Grand Challenges:
A Strategic Plan for Bridge Engineering

AASHTO Highway Subcommittee on Bridges and Structures

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INTRODUCTION

BACKGROUND

The Highway Subcommittee on Bridges and Structures (HSCOBS) of the American Association of State Highway and Transportation Officials (AASHTO) has long recognized the benefit of research in helping its members meet their responsibility to design and manage the nation's highway infrastructure. Because of this recognition, HSCOBS strives to identify ways to fulfill the business needs of its members, and, to that end, annually reviews research problem statements and recommends selected statements to the AASHTO Standing Committee on Research (SCOR) for consideration for funding under the National Cooperative Highway Research Program (NCHRP). In addition, other research needs are addressed by Federal, State and industry-sponsored research and development programs.

2000 WORKSHOP

Because of this review and recommendation process, the subcommittee has obtained funding for various NCHRP projects that have benefited the bridge community. It became apparent to the subcommittee that a more structured procedure for prioritizing research was needed. A workshop was conducted February 14-16, 2000 in Irvine, California to develop a strategic plan for bridge engineering. Participants included AASHTO State Bridge Engineers, the Federal Highway Administration (FHWA), academics, consultants, and industry representatives. The information developed in the workshop represented a consensus of the participating bridge engineering professionals. The strategic plan assisted HSCOBS in identifying and prioritizing the major themes for a coordinated national bridge engineering agenda. HSCOBS has used the resulting agenda to evaluate and prioritize research problem suggestions ensuring a quality-based research program aligned with HSCOBS' needs.

The product of the original workshop is six "thrust" discussions. Each thrust focuses on a specific business need of the AASHTO bridge engineers. The unprioritized thrusts are as follows:

- Enhanced Materials, Structural Systems, and Technologies;
- Efficient Maintenance, Rehabilitation, and Construction;
- Bridge Management;
- Enhanced Specifications for Improved Structural Performance;
- Computer-Aided Design, Construction, and Maintenance; and
- Leadership.

Each thrust discussion starts with a paragraph giving general background on the thrust. A brief statement of the "business need" that would be satisfied with accomplishment of the thrust follows. After listing the thrust's objective, the thrust discussion concludes with a list of "building blocks" (i.e., products or processes that must be available to satisfy the business need).

A list of research areas that complement the business needs of HSCOBS follows the "thrust" discussions in Appendix A. This list is included solely to illustrate the range of researchable topics that are of interest to bridge engineers.

2005 WORKSHOP

The 2000 report is a working document. Thrusts and business needs are dynamic—they must be continually reviewed and revised to reflect the ever-changing societal and technical environment within which the highway system exists. HSCOBS is fully committed to the continued maintenance and improvement of this document and to applying the contents to the identification and prioritization of research. As such, a second workshop was conducted April 18-20, 2005, in Woods Hole, Massachusetts, to refine the 2000 strategic plan. Participants included AASHTO State Bridge Engineers, the Federal Highway Administration (FHWA), academics, and consultants. The group included the Transportation Research Board (TRB) Structures Section chairs.

The products of this workshop are a focused set of critical problems extracted from the 2000 strategic plan that, if solved, would lead to significant advances in bridge engineering, called “grand challenges” that build upon the thrusts of the 2000 plan. The prioritized grand challenges are:

- Extending Service Life,
- Optimizing Structural Systems,
- Accelerating Bridge Construction,
- Advancing the AASHTO Specifications,
- Monitoring Bridge Condition,
- Contributing to National Policy, and
- Managing Knowledge

Each “grand challenge” is defined through a brief statement of the challenge and anticipated outcome, and discussions of the practical importance, the technical importance, and the readiness of the challenge to be solved. Finally, lists of important activities/research areas and minimum measures of success, called benchmarks, are included. The benchmarks are grouped by the time in which they should be accomplished to insure the solving of the challenge: short term (in 2-3 years), mid-term (in 4-5 years) and long term (beyond 5 years.) The benchmarks can also be viewed as a guide to implementation.

At their 2005 annual meeting in Newport, Rhode Island, the AASHTO HSCOBS adopted the report of the workshop as their strategic plan for bridge engineering. The detailed plan follows.

GRAND CHALLENGES:
A STRATEGIC PLAN FOR BRIDGE ENGINEERING

GRAND CHALLENGE 1: *EXTENDING SERVICE LIFE*

To understand the processes that decrease the serviceability of existing bridges and highway structures, and to develop approaches to preserve (maintain and rehabilitate) the existing system by managing these processes.

Anticipated Outcome:

Strategies to extend the service life of existing inventory of bridges and highway structures.

Practical Importance

A significant portion of the nation's inventory of 590,000 bridges is rapidly approaching the end of its intended design life. In order to reduce the demands on already strained construction and maintenance budgets, the option of preservation must be pursued. Therefore, it is imperative to better understand the processes which reduce service life and employ innovative methods to extend the life of these structures.

Technical importance

Our nation's bridges are aging and the increasing traffic volumes and loads that they experience result in a reduction in their planned lives. The resulting necessary rehabilitation and replacement results in reduction in the public's mobility. In addition, owners sometimes employ methods to solve problems in the short term in response to the public's increasing demand for uninterrupted mobility which prove to be deleterious to their structures in the long term (For example, the application of de-icing agents to facilitate mobility resulting in reduced service life.). Guidance should be provided to the engineer to provide cost-effective preventive maintenance and rehabilitation strategies for existing bridges and highway structures.

Readiness

Advancements in our knowledge of materials, details, components, structures and foundations, and an increased array of construction materials and methods makes it an opportune time to develop solutions to extend the service life to solve the problem of preventing premature deterioration of existing bridges and highway structures.

Important Activities/Areas of Research

Investigation of processes that decrease the serviceability of existing bridges and highway structures, and cost effective means of preserving the bridge inventory by prescribing appropriate cost-effective, durable preventive maintenance measures and rehabilitation methods for:

- BRIDGE DECKS – including quantification of the impact of increased traffic volume and loads, nondestructive tests, methods for protection against and extraction of salt ion intrusion, and new materials and techniques for deck construction and repairs
- MAIN LOAD CARRYING MEMBERS – including girder/main member repair and strengthening methods, methods to eliminate expansion joints and bearings, and corrosion mitigation techniques including coatings,

- SUBSTRUCTURES – including methods for corrosion protection and strengthening of piers and abutments
- FOUNDATIONS – including methods to monitor foundations and detect scour, to protect and/or strengthen foundations against scour, earthquake and impact damage, to modify soil (including liquefaction mitigation), to protect salt-water foundations against corrosion (including identification of aggressive environments), and to determine the suitable of existing foundations for proposed rehabilitation or widenings in terms of geometry, integrity and response

Benchmarks

SHORT TERM: identification of the processes which decrease service life, and subsequent identification of the most effective existing and most promising emerging preservation (maintenance and rehabilitation) methods to address the identified processes (including identifications of monitoring devices to determine the optimum time to apply the preservation methods).

MID-TERM: implemention of specifications, guidelines and trial applications leading to deployment of the most effective existing methods, and development of the most promising emerging preservation methods.

LONG TERM: deployment of the most promising emerging preservation methods.

GRAND CHALLENGE 2: *OPTIMIZING STRUCTURAL SYSTEMS*

To understand the advantages and limitations of traditional, newer and emerging materials in terms of safety, durability and economy; and to develop structural systems (optimized materials, details, components, structures and foundations) for bridges and highway structures that efficiently employ these and even newer optimized materials to assure a safe, minimum 75-year service life requiring minimal maintenance.

Anticipated Outcome:

Structural systems which utilize existing and new materials more efficiently in terms of safety, durability and economy.

Practical Importance

The use of high-performance structural systems in transportation structures has been demonstrated to result in significant initial and long-term cost savings, and more efficient construction resulting in less traffic disruption. Nevertheless, to achieve these, and additional, efficiencies, design and construction standards based on optimized materials, details, components, structures and foundations must be developed in order to take advantage of the benefits that can be obtained from these systems. Further, the public funding of bridges and highway structures represents a significant investment, and, maintenance activities to mitigate deterioration of bridges are absorbing an increasing share of this funding. Development of new materials, details, components, structures, foundations and construction procedures aimed at safety, durability and economy will help achieve safe, cost-effective, low-maintenance, long-life structures.

Technical Importance

Existing high performance materials, like high performance concrete and steel, and fiber reinforced polymer composites, are now being more routinely used in bridge and highway structures for new construction, rehabilitation, and repair. Optimized structural systems can increase their efficiency. Meanwhile, some of the newer high performance materials and systems, like self consolidating concrete and ultra high performance concrete for superstructures and ground improvement techniques for improved foundation performance, are now maturing and will soon be ready for widespread use. However, in order to use all of these materials and systems in a structurally efficient, durable and cost effective manner, research is needed to better characterize their properties and optimize their use, and develop efficient design and construction systems, standards and details.

Readiness

Existing classes of materials considered high performance are now being regularly used; new high performance materials are maturing with respect to our understanding of their properties and how design and construction can take advantage of their properties. The need exists both in new construction and existing structure rehabilitation for improved and optimized systems and standards for geotechnical constructions, foundations, and sub- and superstructures that can reduce cost, increase standardization, accelerate construction and result in longer-lasting low-maintenance bridge and highway structures.

Important Activities/Areas for Research

- Characterization and optimization of material properties (including life-cycle performance) for both existing and newer materials including:
    - Traditional, high and ultrahigh performance concretes
    - Traditional, high and ultrahigh performance steels (including weld consumables and corrosion-resistant steels)
    - FRP Composite materials
    - Geomaterials (including more accurate characterization on in situ soil conditions), geosynthetic products and ground improvement techniques
    - Other new (perhaps yet unidentified) materials
- Optimization of geotechnical and structural systems for safety, durability and cost based on optimized materials and systems
- Development of appropriate limit state criteria for the use of these materials, details, components, and structures for adoption into the *LRFD Specifications*
- Development of reliability-based engineering design properties for soil and rock
- Benefit/cost studies of these optimized structural systems (materials, details, components, structures and foundations)
- Assessment of real and perceived barriers to deployment of the various elements of optimized structural systems

Benchmarks

SHORT-TERM: identification of beneficial and achievable material properties (For example, the high performance steels exhibit greater toughness than traditional bridge steels, yet the level of toughness required to reduce fracture-critical member requirements has not yet been quantified.) and structural characteristics for optimized safe, durable and cost-effective structural systems (For example, jointless bridges systems result in more durable bridges.), and identification of barriers to deployment.

MID-TERM: development of optimized structural systems with these properties and characteristics with mitigation efforts toward the identified barriers.

LONG-TERM: deployment of these systems (through standard details and plans, and limit-state design criteria).

GRAND CHALLENGE 3: *ACCELERATING BRIDGE CONSTRUCTION*

To understand the time-restraints, durability and economy of traditional bridge systems and their construction methods, and the possibilities and limitations of newer accelerated methods, and to develop enhanced systems and accelerated methods overcoming traditional time-restraints while maintaining, or enhancing, safety, durability and economy.

Anticipated Outcome:

Strategies to accelerate the construction of safe, durable and economical bridges; both the construction of new bridges and highway structures, and the rehabilitation of existing ones.

Practical Importance

A quarter of our nation's 590,000 bridges are currently classified as structurally deficient or functionally obsolete. Compounding the problem of an aging bridge infrastructure are increasing construction activities leading to traffic congestion, delays, and work-zone accidents. The public has lost patience with the many construction projects, especially when interruptions interfere with their ability to reliably plan their travel time. Innovative construction methods, materials and systems are needed that reduce on-site construction time, while ensuring long-lasting facilities. With available funding that covers only a fraction of the current rehabilitation and replacement needs, strategies are urgently needed to accelerate bridge construction projects to more economically and effectively address the public's demand to "get in, get out, and stay out." Projects can also be completed while maintaining traffic capacity, including in some cases no impact to peak traffic. Accelerated bridge construction results in projects being completed more quickly and therefore impact to users may be lessened. Nevertheless, the benefits of accelerated construction must be weighed against the costs. Finally, recent natural disasters and the increasing threat of terrorism highlight the need for effective hardening and for rapid recovery of the use of our bridges and highway structures.

Technical Importance

Accelerated bridge design and construction research will advance technology by developing improved prefabricated structural systems using enhanced details, materials and foundation systems. The more controlled environment inherent with prefabrication operations facilitates improved quality for more long-lasting systems. Resulting industry advancements will include transportation and erection technology (including new ways of precasting/prefabricating component units) that allows complete bridges to be installed within hours. Specification developments will ensure increased consistency and quality assurance with reduced construction timelines. Research will also result in improved construction work-zone safety strategies and contracting strategies such as incentives/disincentives that ensure the reduced construction timelines while allowing greater flexibility in construction.

Readiness

With highway utilization at capacity, system and public demand requires that the quickest and most efficient construction be done to upgrade the aging infrastructure with more long-lasting systems. To meet this demand, bridge technology is available today to install bridges in hours or days rather than the weeks or months typically required. Also, many states have legislation that mandates minimizing traffic disruption during construction. A cultural change in the public's thinking has occurred such that they now expect that we can do this construction rapidly; these same cultural changes must occur with bridge owners, engineers, and contractors. Environmental restrictions have reduced construction work windows. Highway exposure risks have caused costs for insurance policies to increase; the longer the exposure, the higher the insurance costs. Contractors are requesting field changes to speed up construction projects to reduce their risks. Contracting strategies such as incentives/disincentives are now being used to get the contractor's buy-in to the owner's timeline.

Important Activities/Areas for Research

- Identification of technical and cultural barriers, both real and perceived
- Establishment of a database to track accelerated bridge and highway structures and substructures construction to demonstrate and document successes, including costs
- Implementation and further development of rapidly assembled connection details and joints that are constructible, durable and repairable
- Development of prefabricated seismically resistant systems, including substructures
- Development of more efficient modular sections
- Development of maintenance needs, accessibility, repairability, and inspection criteria
- Identification of transportation and erection issues including loads and equipment
- Implementation and further development of innovative construction methods, including total bridge movement systems, such as Self Propelled Modular Transporter (SPMT), launching, etc.
- Implementation and further development of cost analysis and risk assessment
- Development of quality assurance measures for accelerated techniques for superstructure and substructure construction
- Implementation of advanced materials and continuation of Materials research, e.g., high performance materials, materials durability, lightweight concrete to provide lower self-weight for larger components, etc.
- Implementation and further development of design considerations for hardening of existing structures and rapid recovery after disasters (natural and manmade)
- Implementation of and further development of contracting strategies that encourage spped and quality
- Active and structured dissemination of information on available technologies and successful accelerated bridge construction projects to both decision-makers and designers
- Identification of methods to accelerate construction of bridge foundations and earthwork, demonstrated sources of construction delays

Benchmarks

SHORT TERM: identification of barriers (both technical and cultural) to the application of accelerated bridge construction techniques, the most effective existing techniques, the most promising emerging techniques, and benefit/cost parameters to indicate when accelerated construction is appropriate.

MID-TERM: development of strategies to overcome the barriers identified in the short-term (including a decision-making framework for the routine use of accelerated bridge construction, widespread availability of contractor equipment that accommodates total-bridge installations in hours and guidelines for the states and contractors), development of the most promising emerging techniques into viable options, and deployment of the most effective existing accelerated bridge construction techniques (with success measured through a baseline database populated with completed accelerated bridge construction projects with the goal of at least one bridge project in each state installed within 72 hours, by the year 2010).

LONG-TERM: deployment of the most promising emerging techniques for accelerated bridge construction.

GRAND CHALLENGE 4: *ADVANCING THE AASHTO SPECIFICATIONS*

To understand the limit states required for safe, serviceable and economical bridges and highway structures, and to develop enhanced reliability-based provisions addressing these limit states in a manner relatively consistent with traditional design practice and effort.

Anticipated Outcome:

A stable and comprehensive *LRFD Bridge Design Specifications* that addresses all applicable limit states.

Practical Importance

The *LRFD Bridge Design Specifications* represents a revolutionary change for the highway bridge design community. Not only was it developed as a single completely new set of provisions, but also the strength provisions, which insure the safety of the traveling public, are probability-based yielding uniform safety. The move to the *LRFD Specifications* targeted by AASHTO and the FHWA for 2007 has not been easy for owners due to limited resources. To complete the change of the specifications to a complete probability-based set of provisions, the serviceability provisions should also be calibrated to produce uniform reliability (The service limit states were originally calibrated to produce member proportions comparable with the *Standard Specifications*, not based upon reliability.). Further simplification of some of the more complex provisions may also be warranted. Additionally, there are areas of the specification that are currently undergoing major revision. A new conditional evaluation manual including the load and resistance factor rating (LRFR) methodology is also under consideration. It is urgent that these issues be addressed in a timely nature to satisfactorily complete the implementation process. However, any near-term future changes to the *LRFD Specifications* should be gradual evolutional changes until the community is fully acclimated to the provisions of the 3rd Edition.

Technical Importance

The *Standard Specifications* are no longer supported with yearly interim changes. Hence the adoption of the *LRFD Specifications* is critical. There is a need to improve the design, construction and durability of transportation structures within the context of the *LRFD Specifications*. Specifically, there is a need for further work and clarification in the following areas:

1. Identify and maintain consistent reliability indices within LRFD for all bridge and highway structure elements, including calibration to reflect local materials and practices
2. Identify and calibrate the service limit states
3. Begin transition to a performance-based specification, with an accompanying design manual
4. Integrate information from maintenance and operations into code development and vice versa (poor maintenance procedures should not result in degrading the code provisions)
5. Identify load distribution for foundation elements
6. Develop and incorporate security performance standards
7. Incorporate contemporary seismic design provisions into LRFD
8. Continued development of LRFR provisions

Readiness

The current implementation schedule for the *LRFD Specifications* creates urgency for all of the states, consultants and contractors to train their staff and transition to the new the new specification. The specification has been in use by some owners for over a decade, and there remains a need to stabilize the development of interim changes to the provisions so that the remaining states can adopt them efficiently. Resources such as software cannot be developed completely until the specifications are stabilized. Recent advances in high performance materials and the need to address security concerns require that these important aspects be incorporated into the specifications.

Important Activites/Areas for Research

- Development of a framework for a performance-based specification, and accompanying design manual
- Development of probability-based service limit-states to achieve durability performance goals
- Development of statistical databases for LRFD calibration, e.g. maintenance, operations and geotechnical databases
- Development of performance standards for security
- Completion and adoption state-of-the-art seismic design provisions
- Identification load distribution methods for foundations
- Implementation and maintenance of LRFR, and coordination with the *LRFD Specifications*

Benchmarks

SHORT TERM: implementation of a long-term plan for funding the maintenance of the LRFD Specification by 2006, implementation of LRFR as an acceptable alternative, and adoption of comprehensive LRFD provisions for foundation design and contemporary LRFD provisions for seismic design into the *LRFD Specifications*.

MID-TERM: definition of all of the limit states (including the service limit states) and their associated performance requirements, complete calibration of the design specifications utilizing existing or developed databases for maintenance and operation (including geotechnical issues), and development of performance standards for security design of major bridges.

LONG-TERM: deployment of the performance standards for security design of major bridges, and development of a performance-based specification and accompanying design manual.

GRAND CHALLENGE 5: *MONITORING BRIDGE CONDITION*

To understand what information should be collected from which structural components to characterize the condition, or *health*, of the structure (both superstructure and substructure), and to develop systems to capture this information and approaches to use it to extend the service life of bridges and highway structures through efficient asset management.

Anticipated Outcome:

Monitoring systems and strategies to assist in more efficient management of existing bridges and highway structures.

Practical Importance

Cost savings can be achieved through efficiently managing existing bridges by implementing bridge monitoring systems . The present biennial bridge inspection interval could be transitioned to longer periods through the use of enhanced monitoring. Implementation of effective monitoring systems can result in the reduction in man-hours, and development of optimum inspection and repair schedules. Longer inspection intervals will result in lower user costs and increased safety through less traffic disruption from lane-closures due to rehab and inspection activity. The potential exists for the development of early problem detection and warning systems. Enhanced nondestructive evaluation (NDE) and visual techniques can result in increased structural reliability.

Technical Importance

Effective bridge monitoring systems (not necessarily continuous monitoring) can:

- improve the credibility of inspections and subsequent ratings through less subjective data,
- improve uniformity of data enabling the development of better decision-making tools
- evaluate existing inspection techniques
- assess long-term performance
- improve and augment visual assessment, and provide early detection and warning
- increase system reliability
- result in modified specifications and inspection standards, and optimization of inspection schedules
- allow more rational maintenance scheduling resulting in the optimization of maintenance dollars

Readiness

Resources for bridge inspection are becoming more and more scarce as inspection budgets are strained by our aging bridge inventory, and dedicated inspection forces are less available. These circumstances require more intensive inspection but at lower cost. Even in the absence of these current pressures, known deficiencies exist in the current inspection methods resulting in subjective data. With the recent tremendous increase in available monitoring and computing technology, the challenge of developing and deploying intelligent bridge monitoring systems becomes timely.

Important Activities/Areas for Research

- Identification of the available technology for monitoring structures and soil-structure interaction, and evaluate sensitivity of techniques (including dynamic monitoring to assess condition)
- Identification of most useful data and information to be collected
- Identification of the types of structures/parts of structures where enhanced monitoring is needed and most promising
- Deployment of the most promising technologies as demonstrations
- Development of recommended revisions to the AASHTO condition evaluation manuals
- Evaluation of current visual methods and recommendation of improvements
- Development of automated data collection and reporting
- Development of interpreting protocols and damage models using the data collected by the systems
- Evaluation of cost/benefit of monitoring/assessment systems
- Study the implications of security and traffic management systems

Benchmarks

SHORT TERM: identification of promising cost-effective technologies (including what data and how and where it should be collected) and enhanced monitoring strategies (including how the data should be used).

MID-TERM: implementation and evaluation of prototype strategies, and recommendation of actions.

LONG TERM: deployment of multiple integrated health assessment systems.

GRAND CHALLENGE 6: *CONTRIBUTING TO NATIONAL POLICY*

To understand the functioning and decision-making consequences affecting transportation systems, and to develop approaches to enhance the bridge engineer's contribution to political and social policy development, and to develop contributions to policy decisions.

Anticipated Outcome:

Strategies in which bridge engineers to more effectively contribute to transportation-policy decisions.

Practical Importance

Project decisions affecting technical, cultural and cost issues are being made without receiving adequate input from bridge engineers. Expanded input will provide additional balance to the social and policy development decisions and development of cost-effective solutions by incorporating the bridge engineer into the early decision process. Thus, there is a need to expand the role of the bridge engineer in transportation development, and in social and policy development.

Technical & Cultural Importance

Enhanced contributions of bridge engineers to transportation-policy decisions can result in:

- improved reliability at reduced costs through cost-effective selection of structure types resulting in more realistic estimate of final project costs.
- more practical input to context-sensitive design approaches.
- enhanced utilization of transportation systems through nationwide uniformity in size and weight restrictions
- a balanced view on environmental project requirements (i.e., sustainable projects).

Readiness

Reduced funding and increased public demand coupled with public intolerance for reduced levels of service requires a new approach to transportation-policy decisions. More and more decisions are made in public forums without a process that incorporates critical technical input. The bridge engineering community is being marginalized in many instances. A more uniform system is required for decision makers. In order for bridge engineers to contribute more effectively, training in communication and public involvement is needed.

Important Activities/Areas for Research

- Development of a nationwide policy on oversize/overweight vehicles
- Development of training in communication and public involvement for bridge engineers
- Development of a "common sense" approach to decision making through more involvement from the bridge engineering community in the decision making process
- Development of more rational mitigation options for environmentally sensitive structural situations (including assessments of the observed long-term impacts of construction on the environment)
- Determine costs/benefits to implementing spec/code/policy changes
- Improvement of interaction with related disciplines (e.g., environmental, foundations, hydraulic) by examining how other disciplines deal with issues

- Synthesis of project delivery systems

Benchmarks

SHORT TERM: initiation of studies of project delivery systems, oversize/overweight vehicles and long-term impact of construction on the environment; and development of strategies to enhance public involvement of bridge engineers (including outreach to all stakeholders).

MID-TERM: deployment of strategies enhancing public involvement of bridge engineers, and development of recommendations to AASHTO on oversize/overweight vehicle issues (including outreach to trucking associations), and project delivery systems.

LONG TERM: adoption of recommendations by AASHTO.

GRAND CHALLENGE 7: *MANAGING KNOWLEDGE*

To understand the existing approaches to management and dissemination of bridge-engineering knowledge, and to develop new more-effective approaches consistent with the evolving bridge-engineering community and emerging technology.

Anticipated Outcome:

Strategies to cultivate and support a knowledgeable workforce and effective leaders in bridge engineering.

Practical Importance

The quality of the technical workforce must be maintained to address the rapid development of new technology and the preservation of existing technology. This workforce quality is also being challenged by the loss of institutional memory due to downsizing and retirements. At the same time, the current workforce needs to be trained in succession planning and leadership development. Improvement in relationships between the various bridge industry sectors (including owners, consultants, industry and academe) can assist in maintaining a quality workforce.

Technical Importance

Survival of bridge engineering as a flourishing profession requires:

- continuous education consistent with industry needs,
- increased dissemination of technical information across networks,
- synergy and out-of-the-box thinking that occurs as a result of interactions between dissimilar fields, and
- integration of existing and new information.

Readiness

The transition to the *LRFD Specifications* in 2007 and sunsetting of the *Standard Specifications* provides an optimal time and need for continuous education and development of new technology transfer tools as well as support for more traditional training, such as National Highway Institute (NHI) courses. Information systems are available but need to be coordinated and integrated into bridge engineering to capture the historical and new practice. Current relationships between academia and the bridge engineering community can be used as a foundation to support the development of a highly qualified technical workforce.

Important Activities/Areas for Research

- Determination of the quality of existing professional training (including practices, materials and policies)
- Development of educational materials (materials appropriate to undergraduate education as opposed to available professional education materials) to assist universities in developing and maintaining an undergraduate curriculum consistent with current needs, including planning and political activities
- Identification of undergraduate and professional curricula in other countries for implementation in the U.S.
- Development of e-learning tools

- Development of a bridge-engineering database to preserve knowledge and improve access to knowledge (A complete database will also eliminate unnecessary research duplication)
- Identification of knowledge networks both within and across specialties
- Assessment of current and development of enhanced mentoring strategies
- Assessment of current and development of enhanced succession planning tools for leadership and professional development
- Development of training courses and knowledge networks targeted at contractors and construction personnel with the National Highway Institute (NHI)
- Assessment of the level of current collaboration between academe and the bridge engineering community
- Development of strategies and a plan to establish and promote long term relationships between academe and the bridge engineering community
- Encouragement of University Transportation Centers (UTC's) to participate in facilitating the development of academe/bridge engineering community relationships
- Fostering respect for bridge engineering as a profession and encouraging owners to provide salaries commensurate with other professions (for example, computer industry, law, business, etc.)

Benchmarks

SHORT TERM: identification of good professional and undergraduate training strategies, identification of strategies for the establishment of a bridge-engineering knowledge database, assessment of the current level of collaboration between academe and the rest of the community and identification of successful mentoring and succession planning strategies.

MID-TERM: development of enhanced professional and undergraduate training strategies (including traditional curriculum and e-learning tools), development of a bridge-engineering knowledge database, development of a national program for guiding the training of bridge engineers, development of fruitful collaboration between academe and the bridge-engineering community, and development of mentoring and succession planning strategies.

LONG TERM: deployment of strategies for undergraduate education and professional continuing education resulting in bridge engineers whose education is consistent with owner and industry evolving needs, deployment of a database forming a repository of historical bridge-engineering information, and deployment of mentoring and succession planning strategies resulting in these activities being a structured process in the workplace.

APPENDIX

Workshop Participants

Workshop Participants

(* denotes Steering-Committee Members)

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