



NCHRP Project 20-68A
Scan 09-01

Best Practices In Quality Control And Assurance In Design

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Executive Summary

Overview

On Wednesday, August 1, 2007, at approximately 6:00 p.m., the I-35W highway bridge over the Mississippi River in Minneapolis, Minnesota, experienced a catastrophic failure. As a result, 1,000 feet of the deck truss collapsed. The National Transportation Safety Board (NTSB) immediately began an investigation into the cause of the collapse. The investigation eventually determined that the collapse of the I-35W bridge initiated with the failure of the gusset plates at the U10 nodes on the truss..

The following safety issue, among others, was identified in the investigation:

Insufficient bridge design firm quality control procedures for designing bridges, and insufficient Federal and State procedures for reviewing and approving bridge design plans and calculations. (NTSB, Nov. 2008).

This finding lead the NTSB to recommend to the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) that the two organizations work together to develop a more adequate program of quality control and assurance (QC/QA or QA/QC) in bridge design to be used by the states and other bridge owners. The NTSB recommended that this quality program include procedures to detect and correct bridge design errors before the design plans are made final. In response to this recommendation, AASHTO initiated a study to provide a synthesis of current state department of transportation (DOT) practices for QC/QA in the area of bridge design and plan review.

This domestic scan was initiated following the NTSB recommendation to build on the initial AASHTO studies. The scope of this scan was expanded to incorporate aspects of quality programs in highway design, bridge design, overall project delivery, and QC/QA for special contract projects, such as design-build. The scan team believes that it is important to look at overall project quality, rather than just focus on bridge design, since there are farther-reaching quality issues, such as higher numbers and greater costs of change orders. Finally, the scan team also investigated the QC/QA practices encompassing project programming and planning stages, environmental permitting, and highway and bridge design. The team also examined lessons-learned feedback loops through construction.

A preliminary analysis conducted through a desk scan refined the list of states based on the size of their programs, the region of the country, the nature of their organization (e.g., decentralized, centralized, and percent of work done by consultants) and innovative practices in QC/QA. The team chose the following states for visits because of innovative or standout QC/QA programs:

- New York
- Pennsylvania
- Kentucky
- Minnesota
- Georgia
- Oregon
- California

In addition, the team held separate meetings and teleconferences with the following states to discuss specific components of their QC/QA programs:

- Ohio
- Washington State
- Illinois

The scan team developed amplifying questions and sent them to the selected agencies before the visit to allow the host agencies to center their preparations on the specific areas of interest to this scan topic. The team's amplifying questions fell under the following headings:

- How do you define a successful QC/QA program?
- How do you measure the success of your program?
- How was your QC/QA process developed?
- What are the documentation and administration procedures for your QC/QA process in design?
- What reviews should be done across disciplines?
- What specific qualifications and education practices can you elaborate on?
- What should QC/QA programs do differently for specialized processes, such as design-build projects or value engineering processes?
- How are QC/QA processes involved in standards, drawings, submissions, and software?
- How does your QC/QA design program extend into the construction phase?

Biographical and contact information for the scan team members is provided in Appendix A and Appendix B, respectively. Key contact information for host agencies is provided in Appendix C.

Common Practices

The scan team discovered that many successful QC/QA programs have common practices in place. These common practices are discussed here.

Training and Well-Developed Communication Channels

Overall, the visited states agree that quality includes adequate tools, core competency of staff, and good standards. It is important to note the states believe that while documented quality processes are important, it is also important to have experienced, competent staff and good relationships across disciplines. Quality is also affected by political constraints and funding fluctuations. In the present economy, states are all working with less staff, increasing numbers of projects, and tighter schedules. Plan quality is often affected when the staff is less experienced and schedules leave less time for in-depth quality checks. These issues must be taken into consideration when adopting new quality processes or adapting existing ones.

A number of states with successful QC/QA programs have developed procedures and training classes specifically focused on QC/QA. One way these states are ensuring quality from their designers is by incorporating training rotations for new staff into their programs. New staff often works designing projects and then gains experience in the field building those projects before taking permanent assignments as designers. The experience earned in the field helps to ensure that future projects will be buildable and biddable.

States with well-developed QA programs also have regularly scheduled meetings with all disciplines involved in the projects, involving construction earlier in the process to ensure constructability. These set meetings not only help to develop relationships across disciplines, but also help to contribute to lessons learned feedback loops.

Lastly, good communication between consultants and department staff is important in states with successful QC/QA programs. Many of these states hold lessons-learned conferences with their consultants each year or partner with organizations such as the American General Contractors (AGC) or the American Council of Engineering Consultants (ACEC) to hold joint training or information-sharing sessions.

Drivers to Document QC/QA Processes

Documentation of quality processes and procedures and the use of checklists are also common among states with successful QC/QA programs. Several drivers contributing to the need to provide documentation of quality processes were mentioned.

- **Higher percentage of designs done by consultant**
To maintain consistency, quality processes need to be documented and easily referenced by consultants.
- **High rates of retirement and staff turnover**
Processes need to be well documented to counter the loss of institutional knowledge when long-tenured staff retires and when newer staff quickly rises to management positions.
- **Decentralized organizations**
More guidance is needed to keep processes standardized and communication channels open when designs are completed in regional or district offices instead of in a central location.
- **Use of specialty contracting such as design-build**

More attention is given to QC/QA processes when design-build agreements are used, and this often leads states to look into similar quality processes for traditional design-bid-build projects

Common Review and Approval Practices

Successful states have a few review and approval practices in common in their QC/QA programs, including:

- Checklists outlining processes for designers, reviewers, and contract document compilation are used for each phase of project development.
- Consultants are rated or graded (although not all states use these ratings extensively for consultant selection).
- Decisions about the amount and type of review are made on a risk-based scale, taking into consideration the type and size of the project to determine the depth of the review.
- Although value engineering is done in all states, successful states evaluate the outcomes of these processes and use it as lessons learned feedback for future designs.
- Third-party consultant reviews are done for specialty projects or where DOTs do not have expertise or enough staff to meet deadlines.
- Plan signoffs or PE stampings are done at many different levels, including signoffs on original design, review, and even for design changes that are done in construction.
- States are moving to single-point data systems where multiple users and disciplines can look at and analyze documents to determine problem areas and make improvements in processes.

Summary of Initial Findings and Recommendations

The scan team noted that in successful states, it is important to have upper management support in the development, documentation, and use of a QC/QA program. Again, it is clear that adequate tools and documentation can lead to quality plans, but only with high-quality people and expertise behind the designs.

One of the biggest challenges each of the visited states faced was showing the benefit of time spent on QA processes. They asked, “How can we convey or market to decision makers that these quality programs are worth time and funding?” Overall, a successful quality program should be able to show that better quality in plans equals longer life and cost savings on projects. Many states recognize that a quality set of plans does not always equal a quality design, and that sustainability, constructability, and other considerations should be taken into account to really instill quality into a project.

Overall Successful Strategies

The following sections describe what the scan team determined to be successful strategies utilized by the visited states to ensure quality in their design plans. The scan team recognizes

that QC/QA programs that work well for one state may not work well for others, since there are large variations in organizational structure, political constraints, and funding availability throughout the states. For this reason, the team did not identify best practices, instead choosing to identify strategies that were successful in the given circumstances of each state.

Checklists, Manuals and Standards

All state DOTs, not just those with successful QC/QA programs, use checklists, process manuals, and standard details and drawings. However, successful states use these tools for communication, training, and regular re-evaluation of the processes. One state described the practice of “review training” for engineers who are performing QC reviews on plans. This training concentrates on teaching reviewers the best ways to identify errors or omissions, how to use manuals and checklists, and how to successfully convey comments back to the designer.

Some states have instituted separate divisions or bureaus specifically for QA. These divisions provide centralized points of contact on quality and provide a group of experienced individuals that can maintain and re-evaluate quality processes that are documented within manuals.

One other practice found in several successful states is the use of title blocks on plan sheets that clearly define the designer and the reviewers, as well as include sign-offs for when reviews are completed. This easily implemented, simple method ensures that designers and reviewers take responsibility for the quality of the plans.

Scoping and Environmental

Successful states include all parties involved in design and construction early on in the process. Several of the states the team visited include environmental, right-of-way, utilities, designers, any other relevant agencies, and even construction, in the scoping process. Continued involvement throughout the full design phase of all players involved is important and includes scheduled meetings at key points in the design, during construction, and for post-construction feedback.

Successful states also found that it was helpful to have state-funded positions located at regulatory agencies to help expedite scheduling and reduce external agency bottlenecks in the design process.

Another successful strategy found during the scan was the practice of including “green sheets” or environmental tables within actual plan sets. These sheets (which one state actually prints on green paper) or tables serve as a checklist for the contractor and resident engineer to ensure that all environmental commitments are met on each project.

Value Engineering Feedback

Value engineering (VE) is common and mandated for some projects in all states. However, many successful states are using feedback from their VE processes to analyze trends and make changes to their design processes. Some states have been able to involve contractors in their

processes, although legal issues make this a bit more complicated. Again, the VE process is not necessarily a best or unique practice; however, what is done with the information and feedback can help to ensure improved quality in future designs.

Consultant Selection and Communication

Successful states ensure the quality of their consultants' projects through thorough selection processes and good communication channels. Successful states often require submittal of consultant quality plans before they can be prequalified to perform work for the states, and many require project-specific quality plans to be submitted with proposals.

Construction Reviews and Feedback

Involving key players from construction early on in the design process is a successful strategy in many states. Early involvement is important to avoid comments on constructability at the end of product production when it is not practical to make changes. It is also important to look at feedback during the construction process and information provided during post-construction reviews. Several states survey construction administration staff and contractors to solicit feedback on design and plan quality. This information can show trends, such as the causes of the most change orders, and outline needed changes to standard drawings and manuals.

Quality in Existing Processes

Successful states look at improving quality in existing processes, not necessarily adding more processes. Examining existing processes and formalizing them through documentation can help identify unneeded steps and highlight areas where the process can be improved. After improvements are made, performance measures are developed. One state has looked at all of its checklists to determine the optimal amount of items that should be included, while another state has developed a series of steps for each discipline to go through to help them document all their processes. These actions help to add focus and efficiency to quality programs.

Future Research

The scan team found that in many cases it is hard to quantify the benefit of QC/QA procedures. In the future, it would be useful to identify the marginal benefit of more QC. For example, if another hour is spent reviewing a set of plans, how much quality does that add to the overall project? This also requires determination of how to measure that incremental increase in quality and identification of useful performance measures.

Planned Implementation Activities

The scan team recognizes the importance of implementing the findings of its review. Many important successful solutions and strategies were identified and would be of benefit to other state and local transportation agencies. Included in the team's proposed implementation plan are the following:

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1. **Develop a webinar** – The team intends to present successful solutions to a large audience through webinar training sessions.
 2. **Develop and make presentations to AASHTO and Transportation Research Board (TRB) committees** – These more in-depth presentations can be tailored to specific groups.
 3. **Implement findings locally** – Ideas and successful solutions can be brought directly into the team members' states and host states.
 4. **Identify future research** – The scan identified findings and issues that could be further investigated. Research proposals for these needs will be written and presented to supporting organizations, such as AASHTO or TRB committees.
 5. **Draft a letter to the FHWA to inform it of scan findings** – The scan team will outline the scan findings in a letter to the FHWA's Bridge Technology Office to assist in the development of the Technical Advisory for QC/QA in Bridge Design that will be developed in response to recommendations by NTSB.
 6. **Develop a Web site** – A Web site dedicated to QC/QA processes will make information more readily available.
 7. **Identify places to submit journal articles or post links to the final report** – The team intends to submit articles to academic journals as well as to trade magazines and newsletters.