2. Staffing / Training
3. Electronic technology
4. Providing quality finished products
5. Quality of plans
6. Quicker construction

Performance prediction

Appendix K.
Delphi Survey Round Three

September 27, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Thank you for your participation in the Delphi process for this research project, NCHRP 10-58*, Construction Engineering and Management Research Program*.

The first two rounds of Delphi questionnaires have achieved a significant group consensus on the critical issues; therefore conducting an additional round to clarify the ranking of the critical issues would not be beneficial. However, your knowledge and experience is needed to assist us in identifying current problems, implementation barriers, and gaps between research and practice for the top 20 critical research needs identified by your first and second-round Delphi responses. We are currently conducting a literature search on these critical issues.

In the attached questionnaire, please identify current problems, implementation barriers, and gaps in knowledge for the issues that are in your *area of expertise*. You may identify up to three (3) problems, barriers, and gaps. Any information that you can provide will be extremely helpful.

Please complete the attached, third-round questionnaire and return it by **October 11, 2000**. Please fax your completed questionnaire to us and then mail the hard copy. Our fax number is (979) 845-6554.

The response from the second-round questionnaire was excellent. To-date, we have received 53 completed questionnaires. The Delphi panelists include 36 from state highway agencies and 17 from other organizations (contractors, consultants, FHWA, associations, academics) involved in the highway construction industry. Additional results from the second-round are covered in attachments to the third-round Delphi questionnaire. A summary of your responses and group results from previous rounds of the Delphi process along with the data collected in the third-round survey will be sent to you by late October.

Thank you again for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Dr. Stuart D. Anderson at s-anderson5@tamu.edu or (979) 845-2407.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Attachments (2)

National Cooperative Highway Research Program
Project 10-58
Construction Engineering and Management Research Program

THIRD-ROUND QUESTIONNAIRE

A Study by

The University of Wisconsin –Madison
And
The Texas Transportation Institute

September 27, 2000

THIRD-ROUND QUESTIONNAIRE

NCHRP 10-58 *Construction Engineering and Management Research Program*

PART 1 INDICATE PROBLEM AREAS

<Title> <First Name> <Last Name>
<Organization>

Under each issue statement, please identify problems, barriers, and gaps to the best of your knowledge. Please identify up to three (3) problems, barriers, and gaps for issue statements within your area of expertise. Any input you can provide will be extremely helpful.

Example:

1. Safety of public and workers during highway reconstruction and maintenance

Identify current specific problem areas within the issue:

A. *Reducing traffic speeds in work-zones*

Identify implementation barriers in overcoming each problem:

A. *Large costs associated with traffic control devices (motor assisted patrol) in work-zones and methods to include these costs in contracts*

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. *Need to identify procedure for determining safe speed limits in work-zones*

1. Safety of public and workers during highway reconstruction and maintenance

Identify current specific problem areas within the issue:

A. ____

B. ____

C. ____

Identify implementation barriers in overcoming each problem:

A. ____

B. ____

C. ____

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ____

B. ____

C. ____

2. Alternative construction methods and techniques to facilitate faster reconstruction
Identify current specific problem areas within the issue: A. ______________________________ B. ______________________________ C. ______________________________ ______ Identify implementation barriers in overcoming each problem: A. ______________________________ B. ______________________________ C. ______________________________ ______ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ______________________________ B. ______________________________ C. ______________________________ ______
3. Innovative contracting methods, delivery systems, and contractor incentives to improve cost effectiveness, timeliness, and quality of the constructed facility
Identify current specific problem areas within the issue: A. ______________________________ B. ______________________________ C. ______________________________ ______ Identify implementation barriers in overcoming each problem: A. ______________________________ B. ______________________________ C. ______________________________ ______ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ______________________________ B. ______________________________ C. ______________________________ ______

4. Recruiting, promoting, and retaining of qualified personnel in highway construction (including supervisors to staff projects)
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________
5. Management of traffic during highway construction projects –Project staging of highway projects
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________

6. Training and workforce development of personnel
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ ____________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ ____________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________ ____________
7. Development, implementation, and evaluation of performance based specifications for highway construction
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ ____________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ ____________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________ ____________

8. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection)
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________
9. Strategies to minimize construction delays once construction starts
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________

10. Competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________
11. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods)
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________

12. Impact of construction projects on communities and necessary communication between agency/contractor and general public
Identify current specific problem areas within the issue: A. ______________________________ B. ______________________________ C. ______________________________ Identify implementation barriers in overcoming each problem: A. ______________________________ B. ______________________________ C. ______________________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ______________________________ B. ______________________________ C. ______________________________
13. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)
Identify current specific problem areas within the issue: A. ______________________________ B. ______________________________ C. ______________________________ Identify implementation barriers in overcoming each problem: A. ______________________________ B. ______________________________ C. ______________________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ______________________________ B. ______________________________ C. ______________________________

14. Use of more durable materials in highway construction
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________
15. Night and weekend construction to reduce traffic implications
Identify current specific problem areas within the issue: A. ____________________ B. ____________________ C. ____________________ Identify implementation barriers in overcoming each problem: A. ____________________ B. ____________________ C. ____________________ Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent: A. ____________________ B. ____________________ C. ____________________

16. Compliance with current and future environmental restrictions/requirements

Identify current specific problem areas within the issue:

A. ____

B. ____

C. ____

Identify implementation barriers in overcoming each problem:

A. ____

B. ____

C. ____

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ____

B. ____

C. ____

17. Feasible incentive and disincentive contract provisions assuring more timely completion of projects

Identify current specific problem areas within the issue:

A. ____

B. ____

C. ____

Identify implementation barriers in overcoming each problem:

A. ____

B. ____

C. ____

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ____

B. ____

C. ____

18. Deficiencies in quality and clarity of construction plans

Identify current specific problem areas within the issue:

A. ______________________________

B. ______________________________

C. ______________________________

Identify implementation barriers in overcoming each problem:

A. ______________________________

B. ______________________________

C. ______________________________

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ______________________________

B. ______________________________

C. ______________________________

19. Review of the constructibility of transportation facilities in the planning and design phases

Identify current specific problem areas within the issue:

A. ______________________________

B. ______________________________

C. ______________________________

Identify implementation barriers in overcoming each problem:

A. ______________________________

B. ______________________________

C. ______________________________

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ______________________________

B. ______________________________

C. ______________________________

20. Contractor performed QC and QA testing

Identify current specific problem areas within the issue:

A. ______________________________

B. ______________________________

C. ______________________________

Identify implementation barriers in overcoming each problem:

A. ______________________________

B. ______________________________

C. ______________________________

Identify gaps in knowledge, that is, where do you believe that current research is inadequate or non-existent:

A. ______________________________

B. ______________________________

C. ______________________________

PART 2

SUMMARY OF COMMENTS

Many respondents in the second-round questionnaire suggested combinations of several issues into groups. Several issues have been combined into larger topic areas. A letter was submitted to the research panel that contained the top 15 issue topics. The top 15 topics are composed of the top 20 issues that were identified by the Delphi respondents. The numbers in parentheses following each statement below refer to an original issue statement number from the first two rounds of Delphi surveys (See Attachment C for issue numbers). The top 15 issue topics are as follows:

1. Safety of public and workers during highway reconstruction and maintenance (13)
2. Overall improvement of the construction process –particularly alternative construction methods and techniques, contracting methods and delivery systems to facilitate faster construction/reconstruction. (5 & 23)
3. Development, implementation, and evaluation of the use of incentives/disincentives in for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility. (23 & 1)
4. Development, implementation, and evaluation of performance based specifications for highway construction (19)
5. Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel) (15 & 10)
6. Training and workforce development of personnel (12)
7. Innovative strategies to manage traffic during highway construction projects- Specifically relating to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction. (33, 27 & 7)
8. Performance based quality control/quality assurance tests (including investigation of adequate level of construction inspection) (11)
9. Development, implementation, and evaluation of sampling and testing procedures as related to performance of the end product (including rapid test methods and non-destructive test (NDT) methods) (30)
10. Contractor performed QC and QA testing (4)
11. Review of the constructibility of transportation facilities in the planning and design phases – specifically deficiencies in quality and clarity of construction plans. (29 & 6)
12. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies) (21)
13. Use of more durable materials in highway construction (28)
14. Impact of construction projects on communities and necessary communication between agency/contractor and general public (9)
15. Compliance with current and future environmental restrictions/requirements (3)

If you have any views or general comments, please provide them on the lines below:

Thank you again for your participation in the survey process for this research project.

Please fax your completed survey to:
Dr. Stuart Anderson Fax: (979) 845-6554

Then mail the hard copy to:
Dr. Stuart D. Anderson, Ph.D.
Department of Civil Engineering
Texas A&M University
College Station, TX 77843-3136

Questions contact

Dr. Stuart Anderson at:
Email: s-anderson5@tamu.edu
Phone: (979) 845-2407

or

Andrew J. Damron at:
damron@tamu.edu
(979) 845-9300

Please return by: **October 11, 2000**

Thank you.

Appendix L.
Third Round Delphi Follow-Up Letter

October 12, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

We need your help! About two weeks ago the Third-Round Delphi Questionnaire for the project, NCHRP 10-58 *Construction Engineering and Management Research Program*, was sent to you. To-date, 12 completed third-round questionnaires have been received. If you have already completed and returned the questionnaire, please accept our sincere thanks.

It is very important that your opinions be represented. Any information that you can provide will be extremely helpful. We do not want you to feel obligated to complete the entire third-round survey, but we would appreciate your input in areas that you are aware of specific problems, barriers to implementation, or gaps in knowledge.

If possible, please return the third-round questionnaire by **Friday, October 20, 2000**.

Thank you again for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Andrew J. Damron at damron@tamu.edu or (979) 845-9300.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Appendix M.
Delphi Thank You Letter

November 15, 2000

<Title> <First Name> <Last Name>
<Company>
<Address>
<Address>
<City>, <State> <Zip Code>

Dear <Title> <Last Name>:

Thank you for your participation in the Delphi process for the research project, NCHRP 10-58 *Construction Engineering and Management Research Program*. Your time and expertise were sincerely appreciated.

The Delphi survey portion of the research project is complete. The process identified fifteen critical issues. The remainder of the project will concentrate on the writing of research problem statements to assure that the priorities identified by the survey process are incorporated into future research plans.

Thank you again for your interest and cooperation. If you have any questions or comments please do not hesitate to contact Andrew J. Damron at damron@tamu.edu or (979) 845-9300.

Sincerely,

Stuart D. Anderson, Ph.D.
Associate Professor

Andrew J. Damron
Graduate Research Assistant

Appendix N.
Pre-Workshop Packet

UNIVERSITY OF WISCONSIN-MADISON

DEPARTMENT OF CIVIL AND
ENVIRONMENTAL ENGINEERING

1415 Johnson Drive
Madison, Wisconsin 53706
Telephone: 608/262-7244
FAX: 608/265-9860
E-Mail: russell@engr.wisc.edu

February 19, 2001

Subject: National Cooperative Highway Research Program
Project 10-58, *Construction Engineering and Management Program*
Workshop, March 5 –6, 2001, Irvine, California

Dear Workshop Participant:

We are pleased you have decided to participate in the 2-day workshop on March 5 and 6, 2001, at the National Academies' Beckman Center in Irvine, California. Please note that on Sunday evening, March 4, 2001, there will be a reception at the Four Seasons Hotel, Yorba Room, from 6:30 PM to 8:00 PM to welcome workshop participants.

Mr. Crawford Jencks, in his invitation letter to you, provided some background on the workshop and the NCHRP project supporting it. He noted that we are the contract research team conducting the project and that you should expect to receive the enclosed pre-workshop package. The enclosed packet contains the agenda for the two days, a summary of 16 theme issues, and background on the activity of the NCHRP project thus far. We suggest you become familiar with the material in order to facilitate the workshop discussions.

The ultimate purpose of the workshop will be to assist the research team and the responsible NCHRP project panel in formulating a research agenda for the next 10 years. The research agenda will be directed to finding solutions to pressing problems in construction engineering and management of transportation facilities. Your expertise and experience will be vital to the formulation of this research agenda.

As part of the research project, we have identified theme issues that reflect a number of problems in construction engineering and management. Through the interaction and collaboration of experts, these issues now need to be verified and problem-solving research must be identified. Many of the themes are long-standing concerns, for which resources have been devoted to finding solutions, but still remain concerns. The challenge of this workshop will be: Is the current program acceptable? And what needs to be done differently? You job will be to critique and clarify the current objectives, and to identify other objectives that have not been identified to date.

We believe this will be an experience to remember, professionally and personally. The Beckman Center is an excellent facility in 'Southern California" architectural style and is very conducive to workshop type meetings. The Four Seasons Hotel is also first class. Although the hotel is some distance from the Beckman Center, bus transportation will be provided between the facilities for your convenience. You should also count on having breakfast and lunch at the Beckman Center. Your participation in this two-day workshop will be invaluable.

The workshop will begin promptly at 8:00 AM (previous correspondence said 9:00 AM), March 5, at the Beckman Center. Therefore, please assemble in the Hotel Lobby at 7:00 AM so that buses can transport us to the Beckman Center, allowing enough time for breakfast before the 8:00 start. Casual dress is appropriate for all events.

We look forward to your participation in the workshop and two full days of discussion. See you in California!

Sincerely,

Jeffrey S. Russell, Ph.D., P.E.
Principal Investigator

cc: Stuart D. Anderson
David Trejo
Awad S. Hanna
Corey Hessen
Andrew Damron
Caroline Brandt

Enclosures

*** Summarized Agenda**

Sunday, March 4, 2001	
6:30 PM –8:00 PM	Reception

Monday, March 5, 2001	
7:00 AM –8:00 AM	Bus to Beckman Center and Breakfast
8:00 AM –10:00 AM	Introduction: • Welcome –Crawford F. Jencks and John M. Smythe • Background –Jeffery S. Russell, UW-Madison • Workshop Goals –Corey Hessen, FMI • Keynote Address –Mike Ryan, Pennsylvania DOT • Team Building Exercise
10:00 AM –10:15 PM	Break
10:15 AM –12:00 PM	Breakout Sessions to Discuss Themes
12:00 PM –1:00 PM	Lunch
1:00 PM –2:45 PM	Breakout Sessions to Discuss Themes
2:45 PM –3:00 PM	Break
3:00 PM –4:45 PM	Breakout Sessions to Discuss Future Issues
4:45 PM –5:00 PM	Wrap-up and Adjourn for the Day

Tuesday, March 6, 2001	
7:00 AM –8:00 AM	Bus to Beckman Center and Breakfast
8:00 AM –9:15 AM	Findings from Day 1
9:15 AM –10:00 AM	Breakout Sessions to Discuss Themes
10:00 AM –10:15 AM	Break
10:15 AM –12:15 PM	Breakout Sessions to Discuss Themes
12:15 PM –1:15 PM	Lunch
1:15 PM –2:00 PM	Breakout Sessions to Discuss Themes
2:00 PM –2:45 PM	Breakout Sessions to Discuss Future Issues
2:45 PM –3:00 PM	Break
3:00 PM –3:45 PM	Breakout Sessions to Prioritize Themes
3:45 PM –5:00 PM	Wrap-up and Adjourn

*A complete agenda will be provided at the workshop

GROUP NO.	ROOM #	FACILITATOR	DAY 1					
			Breakout Session #1	Breakout Session #2	Breakout Session #3	Breakout Session #4	Breakout Session #5 (Black Pen)	Breakout Session #5 (Red Pen)
1			1	2	3	7	Future Issues	Future Issues
2			2	3	4	8	Future Issues	Future Issues
3			3	4	5	9	Future Issues	Future Issues
4			4	5	6	10	Future Issues	Future Issues
5			5	6	1	11	Future Issues	Future Issues
6			6	1	2	12	Future Issues	Future Issues

GROUP NO.	ROOM #	FACILITATOR	DAY 2					
			Breakout Session #6	Breakout Session #7	Breakout Session #8	Breakout Session #9	Breakout Session #10	Breakout Session #11
1			8	9	13	14	Future Issues	Future Issues
2			9	10	14	15	Future Issues	Future Issues
3			10	11	15	13	Future Issues	Future Issues
4			11	12	13	?	Future Issues	Future Issues
5			12	7	14	?	Future Issues	Future Issues
6			7	8	15	?	Future Issues	Future Issues

GROUP	ROOM	FACILITATOR	DAY 1 –MONDAY MARCH 5, 2001					
			Breakout Session #1	**Breakout Session #2**	**Breakout Session #3**	**Breakout Session #4**	**Breakout Session #5a**	**Breakout Session #5b**
1	Lecture Room	Donn Hancher	A	B	C	G	Future Issues	Future Issues
2	2A	John Smythe	B	C	D	H	Future Issues	Future Issues
3	5A	Steven DeWitt	C	D	E	I	Future Issues	Future Issues
4	4E	Deborah Fisher	D	E	F	J	Future Issues	Future Issues
5	5B	Julia Perry	E	F	A	K	Future Issues	Future Issues
6	5D	"Rudy" Malfabon	F	A	B	L	Future Issues	Future Issues

GROUP	ROOM	FACILITATOR	DAY 2 –TUESDAY MARCH 6, 2001					
			Breakout Session #6	**Breakout Session #7**	**Breakout Session #8**	**Breakout Session #9**	**Breakout Session #10**	**Breakout Session #11**
1	Lecture Room	Donn Hancher	H	I	M	N	Future Issues	Prioritize Themes
2	2A	John Smythe	I	J	N	O	Future Issues	Prioritize Themes
3	5A	Steven DeWitt	J	K	O	M	Future Issues	Prioritize Themes
4	4E	Deborah Fisher	K	L	M	A	Future Issues	Prioritize Themes
5	5B	Julia Perry	L	G	N	B	Future Issues	Prioritize Themes
6	5D	"Rudy" Malfabon	G	H	O	C	Future Issues	Prioritize Themes

UNIVERSITY OF WISCONSIN-MADISON

DEPARTMENT OF CIVIL AND
ENVIRONMENTAL ENGINEERING

1415 Johnson Drive
Madison, Wisconsin 53706
Telephone: 608/262-7244
FAX: 608/265-9860
E-Mail: russell@engr.wisc.edu

March 27, 2001

Dear Workshop Participant:

Thank you very much for your time and participation in the 2-day workshop on March 5 and 6, 2001, at the National Academies' Beckman Center in Irvine, California. We really appreciate all of the effort you and your colleagues put into making it a success.

Your input was extremely valuable. We have been able to clarify and strengthen our research project because of it.

Attached you will find the data from the workshop. The data has been organized by group. There are many different subheadings for each theme. The following is a short definition of each subheading:

New Objectives - new objectives each group thought should be added.

Delete Objectives - the original objectives each group thought should be deleted.

Rephrased Objectives - the changes each group thought should be made to the original objectives.

Research Products - the end result the group thought should come out of the research project.

Rephrased Title –the changes each group thought should be made to the title

Overall Comments –comments made by each group about the overall theme

Each group did not have input pertaining to each sub-heading.

The input for the theme description was also taken into consideration. That information and the data for the objectives will be integrated in the final report which is due October 31, 2001. A copy of that report can be obtained from Crawford Jencks.

If you have any questions or comments about the data we have provided for you, please call or email Jeffrey Russell.

Again, thank you for your time and for aiding in the success of this research project.

Sincerely,

Jeffrey S. Russell, Ph.D., P.E.
Principal Investigator

cc: Professor Awad S. Hanna
Professor Stuart D. Anderson
Professor David Trejo
Corey Hessen
Andrew Damron
Caroline Brandt

Enclosures

Appendix O.
Workshop Participants

Last Name	First Name	Job Title	Organization Name	Address1	Address2	City	State	Postal Code
Anderson	Stuart D.	Assistant Research Engineer	Texas A&M University			College Station	TX	77843-3136
Benfield	Daniel	Information Specialist	Transportation Research Board	Cooperative Research Programs (Div. D)	2101 Constitution Avenue, NW	Washington	DC	20418
Bourne	John	Project Director	Utah DOT	480 N 2200 W	Building B	Salt Lake City	UT	84116
Brandt	Caroline	Research Assistant	University of Wisconsin - Madison	1415 Engineering Drive	2258 Engineering Hall	Madison	WI	53706
Bush	Joseph	President	McCarthy Improvement Co.	5401 Victoria Avenue		Davenport	IA	52807
Cole	Lawrence	Vice President, Engineering & Research	American Concrete Pavement Association	5420 Old Orchard Road	Suite A100	Skokie	IL	60077-1059
Deatrick, P.E., AICP	John	Director, Transportation & Engineering	Cincinnati Transportation and Engineering Dept.	801 Plum Street	Rm 450	Cincinnati	OH	45202
DeWitt	Steven	State Construction Engineer	North Carolina DOT	PO Box 25201	1 South Wilmington Street	Raleigh	NC	27611-5201
Fisher	Deborah	Associate Professor	University of New Mexico	Department of Civil Engineering	Tapy Hall, Room 209	Albuquerque	NM	87131-1351
Griffin	P. Kay		California DOT	1727 30th Street		Sacramento	CA	95816-7005
Gruhn	Arthur	Construction Administrator	Connecticut DOT	PO Box 317546	2800 Berlin Turnpike	Newington	CT	06131-7546
Haas	Carl	Associate Professor	University of Texas - Austin	Dept of Civil Engineering	MC C1752	Austin	TX	78712-1076
Hancher	Donn	Professor and Department Chair	University of Kentucky	Department of Civil Engineering		Lexington	KY	40506-0281
Hejl	Frederick	Engineer of Materials and Construction	Transportation Research Board	Technical Services (Div. A)	2101 Constitution Avenue, NW	Washington	DC	20418
Henk	Greg		Flatiron Structures, Inc.	21415 Birdhollow Drive		Trabuco Canyon	CA	92679-3358
Hughes	Chuck			318 Miller School Road		Charlottesville	VA	22903
Jencks	Crawford	NCHRP Manager	Transportation Research Board	Cooperative Research Programs (Div. D)	2101 Constitution Avenue, NW	Washington	DC	20418

Last Name	First Name	Job Title	Organization Name	Address1	Address2	City	State	Postal Code
Lord	Byron		Federal Highway Administration	400 Seventh Street, SW	HIPT-1	Washington	DC	20590
Lucas	Donald	Director, Government Affairs	The Heritage Group	1114 S. Centerline Road		Franklin	IN	46131
Lum	Wesley S.C.	Chief, Office of Research	California DOT--Div. of New Tech. and Res. Prog.	PO Box 942873	1101 R Street, Mail Stop 42	Sacramento	CA	94273-0001
Malfabon	Rudy	Director, Construction Management Services	Sverdrup Civil, Inc.	5450 West Sahara Avenue	Suite 150	Las Vegas	NV	89146
Manning	David	Construction Engineer	Ontario Ministry of Transportation	Construction Office	301 St. Paul Street, 2nd Floor	St. Catharines	ON	L2R 7R4 CANADA
Matthews	Tanya		Parsons Brinckerhoff	465 Spring Park Plaza		Herndon	VA	20170
Mendelsohn	Roy		Parsons Brinckerhoff Ohio, Inc.	312 Elm Street	Suite 2500	Cincinnati	OH	45202
Morian	Dennis	Director of Engineering	Quality Engineering Services	7759 Andrews Lane		Conneaut Lake	PA	16316
Onstott	Lee	Highway Engineer	New Mexico SHTD	PO Box 1149	1120 Cerrillos Road	Santa Fe	NM	87504-1149
Perry	Julia	Counsel, Eastern Federal Lands Highway Division	Federal Highway Administration	21400 Ridgetop Circle		Sterling	VA	20166
Pierce	Thomas	Administrative Civil Engineer	Vermont Agency of Transportation	State Administration Building	133 State Street	Montpelier	VT	05633-5001
Rhinesmith	Rory	Director	Wisconsin DOT	PO Box 7916	4802 Sheboygan Avenue	Madison	WI	53707-7916
Riley	Orrin	Principal	Orrin Riley PE PC	80 Wall Street	Suite 1016	New York	NY	10005-3602
Russell	Jeffrey	Researcher	University of Wisconsin - Madison	1415 Engineering Drive	2258 Engineering Hall	Madison	WI	53706
Schexnayder	Clifford	Eminent Scholar	Arizona State University	PO Box 27147		Tempe	AZ	85285
Schmidt	Robert	Senior Vice President	Rogers Group, Inc.	PO Box 25250	12808 Towne Park Way	Louisville	KY	40243
Shuler	Scott	Manager, Engineering	Lafarge	1590 West 12th Avenue		Denver	CO	80204

Last Name	First Name	Job Title	Organization Name	Address1	Address2	City	State	Postal Code
Sniegowski	Rick	Vice President	K Five Construction Corp.	13769 Main Street		Lemont	IL	60439
Sorenson	Jim	Team Leader	Federal Highway Administration	400 Seventh St SW	HIAM-20, Room 3211	Washington	DC	20590
Suszko	Chuck		California DOT	P.O. Box 942874	MS44	Sacramento	CA	94274-0001
Taylor	Gary	Chief Engineer/Deputy Director - Technical Services	Michigan DOT	PO Box 30050	425 W. Ottawa Street	Lansing	MI	48909-7550
Testa	Dean	Chief, Bureau of Construction and Maintenance	Kansas DOT	915 Harrison	Room 881 West	Topeka	KS	66612-1568
Van Buren	James	Vice President, Development	New Enterprise Stone & Lime Co., Inc.	PO Box 77		New Enterprise	PA	16664
Vanikar	Suneel	Concrete Team Leader	Federal Highway Administration	Office of Pavement Technology	400 Seventh Street, SW	Washington	DC	20590
Wells	Paul	Assistant Commissioner for Engineering	New York State DOT	1220 Washington Avenue		Albany	NY	12232-0410
Weseman	William	Paving Engineer	Cement and Concrete Promotion Council of Texas	10401 Forrest Drive		Frisco	TX	75035
Williams	Ron	State Construction Engineer	Arizona DOT	Construction Group	206 S. 17th Avenue, MD172A	Phoenix	AZ	85007
Wittwer	David	President/Owner	Wittwer Paving, Inc.	PO Box 12500	3919 South West Street	Wichita	KS	67277-2500
Yakowenko	Gerald	Highway Engineer	Federal Highway Administration	400 Seventh Street, SW	Room 3134, HIPA-30	Washington	DC	20590

Appendix P.
Workshop Packet

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

Agenda
(Business Casual dress for all activities)

Sunday March 4, 2001

6:30 PM - 8:00 PM	Reception
	Yorba Room, Four Seasons Hotel

Monday March 5, 2001

7:00 AM	Assemble in Four Seasons Lobby for buses
7:15 AM	Breakfast - Beckman Center Dinning Room
8:00 AM	Welcome –Lecture Room
	Crawford F. Jencks (NCHRP)
	John M. Smythe (AASHTO Hwy Subcom on Construction)
8:20 AM	Project Background
	Jeffrey S. Russell, University of Wisconsin - Madison
	Stuart D. Anderson, Texas A&M University
9:05 AM	Workshop Goals & Objectives
	Corey Hessen, FMI
9:25 AM	Keynote Speaker
	Mike Ryan, Deputy Secretary for Highway Administration
	Pennsylvania Department of Transportation
	Research Beyond TEA-21
	Abstract: One of the shortfalls in TEA-21 has been the ear-marking of research projects. For this reason, there has been a lack of unified national research focus. There are several attempts underway to develop a national focus, hopefully as part of the successor to TEA-21 legislation. An overview will be presented on these efforts as they relate to the themes that have been identified as part of NCHRP 10-58.

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

Agenda

Monday March 5, 2001

9:45 AM	Team Building Exercise
10:00 AM	Break –Foyer of Lecture Room
10:15 AM	Breakout #1
	Themes A-F
	See Matrix for Room Assignments
11:10 AM	Breakout #2
	Themes A-F
12:00 AM	Lunch - Beckman Center Dinning Room
1:00 PM	Breakout #3
	Themes A-F
1:50 PM	Breakout #4
	Themes G-L
2:45 PM	Break - Foyer of Lecture Room
3:00 PM	Breakout #5
	Identification of Future Issues (black pen)
4:15 PM	Breakout #5
	Identification of Future Issues (red pen)
	Review Work from Another Group
4:45 PM	Wrap-Up
5:00 PM	Adjourn –Buses back to Hotel

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

<u>Agenda</u>

Tuesday March 6, 2001	
7:00 AM	Assemble in Four Seasons Lobby for buses
7:15 AM	Breakfast - Beckman Center Dinning Room
8:00 AM	Findings from Day 1
	Objectives for Day 2
9:15 AM	Breakout #6
	Themes G-L
10:00 AM	Break - Foyer of Lecture Room
10:15 AM	Breakout #7
	Themes G-L
11:15 AM	Breakout #8
	Themes M-O
12:15 AM	Lunch - Beckman Center Dinning Room
1:15 PM	Breakout #9
	Themes A-C; M-O
2:00 PM	Breakout #10
	Future Issues
2:45 PM	Break - Foyer of Lecture Room
3:00 PM	Breakout #11
	Prioritize Themes
3:45 PM	Wrap-Up
5:00 PM	Adjourn –Buses back to Hotel

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

Travel Instructions

Bus

Each morning at 7:00 a.m. meet in the lobby of the Four Seasons Hotel. A bus will be there to take everyone to the Beckman Center, where the workshop will be conducted.

Each evening, after adjourning from the workshop, the bus will be waiting to take participants back to the hotel.

Personal

You may drive you own car or carpool to and from the workshop. If you decide to do so, please inform Crawford Jencks so that the bus does not wait for you.

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

<u>Post Workshop Follow-Up</u>

This will be a fast-paced workshop in which you will be asked to share your expertise. Because of the pace, you may not be able to contribute everything you have, or you may remember something you wanted to say after you return home. Therefore, this sheet may be used for you to share more information with the research team. You may provide this information in a number of ways. You can call Jeffrey S. Russell and speak with him. You may e-mail him. Or you may write your comments on this sheet of paper and mail it to him.

Here is his contract information:
Jeffrey S. Russell
Department of Civil and Environmental Engineering
2304 Engineering Hall
1415 Johnson Drive
Madison, Wisconsin 53706
Telephone: 608/262-7244
FAX: 608/265-9860
E-Mail: russell@engr.wisc.edu

Thank you!

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

Breakout Session Questions

During each breakout session in which we discuss the themes, you will be asked to answer three key questions. They include:

1. What do you agree with in terms of the theme description and research objectives?

2. What do you NOT agree with in terms of the theme description and research objectives?

3. What items are MISSING from the theme description or research objectives?

NCHRP Project 10-58, FY 2000
Construction Engineering and Management Research Program
First Round Workshop Invitees

1. Doyt Bolling, Utah TT Center
2. Ron Cominsky, Pennsylvania Asphalt Pavement Association
3. John Conrad, Washington State DOT
4. John Deatrick, Cincinnati Transportation and Engineering Dept.
5. Leet Denton, Denton Enterprises, Inc.
6. Joe Dobrowolski, California DOT
7. P. Kay Griffin, California DOT
8. Arthur Gruhn, Connecticut DOT
9. Carl Haas, University of Texas - Austin
10. Greg Henk, Flatiron Structures, Inc.
11. Chuck Hughes, Consultant
12. G. John Kurgan, Michael Baker Jr Inc
13. Peter Kopac, Federal Highway Administration
14. Ken Leuderalbert, Florida DOT
15. Byron Lord, Federal Highway Administration
16. Donald Lucas, The Heritage Group
17. Tanya Matthews, Design-Build Institute of America
18. Roy Mendlesohn, Parsons Brinckerhoff, Inc.
19. Dennis Morian, Quality Engineering Services
20. Joseph Musil, Cedarapids Inc
21. Orrin Riley, Orrin Riley PE PC
22. Leonard Sanderson, North Carolina DOT
23. Clifford Schexnayder, Arizona State University
24. Richard Schmidt, Payne and Dolan, Inc.
25. Jim Sorenson, Federal Highway Administration
26. John Spangler, Milestone Contractors LP
27. Ken Stoneman, Oregon DOT
28. Dale Swanberg, Walsh Construction Co.
29. Gary Taylor, Michigan DOT
30. Dean Testa, Kansas DOT
31. James Van Buren, New Enterprise Stone & Lime Co., Inc.
32. Suneel Vanikar, Federal Highway Administration
33. Paul Wells, New York State DOT
34. William Weseman, Concrete & Promo Council TX
35. Gary Whited, Wisconsin DOT
36. David Wittwer, Wittwer Paving, Inc.
37. Ron Williams, Arizona DOT
38. Greg Xanders, Florida DOT

NCHRP 10-58
Construction Engineering and Management Research Program
Workshop
March 5-6, 2001

Beckman Center
100 Academy
Irvine, California

Group Assignments

Group 1

Facilitator:	Donn Hancher (Panel)
RT Member:	Caroline Brandt
Members:	Peter Kopac
	Chuck Suszko
	P. Kay Griffen
	John Deatrick
	Scott Shuler
	Joseph Bush
	Crawford Jencks (Panel)

Group 2

Facilitator:	John Smythe (Panel)
RT Member:	David Trejo
Members:	John Bourne
	Jim Sorenson
	Gary Taylor
	Chuck Hughes
	Donald Lucas
	Greg Henk
	Wesley Lum

Group 3

Facilitator:	Steven DeWitt (Panel)
RT Member:	Stuart D. Anderson
Members:	Byron Lord
	Rory Rhinesmith
	G. John Kurgan
	Orrin Riley
	Roy Mendelsohn
	Chapin Sipherd
	Daniel Benfield (Panel)

Group 4

Facilitator	Deborah Fisher
RT Member:	Andrew Damron
Members:	Lee Onstat
	Paul Wells
	Tanya Matthews
	Rick Sniegowski
	David Manning (Panel)
	Lawrence Cole (Panel)

Group 5

Facilitator	Julia Perry (Panel)
	Frederick Hejl (Panel)
Members:	Arthur Gruhn
	Dennis Morian
	Suneel Vanikar
	James Van Buren
	Carl Haas
	Thomas Pierce (Panel)

Group 6

Facilitator	Rudy Malfabon (Panel)
	Gerald Yakowenko(Panel)
Members:	Lee Onstat
	Ron Williams
	Dean Testa
	Mike Ryan
	Clifford Schexnayder
	William Weseman
	Robert Schmidt (Panel)

Day 1 –Monday, March 5, 2001

GROUP	ROOM	Facilitator	THEMES FOR DISCUSSION					
			Breakout Session #1	**Breakout Session #2**	**Breakout Session #3**	**Breakout Session #4**	**Breakout Session #5a**	**Breakout Session #5b**
1	Lecture Room	Donn Hancher	A	B	C	G	Future Issues	Future Issues
2	2A	John Smythe	B	C	D	H	Future Issues	Future Issues
3	5A	Steven DeWitt	C	D	E	I	Future Issues	Future Issues
4	4E	Deborah Fisher	D	E	F	J	Future Issues	Future Issues
5	5B	Julia Perry	E	F	A	K	Future Issues	Future Issues
6	5D	"Rudy" Malfabon	F	A	B	L	Future Issues	Future Issues

Themes Covered:

A. Safety of public and workers during highway reconstruction and maintenance
B. Develop and evaluate new construction methods, processes, and materials to facilitate faster construction
C. Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel)
D. Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction
E. Development, implementation, and evaluation of the use of incentives/disincentives for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility
F. Innovative strategies to manage traffic during highway construction projects –as specifically related to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction
G. Training and workforce development of SHA personnel
H. Development, implementation, and evaluation of Performance-Based Specifications (PBS) and Performance-Related Specifications (PRS) for highway construction
I. Performance Based Acceptance Tests (including investigation of adequate level of construction inspection)
J. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)
K. Development, implementation, and evaluation of rapid test methods and non-destructive testing (NDT)
L. Impact of construction projects on communities and necessary communication between agency/contractor and general public

Day 2 –Tuesday, March 6, 2001

GROUP	ROOM	Facilitator	THEMES FOR DISCUSSION					
			Breakout Session #6	Breakout Session #7	Breakout Session #8	Breakout Session #9	Breakout Session #10	Breakout Session #11
1	Lecture Room	Donn Hancher	H	I	M	N	Future Issues	Prioritize Themes
2	2A	John Smythe	I	J	N	O	Future Issues	Prioritize Themes
3	5A	Steven DeWitt	J	K	O	M	Future Issues	Prioritize Themes
4	4E	Deborah Fisher	K	L	M	A	Future Issues	Prioritize Themes
5	5B	Julia Perry	L	G	N	B	Future Issues	Prioritize Themes
6	5D	"Rudy" Malfabon	G	H	O	C	Future Issues	Prioritize Themes

Themes Covered:

A. Safety of public and workers during highway reconstruction and maintenance
B. Develop and evaluate new construction methods, processes, and materials to facilitate faster construction
C. Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel)
G. Training and workforce development of SHA personnel
H. Development, implementation, and evaluation of Performance-Based Specifications (PBS) and Performance-Related Specifications (PRS) for highway construction
I. Performance Based Acceptance Tests (including investigation of adequate level of construction inspection)
J. Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)
K. Development, implementation, and evaluation of rapid test methods and non-destructive testing (NDT)
L. Impact of construction projects on communities and necessary communication between agency/contractor and general public
M. Compliance with current and future environmental restrictions/requirements
N. Review of the constructibility of transportation facilities in the planning and design phases – specifically deficiencies in quality and clarity of construction plans
O. Expanded use of contractor-performed quality control data for acceptance purposes

Michael M. Ryan, P. E.
Deputy Secretary for Highway Administration
Pennsylvania Department of Transportation

As Deputy Secretary for Highway Administration of the fourth-largest state highway system in the nation, Michael M. Ryan is responsible for the Department's design, construction and maintenance programs. The annual program amounts to $2 billion; $1 billion for new construction starts and $1 billion for operations and maintenance for over 40,000 miles of highway. Other responsibilities include management of environmental clearances for all projects, the intelligent transportation system program, and various highway safety initiatives. Total organization is nearly 10,000 employees.

Ryan is a career employee who joined the old Department of Highways in 1968. During his tenure, he has served as Chief Engineer for 3 years, District Engineer for 3 years, Director of Maintenance for 5 years and has held various management and supervisory positions in construction, traffic engineering and maintenance.

Ryan received a Bachelor of Science Degree in Civil Engineering from the University of Pennsylvania in 1968 and an a Master of Science Degree in Civil Engineering from Bucknell University in 1976.

He is a native Pennsylvanian born and raised in Lock Haven. He currently resides in Mechanicsburg with his wife, Bonnie. They have 2 grown sons, Michael and Christopher.

Appendix Q
Anticipated Keynote Speech
"Research –Beyond TEA-21"

Research –Beyond TEA-21
March 5, 2001

Michael M. Ryan, P.E.
Deputy Secretary for Highway Administration
Pennsylvania Department of Transportation

I. Introduction
   a. Thank you/opportunity
   b. NCHRP 10-58, Construction Engineering and Management
   c. Congratulations on your effort
      i. Themes –Vision for Future
      ii. States –Applied research
      iii. Look beyond immediate needs

II. TEA –21
   a. Great effort
   b. More funding for states $30.7B F.Y. 2001 Expansive Growth
   c. Trust Fund reduction
   d. Minimum guarantees
   e. Off budget provision
   f. RABA
   g. Research –problem area
      i. Heavy ear-marks: Universities, Research Centers, Testing Labs
         1. FY 2000 $137M
            77.5M Earmark 57%
            59.5M Flexible
         2. FY 2001 $143M
            99M Earmark
            44M Flexible
      ii. Lack of unified focus
      iii. Need for improved coordination among states
      iv. Understanding Roles and Responsibilities for R&T
      v. After TEA-21 –several efforts

III. RTCC –Mike Walton of UT at Austin
   a. Who
      i. National Research Council
      ii. Industry, Academic, DOTs (18 members)
   b. Purpose –Advise FHWA on matters relating to Research
   c. Background
      i. Nation's highways = $500B, 50% of total assets
         1. Spending = $100B(1998)
         2. VMT up 68% from 1980 to 1997
         3. Capacity up 4%
         4. Conditions are improving –need to sustain

5. 4 major components to highway R&T

d. FHWA –R&T
    i. 2001=$379M
    ii. Aim @ incremental improvements in highway performance and cost reductions
    iii. Small portion –breakthrough technology for dramatic improvement e.g. Superpave
e. States –R&T
    i. 2% of Total Federal-Aid for Research and Planning
    ii. 25% of this amount for Research
    iii. $139M in 2001
    iv. Pool fund –some research (15M)
    v. Applied research –immediate and short range
f. NCHRP
    i. Pool fund = started 1962
    ii. AASHTO, TRB, FHWA/Sponser by States
    iii. $30M/Yr (Part of $139M)
    iv. Problem orientated and immediate application
g. Private Sector
    i. Companies –products to market
    ii. National associations –product focus
    iii. Engineering profession and labs
    iv. Highly focused –specific needs
h. University Transportation Centers
    i. Contract w/public and private sectors
    ii. $27M/Yr
i. Nation's strategic goals/Major Themes
    i. Safety (Work Zones and Employees)
    ii. Congestion/Mobility (Work Zones)
    iii. Economic growth future look
    iv. Human and natural environment (Mitigation Requirements)
    v. Longer lasting (Pavements/Quality Control, Performance-Based Specs)
    vi. $676M Total Funding. Low at a % of Total <1%
    vii. W/o Federal Research some topics may not be addressed
j. FWHA Role
    i. Long term high risk, visionary
    ii. National Issues
    iii. Monitor duplication in States program/Coordination
    iv. Identify gaps in National Research
    v. Special Initiatives
    vi. Flexible to handle emerging and anticipatory research
    vii. Broad based benefits vs single companies
    viii. Far into future e.g. LTPP multi years

IV. F-SHRP

a. Purpose
   i. Develop new SHRP
   ii. Get feedback on topics –use customers
   iii. Mike Walton, UT at Austin is chair
   iv. Initiated by Congress –TEA –21
   v. Product –report to Congress on a small number of critical goals.

b. Process
   i. Started 6/99
   ii. Significant outreach: DOTs, Private sector, TRB, Federal, local, and University
   iii. Theme: Outstanding customer research

c. Goals
   i. Quantum leap highway safety
      1. Factors: enforcement, human behavior
      2. Work zones and worker protection
   ii. Accelerate renewal of America's highways
      1. Interstates approaching useful life –Focus on repairs
      2. Disruption for rehabilitation present user costs and more congestion
      3. Goal: faster repairs, quality control, performance –based specs
   iii. Reduce delay for highway users
      1. Congestion cost = $72B
      2. Construction work zones are mentioned as one of the factors
      3. Opportunity: improve management in work zones –Incentive/Disincentives, nighttime work, weekend
   iv. Meet highway demand to support economic and social goals
      1. Highway system is lifeline of goods movement
      2. Opportunity: improve condition, safety and operations
      3. Focus on community participation, environmental sensitivity, and communicate with customers (design visualization), community impacts

V. R&T Partnerships, TRB, AASHTO, and FHWA

a. Overview/Change
   i. Identify Major Issues
   ii. Review current research and identify gaps
   iii. Determine priority themes
   iv. Benefits analysis
   v. Facilitate Partnerships
   vi. 12/10/98 started
   vii. Draft Reports/Review and Comments
   viii. TRB 1/01 Reports Presented
   ix. Finding to RTCC

b. AASHTO Strategic Highway Safety Plan
    i. Reduce deaths and injuries
    ii. Work zones target area/e.g. ITS
c. Opers and Mobility –Phil Tarnoff, V or MD
    i. Congestion Cost - $70 +B
    ii. Determine Customer Needs
    iii. Establish Performance Measures
d. Planning and Environmental –Elizabeth Dukin U of Cal. @ Berkley
    i. Community and Connectivity, Community Impacts
    ii. Connect with Nature
e. Infrastructure, Earmark Francois
    i. Asset Management
    ii. Part Enhance Materials, Technologies, Automation for Construction Structures, Enhanced Specs, Performance Specs, Constructibility
f. Policy Analysis –Mary Lynn Tischen of AZ DOT, Alan Pisarski, Consultant
    i. Policy Systems Monitoring Research
    ii. Performance measures

VI. A5T60 TRB Task Group
a. History
    i. TRB Special Report 249. Building momentum for change
    ii. Funding from NCHRP (project 20-54) Debate merits of potential innovations
    iii. Don Lucas, Chairman
b. Purpose –accelerate opportunities to implement innovation in highway industry
    i. Remove barriers
    ii. Develop strategies that generate change
c. Workshop #1
    i. November 16 & 17, 2000
    ii. Get in, get out, stay out
    iii. Become traffic sensitive
    iv. Less time to do construction
    v. Focus on customer expectations
    vi. Contractors & state DOTs –current state-of-the-art techniques
d. Workshop #2
    i. 'Swat"team application to a specific project
    ii. Get in, get out, stay out

VII. Summary
a. Themes match up well with other major initiatives. Good linkage for most items
b. Carefully add substance to your theme/identify appropriate research to solve industry related problems

c. Continue to be visionary vs. applied or near term problem solving. Remember 10 yr outlook
d. Hard Work
e. Good luck with your effort. Look for a successful outcome

Appendix R.
Workshop Data Summary

Theme A

Safety of public and workers during highway reconstruction and maintenance.

Initial Objectives

a) Develop innovative methods to reduce traffic speeds in work-zones.
b) Configure work-zone to maximize safety.
c) Improve work-zone safety planning.
d) Use case studies to determine which methods and techniques effectively slow down traffic.

Recommended Changes

Rephrase Theme Title

- Improve safety of traveling public and workers during highway reconstruction and maintenance. (Group 4)
- Safety of public workers in the work-zone during highway reconstruction and maintenance. (Group 5)

Rephrase Objectives

a) Develop innovative methods using new technology to reduce traffic speeds in work-zones. (Group 1)
a) Develop innovative methods to improve safety including speed reduction in work-zones. (Group 4)
a) Develop innovative methods to improve safety in work-zones. (Group 6)
b) Investigate methods to configure work-zone to optimize safety. (Group 1)
b) Identify and develop best practices to configure work-zones to maximize safety. (Group 5)
c) Develop guidelines for consistent, effective work-zone safety planning, to include public relations, scheduling, road closures/detours, construction sequencing, configuration of work-zone, worker safety, and utilization of barriers. (Group 5)
d) Use case studies (maintenance, rehabilitation, and reconstruction) to determine which methods and techniques effectively slow down traffic and/or reduce traffic volumes. (Group 1)
d) Use case studies to determine which methods and techniques effectively improve work-zone safety, including slowing traffic speeds. (Group 4)
d) Use case studies to determine which methods and techniques effectively improve safety in work-zones. (Group 6)

New Objectives

- Need comprehensive database for traffic planning during construction. (Group 1)
- Develop guidelines for work-zone safety planning. (Group 4)
- Measure effectiveness of communications devices (signs, variable message signs). How can IT be used to communicate with the public in advance of and during construction? (Group 6)
- What are best practices for emphasizing safety on a daily basis? (Group 6)
- Investigate proper balance between signing information overload and adequate signing in work-zones. (Group 6)

Theme B

Develop and evaluate new construction methods, processes, and materials to facilitate faster construction.

Initial Objectives

a) Identify construction processes to minimize the impacts of highway construction on highway users.
b) Investigate the use of modular construction techniques in highway and bridge projects.
c) Develop knowledge base for best practice construction methods.
d) Develop knowledge base for the best practice construction methods when using non-traditional/new materials.
e) Identify processes for implementing new materials into practice with examples of successful implementation plans.
f) Develop user-friendly models that identify potential cost savings for implementing the use of new durable materials.

Recommended Changes

Rephrase Theme Title

- Evaluate new construction methods, processes, and materials to facilitate faster construction. (Group 5)

Delete Objectives

e) Identify processes for implementing new materials into practice with examples of successful implementation plans. (Group 5)
f) Develop user-friendly models that identify potential cost savings for implementing the use of new durable materials. (Group 5)

Rephrase Objectives

a) Identify faster construction methods and processes. (Group 5)
b) Investigate the use of precast modular construction techniques in highway and bridge projects. (Group 6)
c) Develop knowledge base for best practices of rapid construction methods. (Group 5)
d) Develop knowledge base for best practices of rapid construction materials. (Group 5)
f) Develop user-friendly models that identify potential cost savings for implementing the use of new durable materials (including cost/benefit analysis, project cost, etc.). (Group 1)
f) Develop user-friendly models that identify potential time-savings for implementing the use of new durable materials. (Group 2)
f) Develop models that detect potential long-term cost savings for implementing the use of new durable materials. (Group 6)

New Objectives

- Identify better methods to gather input from utilities for GIS detection. (Group 1)
- Analyze methods to produce better "as-built" records for construction projects. (Group 1)
- Investigate better coordination with utilities. (Group 2)
- Develop evaluation tool to determine if method is in fact "faster." (Group 2)
- Develop design/program based on traffic management needs. (Group 2)
- Investigate ways to use new materials and the relative barriers associated with new materials and allocation of risk. (Group 2)
- Conduct analysis to identify bottlenecks in construction methods. (Group 5)
- Identify critical requirements to implement faster construction methods (handbook, training, guides, etc.). (Group 5)
- Identify issues/problems related to new rapid construction methods and materials (special requirements for rapid-set concrete). (Group 5)
- Develop methods to allow construction to continue in cold/hot weather. (Group 5)
- Investigate the tradeoffs between speed, quality, and cost when using new methods, processes, and/or materials. (Group 6)

Theme C

Recruiting, promoting, and retaining of qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel).

Initial Objectives

a) Investigate methods for state highway agencies to provide competitive careers.
b) Benchmark employee practices between the public sector, private sector, and other disciplines for entry level employees and/or experienced personnel.
c) Develop optimum strategies for staffing and contract administration.
d) Evaluate the pool of employees available, recruitment strategies, and corresponding retention rates.
e) Quantification of the need to invest in human resources.

Recommended Changes

Rephrase Theme Title

- Recruiting, retaining, and promoting qualified personnel in highway construction (including competition between the public sector, private sector, and other engineering disciplines for entry level employees and/or experienced personnel). (Group 1)

Rephrase Objectives

e) Quantify the need to invest in human resources. (Group 1)

New Objectives

- High School programs to get more students interested in civil engineering –highway construction. (Group 1)
- Synthesize methods in highway construction to provide competitive careers. (Group 2)
- Promoting careers in transportation construction. (Group 2)
- Investigate opportunities for cross-utilization of employees in different functional areas. (Group 2)
- Develop programs to interest youth in transportation construction careers. (Group 5)
- Determine construction job characteristics that are a detriment/attribute to recruitment (SHAs and construction contractors) and provide recommendations for overcoming impediments/emphasizing benefits. (Group 5)
- Develop ways to measure white-collar productivity. (Group 5)
- Develop high value-added/high wage work strategies. (Group 5)
- Investigate job satisfaction as a supplement to monetary compensation for recruiting and retaining. (Group 6)
- Study the use of retention bonuses to keep qualified staff. (Group 6)
- What institutional barriers exist that should be revisited to enhance an agency's ability to recruit and retain valuable staff? (Group 6)
- Examine Professional Engineer License requirements for certain positions. Are they really necessary? (Group 6)

Research Products

- Best practices. (Group 3)
- Restructured organizations –Reflect region, size or organization, urban component. (Group 3)
- State of current practices. (Group 3)

Theme D

Innovative contracting methods and delivery systems to facilitate faster construction/reconstruction.

Initial Objectives

a) Develop an empirical method to select the most efficient and economical contracting strategy based on known specific project factors, characteristics, sizes, and complexities.
b) Evaluate the results of various, non-traditional contracting strategies including the effects on schedule, cost, and quality. Additionally, assess the potential risks associated with alternative methods.
c) Investigate the compatibility between innovative contracting strategies (non-traditional) and the traditional, low-bid competitive system.
d) Assess impact on SHA stakeholders' culture, risk, and responsibility.

Recommended Changes

Rephrase Theme Title
- Develop a method to select alternative contracting strategies to speed construction based on known project characteristics, sizes, complexities, and owner objectives and compare those alternatives with the low-bid competitive system. (Group 2)
- Innovative contracting methods and delivery systems for construction/reconstruction projects to improve quality and safety. (Group 3)
- Innovative contracting methods and delivery systems for construction/reconstruction to mitigate impacts on the traveling public. (Group 4)

Rephrase Objectives
a) Develop a method to select the most efficient and economical contracting strategy based on known specific project factors, characteristics, sizes, and complexities. (Group 6)
a) Develop a model or method to select the most efficient and economical contracting strategy based on known specific project factors, characteristics, sizes, complexities, owner objectives, and constraints. (Group 2)
a) Develop a rational decision making process to select the most effective contracting strategy based on known specific project characteristics. (Group 4)
b) Evaluate successes/failures of innovative contracting methods on past projects including effects on schedule, cost, quality, and user impacts. (Group 4)
c) Product synthesis that will investigate the compatibility between innovative contracting strategies (non-traditional) and the traditional, low-bid competitive system from both the owner and contractor perspective and impacts on culture, risk, and responsibility. (Group 2)

New Objectives
- Develop methods SHAs can use to determine responsible, qualified contractors that will withstand legal challenges and provide agencies with skilled competent contractors that can complete quality projects on time. (Group 5)
- Investigate the use of procurement procedures used in emergency situations. (Group 6)
- Evaluate the use of performance based qualification criteria used in the procurement process through innovative contracting. (Group 6)
- Investigate legislative changes needed to allow best-value selection of traditional design-bid-build projects. (Group 6)

Research Products
- Develop best practices. (Group 3)
- Analyze use by public and private sectors. (Group 3)
- Quantify benefits. (Group 3)
- Recommend benefits to enhance low-bid system. (Group 3)

Theme E

Development, Implementation, and Evaluation of the use of Incentives/Disincentives and contract provisions to improve cost, effectiveness, timeliness, and quality of the constructed facility

Initial Objectives

a) Assess current use of incentives/disincentives within contracts
b) Determine fair and effective incentives/disincentives
c) Create guidelines and examples that uses incentives/disincentives as a contract clause

Recommended Changes

Rephrase Title

Evaluate the use of and develop guidelines for the use of I/Ds for contractors and in contract provisions to improve cost effectiveness, timeliness, and quality of the constructed facility (Group 4)

Rephrase Objectives

a) Assess the current use of and magnitude (dollar amount) of I/Ds within contracts (Group 4)
a) Expand to include an assessment of the impact on the entire program by pulling resources to work on I/D projects (Group 5)
b) Expand to include methods of calculations and how to make them enforceable (Group 5)

Research Products

- Evaluate the state of practice (Group 3)
- Identify current models and best practices (Group 3)
- Determine the fair level of I/Ds (Group 3)
- Create measurable and objective criteria (Group 3)

Theme F

Innovative strategies to manage traffic during highway construction projects –as specifically related to project staging of highway projects and strategies to minimize construction delays such as night and weekend construction.

Initial Objectives

a) Investigate the effectiveness of innovative contraction methods (A+B bidding, lane rental) to influence timely completion of projects and minimize construction complications on traveling public and businesses.

b) Analyze the availability and effectiveness of software applications to simulate and visualize highway construction projects.

c) Identify recommended guidance, best practices, and training associated with specifying, designing, implementing, managing/operating various travel management and traffic control strategies associated with different types of projects.

d) Study the impact of shifting more responsibility for traffic control to the contractor, potentially by the addition of a traffic control contract bid item.

Recommended Changes

Rephrase Theme Title

- Study of best practices and guidelines to produce a synthesis of methods to manage traffic during highway construction projects –as specifically related to project staging/phasing and constructibility of highway projects. (Group 4)
- Impacts of innovative strategies to manage traffic, such as project staging, night and weekend construction, on construction methods, productivity, and quality. (Group 5)
- Innovative strategies to manage traffic during highway construction projects –as specifically related to project staging of highway projects and strategies to minimize construction delays. (Group 6)

Delete Objectives

d) Study the impact of shifting more responsibility for traffic control to the contractor, potentially by the addition of a traffic control contract bid item. (Group 4)

Rephrase Objectives

a) Investigate the effectiveness of innovative construction methods to minimize construction complications on traveling public, communities, and businesses. Should focus on construction methods only, not contracting methods. (Group 5)

a) Investigate the effectiveness of innovative contraction methods (A+B bidding, lane rental, incentives/disincentives) to influence timely completion of projects and minimize construction complications on traveling public and businesses. (Group 6)

b) Evaluate the use of existing software for traffic design and assess the impacts of various construction operations (e.g. Lane closures) on traffic flows. (Group 4)

c) Identify recommended guidance, best practices, and training associated with travel management strategies with different types of projects. (Group 5)

d) Study the impact of shifting more responsibility for traffic management to the contractor, potentially by the addition of a traffic control contract bid item. (Group 5)

New Objectives

- Assess strategies to evaluate delivery methods of material at the job site. (Group 6)
- Evaluate and determine best practices for ITS. (Group 6)

Research Products

- Evaluate current practice. (Group 3)
- Identify benefits and risks to SHAs and industry. (Group 3)
- Identify possible applications. (Group 3)

Theme G

Training and workforce development of SHA personnel

Initial Objectives

a) Assess the current training programs used by SHAs related to Construction Engineering and Management (CEM)
b) Determine necessary CEM skills and where more training is needed in those skills
c) Determine who could deliver training and how it could be delivered
d) Investigate institutional barriers to training programs (limited time and out-of-state travel)
e) Standardize training programs and create reciprocity between states

Recommended Changes

Rephrase Objectives

a) Expand objectives to include all SHA personnel, not just engineers (Group 1)
b) Determine necessary CEM skills, where more training is needed in those skills, and what training programs are available to develop those skills (Group 5)
c) Determine who could deliver training, how it could be delivered, how the training could be kept current, and also a methodology to fund a continuing program (Group 5)
d) Develop model training programs which are designed to overcome traditional institutional barriers (limited time, out-of-state travel, funding) (Group 5)

New Objectives

- Identify and/or develop innovative training programs (web, CD, video conferencing) (Group 1)
- NHI review courses for upgrading/updating – 23 packages sent out by NCHRP 6 or 7 years ago (Group 1)
- Identify opportunities and procedures to provide joint training to SHAs, contractors, and consultants (Group 5)
- Develop cost/benefit or return on investment and risk models to assess value of training (Group 5)
- Develop recommended 'career path' training guideline for SHA construction personnel (Group 5)
- Determine benefit of providing/encouraging advance education for mid-level SHA employees (Group 5)
- Develop effective mentoring programs for both new and experienced SHA personnel (Group 6)
- Evaluate the use of technical career paths as well as managerial career paths for SHA personnel (Group 6)
- Compare the level and funding and support of SHAs to those in other industries. How does the level of funding and support compare with the quality of trained employees? (Group 6)

Theme H

Development, implementation, and evaluation of Performance-Based Specifications (PBS) and Performance-Related Specifications (PRS) for highway construction

Initial Objectives

a) Assess the current use of performance-based specifications and how their use impacts a project
b) Determine whether individual state laws will permit the use of a performance-based specification for public agencies
c) Determine which types of project components, i.e., pavements, bridges, etc., will benefit from the use of performance-based specifications
d) Evaluate the methods to develop performance-based specifications and provide guidance to SHAs for writing effective performance-based specifications
e) Provide guidance to contractors for bidding and working under performance-based specifications so as to minimize life-cycle costs
f) Provide the training/education of SHA and contractor personnel needed to implement performance-based specifications

Recommended Changes

<u>Delete Objectives</u>

b) Determine whether individual state laws will permit the use of a performance-based specification for public agencies (Group 2)
e) Provide guidance to contractors for bidding and working under PRS so as to minimize life-cycle costs (Group 2)

<u>Rephrased Objectives</u>

- Determine which types of elements may benefit from the use of performance-based specifications (Group 2)
- Expand to include warranties (Group 5)

<u>New Objectives</u>

- Define the difference between performance-related and performance-based specifications (Group 1)
- Develop PRS for pavement systems, structures, etc. (Group 1)
- Continue to develop performance models and criteria, not only for pavements, but all types of construction (Group 1)
- Develop an AASHTO guide for performance-related specifications (Group 1)
- Define/Clarify performance-based versus performance-related specifications and specifically note ‘why’ these are needed, with examples. (Group 2)
- Develop and evaluate the methods for PBS and PRS –Need fundamental measures in a practical mode to base PBS (Group 2)
- Provide guidance to SHAs for writing effective performance-based and related specification (Group 2)
- Develop training programs for the construction inspections and technicians, including statistical analysis and how it relates to construction sampling (Group 6)
- Develop a program to overcome implementation barriers (Group 6)
- Create a plan to aid inspectors in maintaining accountability under the performance period (Group 6)

Theme I

Performance-Based Acceptance Tests (including investigation of adequate level of construction inspection)

Initial Objectives

a) Assess the current use of Quality Control/Quality Assurance (QC/QA) performance-based tests
b) Determine what performance-based QC/QA tests need to be developed and prioritize them
c) Develop uniform testing procedures for those determined from above
d) Investigate institutional barriers to implementation
e) Identify strategies and barriers of why developed tests are not being used
f) Develop accelerated field performance test methods for durability

Recommended Changes

Rephrased Title

Acceptance tests for highway construction (Group 1)
Drop last part of title and make it an objective (Group 1)

Rephrased Objectives

e) Identify strategies to develop tests (Group 1)
f) Develop accelerated field performance test methods, such as durability (Group 1)
- Take out 'QC/QA' and 'performance-based' of objectives. Concentrate on acceptance testing. (Group 1)

a) Remove QC/QA (Group 2)
b) Remove QA (Group 2)
d) Identify institutional barriers to implementation and recommend strategies to overcome (Group 2)
e) Identify strategies to eliminate or mitigate the impact of barriers (Group 2)

New Objectives

- Determine what properties need to be measured to predict performance (Group 1)
- Determine the needed level of acceptance testing (Group 1)
- Evaluate the cost effectiveness of testing (Group 1)
- Develop testing to determine variability and how that affects performance (Group 1)
- Identify QA monitoring required in transition to PBS (Group 2)

Research Products

- Identify the states of practice (Group 3)
- Identify and/or develop best practices relate to particular items, must prioritize and determine what is key (Group 3)
- Critical issues for this subject (Group 3)
  - What, when, how to measure
  - What role should be regarding contractor and SHA
  - Determine barriers

Theme J

Reduced staff size with increased workload (including adequate state inspectors to staff projects, and outsourcing of construction inspection to private companies versus public agencies)

Initial Objectives

a) Assess the current ways SHAs are approaching the problem of increased workload with reduced staff size
b) Evaluate the use of outsourcing as a technique to contend with reduced staff size
c) Develop decision support tool to assess outsourcing of CEM processes versus work retained in-house
d) Develop new programs that can be used to contend with this problem and assess their effectiveness

Recommended Changes

Rephrase Title

More effective project management to confront the reduced staff size with increased workload (Group 4)

Delete objectives

b) Evaluate the use of outsourcing as a technique to contend with reduced staff size (Group 4)
c) Develop decision support tool to assess outsourcing of CEM processes versus work retained in-house (Group 4)
d) Develop new programs that can be used to contend with this problem and assess their effectiveness (Group 2)

Rephrased Objectives

a) Assess the current ways SHAs and others are approaching the problem of increased workload with reduced staff size (Group 2)
a) Assess the current ways agencies are approaching the problem of increased accountability with reduced project management resources (Group 4)
b) Evaluate the effectiveness and efficiency of alternative techniques as identified under objective 1 (Group 2)
c) Develop decision support tool on how and when to select use of the effective tools identified in objective 2 (Group 2)
d) Develop new approaches that can be used to develop cost effective project management processes (Group 4)

Research Products

- Best Practices –outsourcing (time it takes) versus optimum resourcing (Group 3)
- Innovative approaches (Group 3)
- $ effectiveness –true honest comparison (Group 3)
- Barriers and potential ways to overcome barrier (Group 3)

Theme K

Development, implementation, and evaluation of rapid test methods and non-destructive testing (NDT)

Initial Objectives

a) Assess current non-destructive and rapid test methods used in practice
b) Determine where the needs are for new non-destructive and rapid test methods
c) Create a program that assists in the development and research of new test methods
d) Evaluate cost versus benefit of new test methods compared to updating existing test methods

Recommended Changes

Rephrase Title

Identification, development, evaluation, and implementation of rapid test methods and non-destructive testing (NDT) to assess quality in the construction process (Group 4)

Rephrase Objectives

a) Identify current non-destructive and rapid test methods used in practice and assess cost/time savings vs. quality tradeoff of the results. (Group 5)
b) Determine and prioritize where the needs are for new/improved non-destructive and rapid test methods. (Group 5)
c) Develop and research new test methods (Group 4)
c) Recommend a research program for the development and implementation of new test methods. (Group 5)
d) No problem with objective, but could be incorporated with third objective. (Group 5)

New Objectives

- Create process to implement research and display new methods and elimination of old methods (Group 4)

Research Products

- State of practice and best practice (Group 3)
- Identification of critical parameters (Group 3)
- Develop tests (Group 3)
- Provide implementation plan with uniform training (Group 3)

Theme L

Impact of construction projects on communities and necessary communication between agency/contractor and general public

Initial Objectives

a) Assess public perceptions regarding impact of construction on motorists and businesses
b) Assess the current community involvement programs
c) Determine other types of programs or methods that are needed
d) Create examples that can be used as guidelines for different options of obtaining and making use of community input

Recommended Changes

Rephrase Title

Develop best practices for community outreach and involvement during construction (Group 4)

Rephrase Objectives

a) Assess public perceptions regarding impact of construction on motorists and potentially impacted properties (Group 5)

New Objectives

- Develop best practices for community outreach and involvement during construction (Group 4)
- Determine cost-benefit of context-sensitive design (Group 5)
- Develop recommendations and training programs for visual simulation technology (Group 5)
- Develop uniform methods for SHAs to use to obtain public feedback on agency construction programs on a regular basis (Group 5)
- Develop a process to partner with the news media (Group 5)
- Develop guide specifications regarding contractor responsibility to assist with public involvement and notification. (Group 5)
- Create a best practices program, which includes all current SHA efforts to date (Group 6)
- Compare the benefits of having a public involvement program versus the cost of the program (Group 6)
- Determine the best methods for communicating with the public (Group 6)

Theme M

Compliance with current and future environmental restrictions/requirements

Initial Objectives

a) Evaluate the impact of changing regulations of noise, air, storm water management on construction and identify mitigating measures
b) Assess the current programs to identify best practices that focus on compliance of environmental regulations
c) Determine what other programs or areas of study are needed that will aid the SHAs in compliance of environmental regulation

Recommended Changes

Rephrase Title

Identification and implementation best practices for awareness and compliance with impending environmental restriction/requirements during construction (Group 4)

Rephrase Objectives

a) Evaluate the impact of current and impending regulations of noise, air, storm water management on construction and identify mitigation measures (Group 4)
b) Identify best practices that focus on compliance of environmental regulations (Group 4)
c) Document best practices in a format usable by SHAs (Group 4)

New Objectives

- Create a program to facilitate the communication of environmental decisions that were made in pre-construction planning/permitting stage to the construction team (Group 1)
- Develop innovative ways to handle environmental requirements (Group 1)
- Develop a continuously updated database that encompasses and explains all environmental regulations (Group 1)
- Create guidelines to minimize delays and impacts due to environmental issues while protection or improvement of the environment is in process (Group 3)

Research Products

- Inventory of current regulations and impact (Group 3)
- Best practices –models (Wisconsin DOT has a good model) (Group 3)
- Evaluation of best practices and models (Group 3)
- Identify opportunities for improvement and potential savings (Group 3)

Theme N

Review of the constructibility of transportation facilities in the planning and design phases –specifically deficiencies in quality and clarity of construction plans.

Initial Objectives

a) Study the results of projects, successes and failures, that have used a formalized constructibility review process (CRP) and document the benefits and indicate where the CRP is ineffective and in need of alteration.
b) Investigate the use of computer applications in the CRP (e.g. lessons learned database, 3D CAD).
c) Institute courses to train agency design staff to identify constructibility issues in project plans and specifications.

Recommended Changes

Delete Objectives

c) Institute courses to train agency design staff to identify constructibility issues in project plans and specifications. (Group 2)

Rephrase Objectives

a) Study the results of projects, successes and failures, that have used a formalized constructibility review process (CRP), document the benefits, and indicate where the CRP is ineffective and in need of alteration. (Group 5)
b) Investigate the potential use of computer applications in the CRP (e.g. lessons learned database, 3D CAD). (Group 2)
b) Determine what computer applications are of value to a CRP and recommend where in the process they should be used. (Group 5)
c) Institute courses to train agency staff to identify constructibility issues in project plans and specifications. (Group 1)

New Objectives

- Identify methods to overcome barriers and successfully implement a formal CRP. (Group 1)
- Identify and measure successes/barriers of informal utilization of staff in design and construction in constructibility reviews. (Group 2)
- Investigate the impact of a traffic management plan on the CRP. (Group 2)
- Create a 'lessons learned" database with an effective means of updating the database. (Group 5)
- Development of an easy to use method to measure costs and benefits of a CRP. (Group 5)

Theme O

Expanded use of contractor-performed quality control data for acceptance purposes

Initial Objectives

a) Assess the use and effectiveness of current contractor QC testing
b) Examine the states of knowledge and practice of other public agencies
c) Assess the current practices and/or problems with verification and validation of QC data for acceptance
d) Determine the areas in which contractor QC data can be applied
e) Evaluate cost/benefit trade-offs including impact on construction costs
f) Create examples that provide guidance for contractor QC testing

Recommended Changes

Rephrase Title

Expanded use of contractor-performed test data for acceptance testing (Group 2)
Expand the use of contractor-performed quality control data for acceptance purposes (Group 4)

Delete Objectives

a) Examine the states of knowledge and practice of other public agencies (Group 2)
b) Assess the current practices and/or problems with verification and validation of QC data for acceptance (Group 2)
d) Determine the areas in which contractor QC data can be applied (Group 2)

Rephrase Objectives

a) Assess the use and effectiveness of current contractor testing and determine where contractor tests results are used for acceptance (Group 2)
a) Examine the states of knowledge and practice of other public agencies (Group 4)
b) Assess the current practices and/or problems with verification and validations of QC data for acceptance can be applied (Group 4)
c) Provide examples and guidelines for providing guidance for contractor QC testing (Group 4)
g) Identify and document case study examples of contractor perform testing and evaluate benefits of and examine the states of knowledge and practice of other public agencies (Group 2)

New Objectives

- Create certification programs for technicians to insure unified testing procedures for all tests (Group 1)
- Identify cases of where contractor tests were used for acceptance. Study those cases to determine if the method reduced duplication, if the SHA got the results they desired, and what verification procedures were used (Group 2)
- Develop new verification processes for quality testing (Group 2)
- Determine the appropriate application of incentives in a QC/QA process (Group 6)
- Identify practices that contractors do to maximize the use of incentives (Group 6)
- Identify what are other agencies are doing to implement contractor test results in the acceptance program (Group 6)

Research Products

- States of practice –look to other industries (Group 3)
- Evaluate alternative approaches against barriers, risks, and benefits (Group 3)
- Test, evaluation, and additional development of quality testing (Group 3)
- Implementation plan (Group 3)

Theme P –Future Issues

Automated and Tele-operated Construction and Maintenance

An opportunity exists to improve safety, cycle time, and quality by automating some construction operations. Examples include automated pothole fillers and crack sealers that reduce labor costs by up to 75 percent, improve safety by removing workers from exposed conditions, and potentially increase work speed thus reducing user costs. Automated positioning and locating systems can be used to eliminate surveying time required for grade stake placement, to enable automatic paver and grader control, and to monitor compaction passes. Robotic control systems allow equipment to be operated by less skilled workers and yet produce superior quality results. At the extreme, autonomous vehicle control may allow shadow vehicles and convoys to be served by a single operator. Many of these technologies already exist but are underutilized because of lack of awareness and because of typical impediments to innovation and automation in construction. Automation opportunities need to be identified, and way need to be suggested to overcome the impediments to their use.

Objectives:

a) Identify opportunities for automation and tele-operation in construction and maintenance.
b) Identify current efforts and innovations that could be utilized in highway construction, with recommendations as to implementations.
c) Recommend ways to overcome impediments to construction automation that have been previously identified in other studies.
d) Develop cost-benefit comparisons of automated/remote operations to standard construction methods.

Electronic Bidding

Electronic bidding offers the potential for certain administrative efficiencies for both contractors and State DOTs. However, there are certain issues regarding security, timeliness, and others which must be addressed before internet based bidding can become a reality.

Objectives:

Define security issues
- For contractor information
- Electronic signatures
- Legislative issues
- Bid bond, payment bond issues, (collateral)
- Funding mechanism
- Reliability
- Security
- From the contractor's perspective, what is working, what is not?

Theme P –Future Issues

Elimination of Delays Caused by Utilities

Objectives:

a) Determine state-of-the-art for locating active and abandoned utilities, horizontally and vertically, and cost for increasing accuracy
b) Determine impediments to and best practices for relocation in a timely manner.
c) Develop guide specification for utility relocation.

Planning to eliminate delays caused by utilities

Description:

- Delays costing time and money (claims issues)
- Public expectations not being met
- Projects schedules not being met
  - Control of Industry (utility)
  - Limited control of SHAs over utilities
- Utility companies have efficiency, funding, workforce issues as do SHAs and industry
- Need to know the issues facing the utility companies

Objectives:

a) Investigate existing and emerging technologies for locating utilities
b) Develop best practices
c) Look at alternate approaches
d) Investigate opportunities for future utility placement
e) Use GPS technology to locate utilities (as placed or locations in place)
f) Investigate possibility comprehensive utility cooperative
g) Investigate I/D for utility relocation or other innovative methods

Planning to avoid delays caused by utilities

Objectives:

a) Review and evaluate existing owner and utility accommodation policies to identify how changes can reduce delays
b) Develop and evaluate strategies to avoid construction delays caused by utilities
c) Synthesize current research projects and best practices
d) Synthesize what utility companies feel can be done to avoid delays
e) Develop a guide to aid in the consideration of the impact of future construction in that area before utilities are placed for new construction
f) Create a best practice guide

Theme P –Future Issues

Warranties

Description:
- Quality (contractor has incentive)
- State DOT workforce is decreasing
- Incentive for innovation
- Everybody can win when done right
- Includes maintenance (long –term warranties)
- Warranties are here now, will be here in the future

Objectives:

a) Assess the current use of warranties and where warranties have worked
b) Evaluate the use of contractor input into design for warranty contracts
c) Compare conventional bonding to long term warranties in terms of long term maintenance
d) Identify 3rd parties to provide the insurance for warranties
e) Determine the extent of warranty maintenance, for example does it include snow plowing, salting, landscaping, etc.
a) Create an implementation plan for current and future warranty specifications

Warranties

Description:
- Managing warranty from SHA perspective
- Bonding of warranty periods –Are there alternatives to bonds
- Service warranties vs. performance warranties (bidding on maintenance vs. bidding on construction
- Experience in other elements of the construction industry that are non-highway

Examine true value of warranties

Objectives:

a) Document experience with warranties
b) Identify the purpose of warranty (avoid defects, extended maintenance)
c) Determine methods to establish performance criteria
d) Establish enforceability/contractor liability
e) Perform cost/benefit analysis to determine which projects are best suited for warranties
f) Recommend utilization or when not to use
g) Develop sample contract clauses to be used as a guide for SHAs