Alternative Quality Management Systems for Highway Construction

DETAILS

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EXECUTIVE SUMMARY

This report is an extension to the NCHRP Guidebook on Alternative Quality Management Systems for Highway Construction. The research report documents the research process, data collection and analysis used to develop the guidebook. This intent of this research report is to provide more detailed information to individuals conducting future quality management research and state transportation agency (STA) engineers who are charged with implementing alternative quality management systems (QMS).

The need for research is, in part, a consequence of both the growing use of alternative project delivery methods and the need for a better definition of quality management in the context of alternative project delivery. Innovations in quality assurance organizations (QAO) and other features of quality programs are being used by STAs across the country. The roles of owners and contractors in QMSs are changing. These changes are leading to varying QAOs, which range from the agency-dominated system of quality management associated with the traditional design-bid-build (DBB) method to design-build (DB), construction manager/general contractor (CMGC) and public-private partnership (PPP) agreements where the responsibility for quality management is shared to varying degrees between the contractor and owner. This research has resulted in QMS guidance that will promote efficiency and allow for the transfer of knowledge to continuously improve these systems.

This research was conducted in nine tasks as documented in this report. Task 1 established the state of practice regarding alternative QMSs through a comprehensive literature review and online survey. Task 2 developed a consistent coding structure for use with the literature review, survey and case study analysis. Ten case studies were conducted and analyzed in the third task. Task 4 involved a critical analysis of the QMS approaches discovered in Tasks 1-3 to form conclusions on their use and Task 5 compared these QMS approaches to the baseline system. The research team worked closely with the NCHRP panel in Tasks 6 and 7 to outline and develop the guidebook. Task 8 documented incremental improvements to the baseline system through the development of 25 quality management tools relating for pre and post-award functions. The final task involved the development of the guide and research report by the research team and a review and approval of these documents by the NCRHP panel.

This research report records the activity from all nine tasks. The work is presented in six chapters and 13 appendices. The work from Tasks 1-9 is incorporated throughout the various chapters of the report. Chapter 1 provides an introduction and overview of the research process. Chapter 2 contains data from the literature review, industry survey and coding structure. Chapter 3 presents a series of documented quality management models. Chapter 4 includes case study summaries with basic project information, the QAO model employed on the project, a comparison to the baseline system, and relevant findings and observations. Chapter 5 discusses the QAO and tool selection procedures. Chapter 6 addresses the conclusions, limitations and future research. The appendices include definitions, the online survey, the case study protocol and the full-length summaries of each case study.

CHAPTER 1 : INTRODUCTION

1.1 Introduction

This research project is focused on the identification, understanding, and dissemination of alternative QMSs being applied in the highway industry throughout the United States. Innovations in QAO and other features of quality programs are being used by state departments of transportation across the country on projects using both traditional DBB delivery and alternative delivery methods as well. The need for this research is partially a consequence of both the growing use of alternative project delivery and the need for a better definition of quality management in the context of alternative project delivery.

Changes in the roles of owners and contractors in QMS are occurring. These changes are leading to varying QAO, which range from the agency-dominated system of quality management associated with the traditional DBB method to PPP agreements where the responsibility for quality management is shared to varying degrees between the contractor and owner. One of the attractions of projects using alternative delivery methods like these is the transfer from the owner to other parties of some project responsibilities, which may include design, finance, and/or quality management. These alternatives may result in substantial savings to the owner, which have proven to be efficient and effective in many types of construction and are increasingly making inroads into the highway construction industry.

In order to be considered for use, all projects using alternative quality management methods must be delivered with at least the same standard and level of performance that is found in the baseline method. In traditional DBB contracting in the transportation industry, decades of quality assurance (QA) and quality control (QC) experience provide a wealth of knowledge and standard practices that are readily accessible and widely accepted for assuring quality on infrastructure projects. For projects using alternative QMS (whether modifications of the baseline method or projects with alternative delivery methods) on the other hand, there exists a limited, but rapidly expanding, body of experience associated with assuring quality. The purpose of this research is to bring together this relatively new body of experience and summarize it in one easily accessible reference treating the subject of quality management in alternative projects.

To that end, this report represents the first step in developing such a reference. The purpose of this report is to summarize the work and findings of the research effort of the project. This first chapter of the report opens with the research problem as a whole including its problem statement, goals, and primary questions. It then introduces the specific tasks performed to complete the project and the workflow used to accomplish those tasks. Finally, it closes with a guide to the rest of this report, mapping each task with the material in this report that supports it.

1.2 Problem Statement

Quality management systems in the United States transportation industry are evolving. This is due in part to experimentation with changes to the baseline QMS and in part to accommodate the needs of alternative delivery methods, which are being used more frequently. These methods include DB, CMGC, and PPP and their use is becoming more prevalent, particularly on larger and higher profile rapid renewal projects.

However, these alternative QMS are being applied on a project-by-project basis due to the lack of national guidance to promote standard approaches. For highway agencies, this lack of guidance is resulting in significant investment to develop individual programs and is minimizing the ability to capture and utilize knowledge across agencies. For consulting engineers and contractors, this lack of guidance is resulting in significant investment in response to project solicitations which require unique QMS for different agencies. The speed at which rapid renewal projects must be delivered creates a demand for a well-defined QMS that can be successfully replicated on a variety of projects. QMS guidelines on a national level will promote efficiency and allow for the transfer of knowledge to continuously improve these systems.

1.3 Research Objectives and Tasks

The objective of this research is to address the needs for QMS guidance for evolving alternative project delivery methods. The following research objectives have been established for this:

1) Identify and understand alternative QMS; and
2) Develop guidelines for their use in highway construction projects.

The successful accomplishment of these objectives will yield a *Quality Management Organization* that can apply to adaptive project delivery approaches.

The products from this research study include:

1. A Guidebook to match appropriate QMS to alternative delivery methods;
2. A research report that addresses implications of adopting the guidelines and barriers to implementation.

The main objectives will be addressed through a focus on the following questions and sub-objectives:

1. **What is the fundamental definition of quality and what is the underlying purpose of a “quality program”?**

   Document and discuss the underlying motivation for quality management through a fundamental exploration of literature describing quality programs in a variety of industries (e.g., transportation, process industry, aerospace and automotive).

2. **How are projects using alternative delivery methods currently applying QMS?**

   Document practices as found in quality management literature, surveys and case studies.

3. **What are the advantages and disadvantages to the contractor and the owner of alternative QMS relating to various project delivery alternatives?**

   Analyze the benefits and challenges of the alternative QMS through rigorous and scientific case study means and develop a selection model for matching these systems to alternative project delivery methods.

4. **What changes must be made to the baseline QMS to adapt to evolving project delivery methods?**

   Provide agencies with a roadmap of changes to the baseline QMS to accommodate alternative delivery methods and improve the efficiency and effectiveness of the overall delivery system and end product.

The research team focused on these four research questions and sub-objectives of the research project to insure that the main objectives are successfully achieved.

1.4 Research Framework

In order to fully answer each of the four primary research questions, the research team developed a roadmap indicating how work would proceed from a state-of-practice review to a Guidebook detailing practices for alternative QMS. This roadmap, shown in Figure 1-1, maps the progress of the project from an understanding of baseline quality theory at the start of Phase 1, to the development of a catalogue of common practices for alternative QMS at the conclusion of Phase II.

One of the key deliverables for this research project is a Guidebook which disseminates information related to alternative QMS. As a result, research questions 2 and 3 are the primary questions to be answered in the course of this research project. However, care must be taken to answer these questions in a justifiable and rigorous manner. To that end, the research team has developed a research framework that will ensure both questions are answered thoroughly through the case studies and research of this project as a whole. The case studies conducted by the team were the primary sources of information to answer research questions 2 and 3. These case studies are in-depth studies of exemplary transportation projects using alternative methods of quality management. They were conducted on a wide variety of projects of many different sizes, locations and owners, and used information gathered through interviews, participant questionnaires and document analysis.

Phase I – Quality Management Theory *about* Practice	
From Baseline Quality Management Theory ⇨ *To* Integrated Quality Management Theory	Fundamental understanding of quality definitions and the purpose of quality ⇨ Coding of alternative delivery, procurement, and contracting approaches ⇨ Defining the current state of practice in alternative quality management approaches ⇨ Describing the advantages and disadvantages of the alternative quality management models in comparison with the baseline ⇨ Documenting the Quality Management Organization
Phase II – Quality Management Theory *for* Practice	
From Integrated Quality Management Theory ⇨ *To* Integrated Quality Management Practice	Documenting the Quality Management Organization ⇨ Creating the "business" case and key messages for upper management ⇨ Mapping a path from the baseline to the quality assurance organizations for program management ⇨ Decision support for quality management organization selection with innovative project delivery for project management ⇨ Cataloging common practices for project engineers

Figure 1-1 –Project "Roadmap"

The QAO, shown in Figure 1-2, is a model that could adequately describe the quality management system used for every type of project delivery. The model acts as a framework to structure the analysis of other alternative project delivery quality systems that are common in highway construction and was used in that manner throughout this project. The boxed area represents the universe of QA requirements that exist during both the design and construction phases of a highway project. In this form, it makes no specific assignment of QC and quality acceptance roles and responsibilities between the owner, the designer and the constructor.

The owner is free to make QC and quality acceptance assignments to whichever entity is best suited to carry them out in a satisfactory manner. The QAO model shows that no matter who actually performs the classic design and construction review, inspection, or testing tasks, at some point, the owner must make a business decision as to accept or not accept the completed design product and the finished construction product. In the case of design, this decision is indicated when the owner agrees to allow the completed construction documents to be "released for construction." In construction, this decision is indicated when the owner agrees to make final payment, and when both these decision have been made, the highway project is accepted.

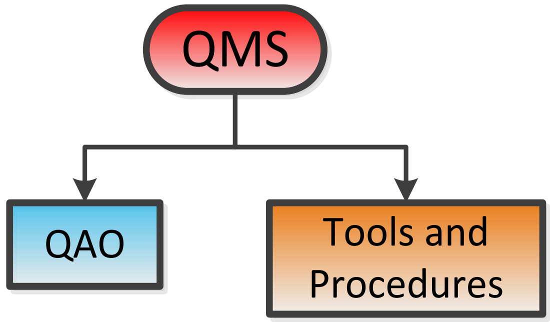

Figure 1-2 – Quality Assurance Organization (QAO) Framework

1.5 Task Descriptions

To answer the four primary research questions, the team has completed the following nine tasks. Figure 1-3, Figure 1-4, and Figure 1-5 show the flow of work from Task 1 to Task 9 with key research products along the way shown in the bold lines.

Phase I

- **Task 1 – Evaluate State of the Practice (see Chapter 2)**

  The primary focus of Task 1 was establishing the state of practice regarding alternative QMS. This was achieved using a two phase approach. First, a comprehensive literature review was conducted that established the characteristics of baseline QMS and explored what literature existed to characterize alternative QMS. Second, the information gleaned from the literature review was used to structure an online survey to establish the current state of practice of alternative QMS among various transportation agencies and owners.

- **Task 2 – Documentation of Alternative QMS Approaches (see Chapters 2 and 3)**

  The main goal of Task 2 was to establish a consistent coding structure for use throughout this research project. The structure was to be used to organize the case study protocol and to analyze the results of the literature review, survey, and case studies.

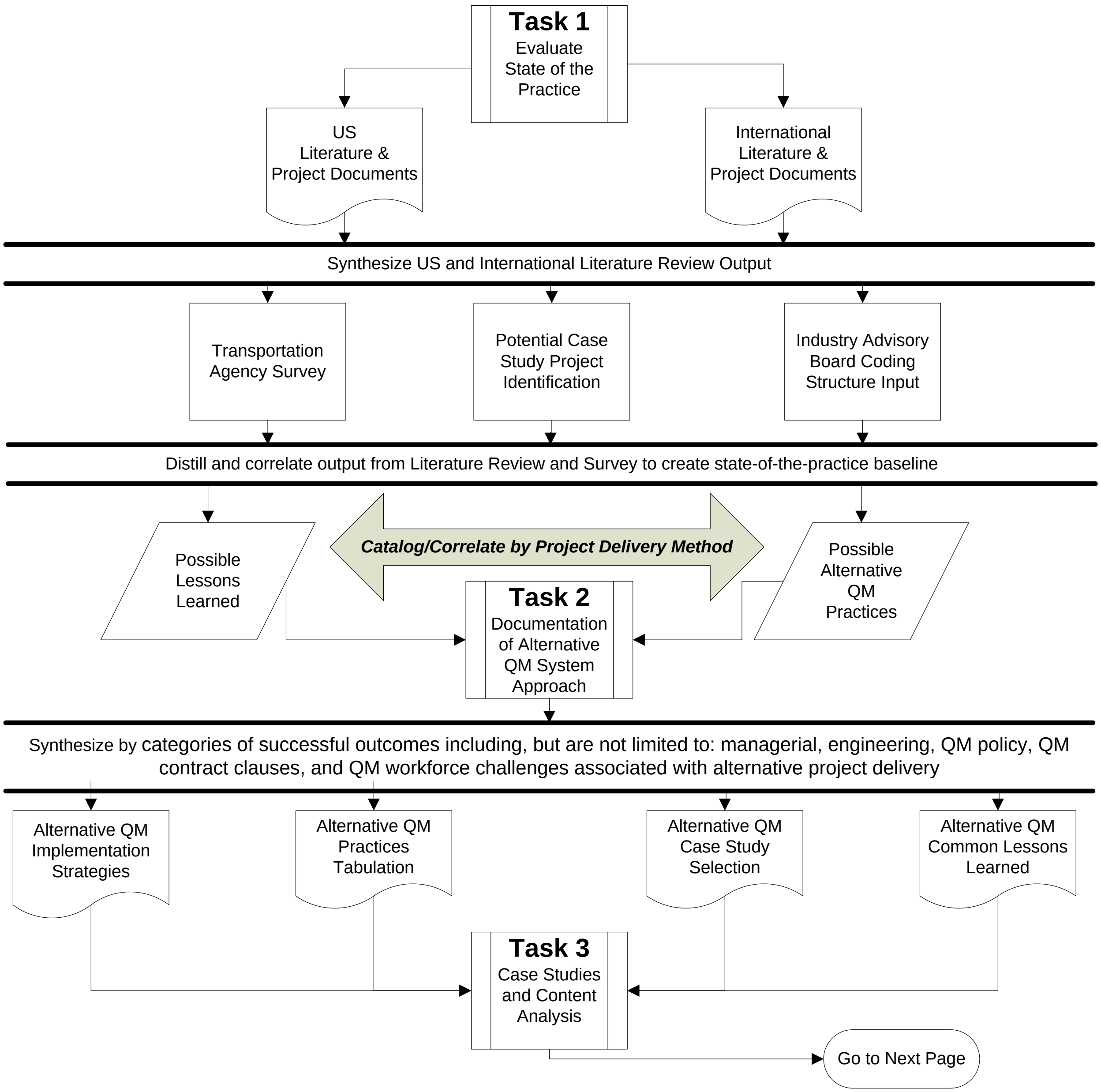

Figure 1-3 – Work Flow Tasks 1 to 3

- **Task 3 – Case Studies and Content Analysis (see Chapter 4)**

  Task 3 focused on both gathering case study data and analyzing it in the light of existing models. To do this, a case study protocol was created to maintain consistency between case studies across the project team. After conducting the case study interviews and gathering the relevant documents, a thorough content analysis was performed to discover trends and usable indicators among the case studies.

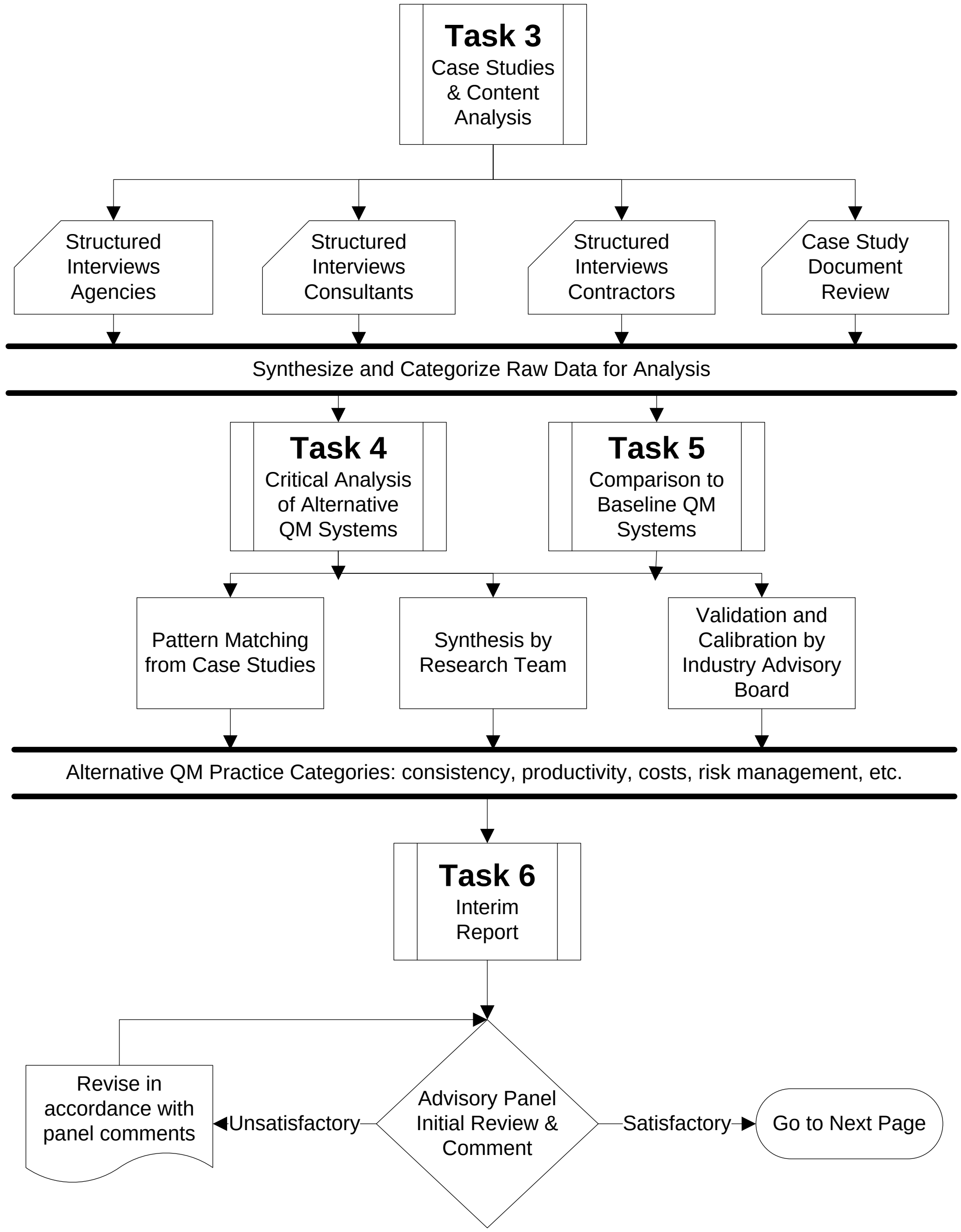

Figure 1-4 – Work Flow Tasks 3 to 6

- **Task 4 – Critical Analysis of Alternative QM Systems (see Chapter 4)**

  The objective of Task 4 was to perform a critical analysis of the QMS approaches discovered in Tasks 1-3 and form conclusions on the use of these systems for alternative project delivery methods. The analysis took into account both the advantages and disadvantages of each system from the agency's and the designer's/ constructor's points of view and used the QAO framework to organize and compare systems.

- **Task 5 – Comparison to Baseline QM Systems (see Chapter 4)**

Task 5 focused on comparing alternative QMS to the baseline QMS. The task was performed concurrently and tracked closely with the analysis of Task 4 on this project. The QAO framework was used to compare each alternate model to the baseline model to identify key differences, paying special attention to design quality management, an area typically lacking in the baseline model.

- **Task 6 – Interim Report**

  The main goal of Task 6 was to summarize the work, results, and findings from Tasks 1 to 5 in an Interim Report.

Phase II

- **Task 7 – Develop Guidebook**

  Task 7 was devoted to the development of one of the key deliverables of the research project, the Guidebook. The Guidebook has a wide audience and describes the business case for making the change, discusses the barriers to making the change, provides a tool for selecting appropriate systems, and provides tools for implementation. Due to its large scope and varied audience, the Guidebook only offers guidance, not specific instructions for direct implementation. The guidebook does provide a selection process for determining the proper QAO, which was tested, calibrated, and validated using the Delphi method.

- **Task 8 – Incremental Improvement of Baseline Systems**

  The goal of Task 8 was to suggest and document incremental improvements to the baseline QMS. The research methods employed in Tasks 1 through 7 support this goal. The outcome of this task is included as a subsection in the Guidebook.

- **Task 9 – Prepare and Submit Final Reports**

  The main goal of Task 9 was to finalize the Guidebook and prepare the final report, the key deliverables for this project. The Guidebook is expected to be published by NCHRP for use by highway agencies and industry professionals. This report includes most of the project documents including the literature review, state of practice survey, case study protocol, case study summaries, the Guidebook, and any other relevant documents.

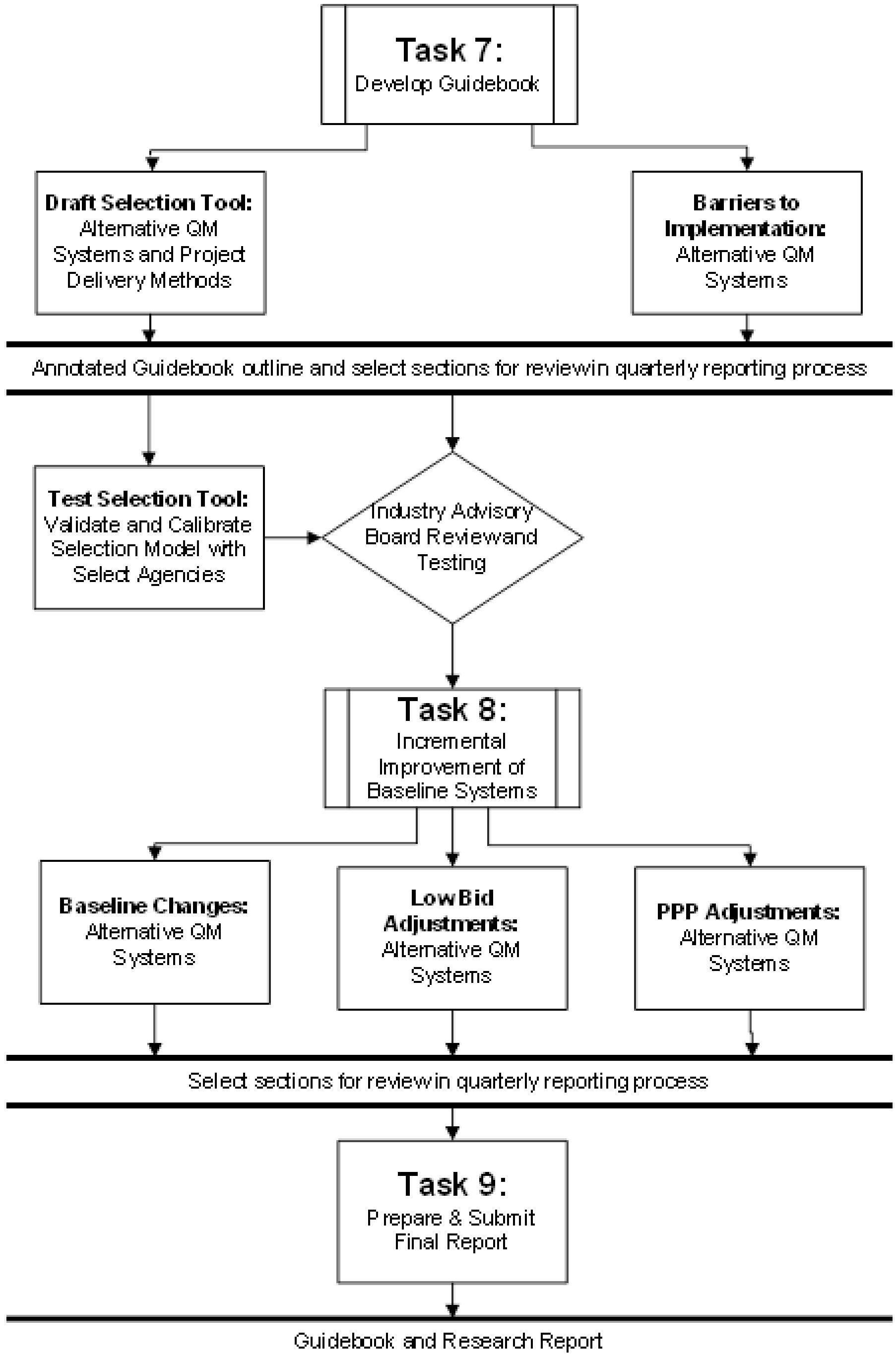

Figure 1-5 – Work Flow Tasks 7 to 9

1.6 Report Format

The Final Report records the activity from the all nine tasks and is broken into six chapters and 13 appendices. The work from Tasks 1-9 is incorporated throughout the various chapters of the report.

- Chapter 1, this introduction, provides a brief background for the research project and functions as a guide to the rest of the report.
- Chapter 2 is focused on establishing and documenting the current state of practice for alternative QMS. Work from Tasks 1 and 2, the literature review, industry survey, and coding structure is contained in this chapter.
- Chapter 3 presents a series of common quality management models which were identified and developed in part through the completion of Tasks 1 and 2.
- Chapter 4 is devoted to the case studies which provide much of the material for Tasks 4 – 9. This chapter represents the work of Tasks 3 – 5 and contains brief summaries of each case study conducted (the full summaries are contained in the appendices). Each summary includes basic project information in addition to an analysis of each case study in terms of the QAO model, a comparison to the baseline system, and relevant findings and observations.
- Chapter 5 discusses the QAO and tool selection procedures. It provides a background on the methodology, data and validation of the selection procedures. The procedures themselves can be found in the accompanying guidebook.
- Chapter 6 includes the conclusions, limitations and future research. It summarizes the main findings. It discusses the research limitations that were encountered due to the nature of the research question and resources available. It also provides a brief discussion of future research topics that stem from this work.
- Appendix A contains definitions for this report.
- Appendix B contains the online survey used in Task 1.
- Appendix C contains the case study protocol used in Task 3.
- Appendices D – M are full-length summaries of each case study that was conducted to complete this research.

CHAPTER 2 : STATE OF THE PRACTICE

2.1 Introduction and Overview

2.1.1 Background

During the 1990's, the transportation industry began catching up with the building construction industry by experimenting with various forms of alternative project delivery (Songer and Molenaar 1996; Anderson and Damnjanovic 2008) as well as alternative quality management systems (Miron et al 2008). In the state department of transportation sector this was facilitated by the Federal Highway Administration (FHWA) Special Experimental Project 14 (SEP-14) (FHWA 2006), which authorized the use of DB and CMR (also called Construction Manager/General Contractor or CM/GC) project delivery.

In the past decade, transportation agency procurement programs have matured and project delivery methods, which in the 1990s were termed as either "alternative" or "innovative," have been institutionalized and now are viewed as merely tools in the typical agency's procurement toolbox (Trauner 2007). A paper written at the turn of the 21st century (Miller et al 2000) proposed "simultaneous use of multiple project delivery methods" as the "new paradigm." Those authors were prescient because recent project delivery research has confirmed that many transportation agencies across the country employ more than one project delivery method (Touran et al 2010; Scott et al 2006).

Driving the shift in public procurement culture was the perception by practitioners both in government and industry that benefits could be accrued by integrating the project team and bringing the constructor into the project before design was complete to furnish substantive input on cost, schedule, and constructability to the final design (Miller et al 2000; Touran et al 2010). Beyond time and cost savings, the salient question has been to determine if the quality of the ultimate product was degraded through either the speed at which the design and construction had to be completed or by an agency loss of control over the design and construction process (Gransberg and Molenaar 2008).

2.1.2 Objective

Most authors that have written about the dangerous condition of the nation's highway network concluded that public transportation agencies must find ways to deliver infrastructure projects "better, faster, cheaper" (Atzei et al. 1999; Avant 1999; Richmond et al. 2006). Yet, the political will to make fundamental changes in the methods used to deliver infrastructures is often difficult to muster. For example, the length of time California Department of Transportation (Caltrans) needed to gain authorization to utilize design-build (DB) contracting is a typical example of the constraints faced by many transportation agencies. The Federal Highway Administration (FHWA) Special Experimental Projects No. 14 – Alternative Contracting (SEP-14) was introduced in 1990. By 2009, the FHWA had authorized more than 400 DB highway projects (FHWA 2006; FHWA 2009). California has led the nation in terms of traffic congestion for decades and as a result accelerating the delivery of projects to increase the capacity of

California's highways will generate enormous benefits to the traveling public and the environment (Dowall and Whittington 2003). However, it took Caltrans 19 years from the inception of SEP-14 to obtain the legislative authorization to proceed with a demonstration program of six DB projects.

In June, 2010, the FHWA introduced its "Every Day Counts" (EDC) initiative to address this and other issues of similar importance. The program is designed to accelerate the implementation of innovative practices that are immediately available, as described by then FHWA Administrator Victor Mendez:

> "Our society and our industry face an unprecedented list of challenges. Because of our economy, we need to work more efficiently. The public wants greater accountability in how we spend their money. We need to find ways to make our roads safer. And we have an obligation to help preserve our planet for future generations. But it's not enough to simply address those challenges. *We need to do it with a new sense of urgency*. It's that quality—*urgency*—that I've tried to capture in our initiative, Every Day Counts."(Mendez 2010, italics added).

Again, many authors have documented the "urgent need to replace aging infrastructure" (Dowall and Whittington, 2003), but creating an atmosphere of urgency inside technocratic public transportation agencies is a challenge in and of itself. The resistance to change is rooted in the fear that the agency's historic set of checks and balances will be upset and control over cost, schedule and quality will be lost (NSPE 1995). Hence, the FHWA EDC focus is on innovations that have already been successfully employed by typical State Transportation Agencies (STAs), which theoretically will no longer be considered "experimental" as the SEP-14 label implies.

> "EDC is designed to identify and deploy innovation aimed at *shortening project delivery*, enhancing the safety of our roadways, and protecting the environment…it's imperative we pursue better, faster, and *smarter ways of doing business*" (Mendez 2010, italics added).

Note that Administrator Mendez changed the "better, faster, cheaper" mantra to "better, faster, and *smarter*." This relieves a great deal of pressure in the political process when a state agency no longer must find the *cheapest* solution to obtain federal-aid funding. Plus, the notion of "shortening," rather than accelerating, the project delivery process *subtly implies lowering the risk of the agency losing control* over its design and construction quality and costs.

2.1.3 Scope

There are two key concerns to all public transportation agencies: project quality management and project delivery method. With the growth of alternative project delivery methods in the past few decades, the issues have become interrelated. It is important to understand how agencies that are using alternative project delivery are approaching the quality management (QM) issue on their projects. In project delivery methods where selection of the contractor occurs before design completion so that the contractor can contribute to the design, the agency ought to consider the impact of that shift on quality management planning and execution at every phase of project development. Table 2-1 compares the potential for meeting three quality objectives among three project delivery methods based on an analysis of federal projects (Uhlik and Eller 1999).

Table 2-1 – Quality Management Comparison of Project Delivery Methods (Adapted from Uhlik and Eller 1999)

Likelihood of Meeting Objective			
Quality Objectives	**DBB**	**CMR**	**DB**
A system of checks and balances exists between design and construction	High	High	Low
Input on quality is provided during design by someone with construction expertise	Low	High	High
Single point of responsibility for design and construction quality	Low	Low	High

This study concludes that CMR project delivery has a high likelihood of delivering two of three quality objectives. The third objective, single point of responsibility, can only be achieved by DB project delivery and DB has a low probability of achieving the checks and balances objective. The chart indicates that CMR and DB may be the preferred project delivery methods for projects where assuring quality is difficult. Another author reached the same conclusion when it stated: "CMR improves quality and value… [by keeping] focus on quality and value – not low bid" (Ladino et al 2008). The scope of this section is to discuss the state-of-the practice regarding QM as implemented in projects delivered using alternative project delivery methods.

2.1.4 Essential Questions

Chapter 2 will seek to answer the following questions regarding QM in alternative project delivery:

- What is the purpose of a Quality Management program?
- Why do alternative project delivery methods need a different approach to quality management?
- What quality management tools, techniques and methods are currently in use on alternative project delivery methods and currently in use for highway design and construction?

2.2 Relevant Definitions

Throughout the construction industry, there are certain terms that are used to define aspects of quality programs. The literature review exposed "confusion" among the various authors as to precise definitions for the various aspects of "quality" and the terminology used to describe the tasks involved in design and construction quality management. The American Society for Quality defines quality as, "the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs" (ASQ2013).

That definition is quite broad, but the focus on "satisfy given needs" is cogent to this section. The owner must clearly articulate the "given needs" for design and construction quality in project documents (i.e. RFPs, specifications, etc.). One way to do that is by requesting specific quality-related submittals as a part of any pre-award proposals if applicable. The other way is to include the requirements for design and construction quality management as submittals required after contract award. The ASQ goes on to define five varying types of quality as follows (ASQ 2013):

- Relative Quality: loose comparison of product features and characteristics.
- Product-Based: quality is a precise and measurable variable and differences in quality reflect differences in quantity of some product attribute.
- User-Based: fitness for intended use.
- Manufacturing-Based: conformance to specifications.
- Value-Based: conformance at an acceptable cost. (ASQ 2013)

Thus, one can see that the concept of quality has many facets. As a result, an owner attempting to articulate the requirements for both design and construction quality needs to be very precise in the working definition of quality for each feature of work. One way to measure quality is by conformance to a quality plan (Arditi and Lee 2004).

Additionally, as the methods used to deliver highway projects evolve, the transportation industry must develop new definitions to describe the altered state of roles and responsibilities for managing the quality process. A previous NCHRP report by Halstead (1979) simplified the definition a quality management system to four basic questions that provide a concise reference to ensure that a quality management system fulfills its needs. The questions are:

1. What do we want?
2. How do we order it?
3. Did we get what we ordered?
4. What do we do if we do not get what we ordered? (Halstead 1979)

The Transportation Research Circular E-C090 provides an example of the need for new definitions, which recognized the specific need for new definitions for quality in projects delivered using alternative delivery methods and stated:

> As it relates to QA, the owner is responsible for oversight management and *a new definition of QA. This new definition includes oversight* to provide confidence that the design–builder is performing in accordance with the QC plan, design monitoring and verification through auditing, spot-checking, and participation in the review of the design (Warne 2006 italics added).

2.2.1 Standard Definitions

For the purposes of this report, the *Transportation Research Circular E-C074: Glossary of Highway Quality Assurance Terms* (Leahy 2009) will be used to define exactly what the quality assurance terms in this report mean. The major definitions are reproduced below.

- Quality. (1) The degree of excellence of a product or service; (2) the degree to which a product or service satisfies the needs of a specific customer; or (3) the degree to which a product or service conforms with a given requirement.
- Quality assurance (QA). All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. (QA addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities).
- Quality control (QC). Also called process control. Those QA actions and considerations necessary to assess and adjust production and construction processes so as to control the level of quality being produced in the end product.
- Independent assurance (IA). A management tool that requires a third party, not directly responsible for process control or acceptance, to provide an independent assessment of the product and/or the reliability of test results obtained from process control and acceptance testing (The results of independent assurance tests are not to be used as a basis of product acceptance).
- Acceptance plan. An agreed–upon method of taking samples and making measurements or observations on these samples for evaluating the acceptability of a lot of material or construction.

To the above definitions, the report will add two that are not contained in Transportation Research Circular E-C074. These definitions are for "quality management" and "project quality assurance."

- Quality Management (QM): The totality of the system used to manage the ultimate quality of the design as well as the construction encompassing the quality functions described above as QA, QC, quality acceptance, independent assurance, and verification.
- Project Quality Assurance (PQA): All those actions necessary for the owner to ensure that the design-builder performed quality acceptance activities given a true representation of the quality of the completed project. This may include owner verification and acceptance testing or independent assurance as owner oversight actions when assigning the design-builder the responsibility for design and/or construction QA activities. Additionally, these also include owner oversight, verification, validation, acceptance, and other activities necessary to satisfy FHWA Technical Advisory 6120.3 (FHWA 2004) for projects with federal funds and the employment of independent quality consultants that may be necessary in DB projects with post-construction operations and/or maintenance options.

Finally, to understand the relationship between quality and the project procurement process, the following list defines project delivery methods, procurement procedures, contract payment provisions and other terms used commonly throughout the report.

- Design-bid-build (DBB): A project delivery method where the design is completed either by in-house professional engineering staff or a design consultant before the construction contract is advertised. Also called the "traditional method."
- Design-build (DB): A project delivery method where both the design and the construction of the project are simultaneously awarded to a single entity.
- Construction Manager/General Contractor (CM/GC): A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.
- Construction Manager-at-Risk (CMR): A project delivery method similar to CMGC, but where the CM does not self-perform any of the construction work.
- Project delivery method: the comprehensive process by which designers, constructors, and various consultants provide services for design and construction to deliver a complete project to the owner. While names can vary in the industry and owners often create hybrid delivery methods, there are essentially three primary project delivery methods: design-bid-build (DBB), construction manager-at-risk (CMR), and design-build (DB).
- Procurement procedure: the process of buying and obtaining the necessary property, design, contracts, labor, materials, and equipment to build a project. The four primary procurement procedures are low-bid, best-value, qualifications-based, and sole-source procurement.
- Contract payment provision: the contract language that defines how design and construction professionals will be paid for their services. The four primary contract payment provisions are fixed price lump sum, guaranteed maximum price (GMP), cost plus fee, and cost reimbursable.
- Design deliverable: A product produced by the design-builder's design team that is submitted for review to the agency. (i.e. design packages, construction documents, etc.)
- Construction deliverable: A product produced by the design-builder's construction team that is submitted for review to the agency. (shop drawings, product submittals, etc.)
- Administrative prequalification: A set of procedures and accompanying forms/ documentation that must be followed by a construction contractor to qualify to submit bids construction projects using traditional project delivery.
- Performance based prequalification: A set of procedures and back-up documents that must be followed by a construction contractor to qualify to submit a bid on a construction project based on quality, past performance, safety, specialized technical capability, project-specific work experience, key personnel, and other factors.

2.3 History of Alternative Quality Management Program Development

The requirement for quality pervades the life cycle of a transportation project. Decisions made in the concept and feasibility phases of a project's life create impacts that may not be evident until many years after the completed project has been in operation. The failure of the I-35W bridge in Minneapolis in 2007 is an extreme example of how an early design decision, in this case deciding to exclude the gusset plates that ultimately failed in the bridge load rating design guidance, can ultimately degrade the quality of a large project (NTSB 2008).

The literature contains many models for a typical transportation project's life cycle. However, the simplest one specifically oriented to highway construction is offered by Anderson and Blaschke (2004) and is shown in Figure 2-1. This model tracks with the traditional DBB project delivery where the project is developed in linear fashion with little overlapping of the various phases of the project's life cycle. Thus, quality checks occur in each phase before the next phase starts. In alternative project delivery, these phases can run in parallel and that has the overall effect of compressing the project delivery period. It also furnishes less opportunity for iterative quality verification activities and makes controlling ultimate quality more difficult.

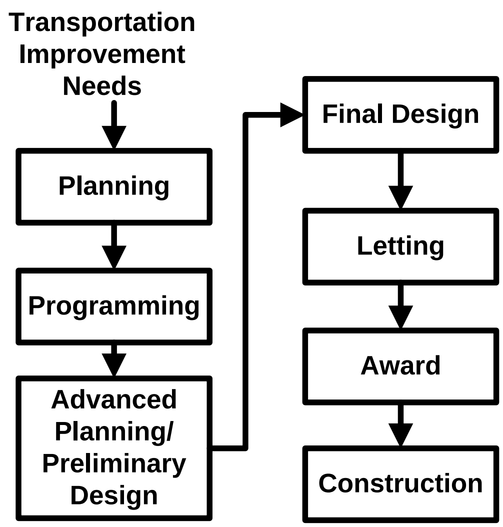

Figure 2-1 – Project Life Cycle (adopted from Anderson and Blaschke 2004)

However, using CMGC or DB project delivery does not make the components of the phases disappear. The owner must still conceive, study, develop, design, construct, commission, and operate the project regardless of how many activities are being done in parallel. Each of these life cycle components has a requisite quality standard associated with its deliverables and each of those must be managed to ensure that the ultimate quality of the constructed product is responsive to the operational requirements of the infrastructure project. Therefore, it is useful to study the quality management requirements that occur in each phase of the CMGC or DB project's life cycle without attempting to account for parallelism. This feature of alternative project delivery can then be approached as an additional constraint imposed by the project delivery method, i.e. the need to control quality in a manner that permits the overlap of tasks that were traditionally completed in series.

2.4 Methodologies

An efficient, well-built, and sustainable highway project needs highly qualified designers and constructors to build it. For each transportation project, the quality process starts in the procurement phase. This report then defines the procurement phase as including all actions taken by the STA prior to awarding the design or construction contracts. Thus, it will encompass all preliminary planning and design activities necessary for the identification of right-of-way requirements, environmental clearances, as well as advancing the design to a point where it becomes an adequate description of the scope of work. This phase also includes the activities undertaken during advertising, qualifications review, proposal evaluation, discussions, and best and final offers as applicable to the project delivery method. Once the STA awards the contract, the procurement phase is complete.

The early phases of programming and preliminary engineering are the points where the requirements for design and construction are identified. These phases lead to the concurrent development of required qualifications for the designers, builders, and others that must be present to verify the quality of the final projects. These requirements are defined, evaluated, and assured in the project's procurement phase.

NCHRP Syntheses 376 (Gransberg et al. 2008) and 402 (Gransberg and Shane 2010) found that owners, designers, and builders agreed on the key role of defining the necessary qualifications to ensure the selection of highly qualified teams during this phase. Each synthesis asked both the agencies and their contractors to comment on the impact of various aspects of the procurement phase in the CMR and DB delivery methods on a project's final quality. Table 2-2 illustrates the results.

Table 2-2 – Impact on Final Project Quality of Procurement Components for DB & CMR

Procurement Phase Component	Agency Ratings			DB and CMR Contractor Ratings		
	Very High or High Impact	**Some or Slight Impact**	**No Impact**	**Very High or High Impact**	**Some or Slight Impact**	**No Impact**
Qualifications of DBr or CMR's staff	91%	9%	0%	100%	0%	0%
DBr or CMR's past project experience	76%	24%	0%	100%	0%	0%
Use of performance criteria/specifications	72%	28%	0%	67%	33%	0%
Early contractor involvement in design	70%	30%	0%	100%	0%	0%
Level of agency involvement in the QA process	69%	31%	0%	33%	67%	0%
Level of detail in the procurement documents	68%	32%	0%	0%	83%	17%
Preconstruction services	63%	30%	7%	100%	0%	0%
Quality management plans	61%	39%	0%	83%	17%	0%
Warranty provisions	55%	38%	8%	33%	50%	17%
Use of agency specifications and/or design details	51%	42%	7%	17%	67%	17%

DBr = design-builder

There was nearly unanimous agreement that the aspects, which have the greatest impact on project quality, are the qualifications of the Design-builder or CMR's personnel and its past project experience. The Oregon DOT interviewee stated that "qualifications are critical to achieving quality." This corresponds with the information cited in the literature with regard to the value of these aspects. Taken together, it leads to the conclusion that tailoring procurement documents to fit the project's specific technical and management requirements will attract the kinds of competitors that have the correct set of personnel and experiences.

2.4.1 FHWA Quality Assurance Policy for Alternative Project Delivery

Understanding FHWA alternative project delivery quality assurance policy involves remembering that the foundation for it comes from 23 CFR 627, which springs from Title 23 US Code. The 1968 Federal Highway Act revised Title 23 USC which required construction contracts to be awarded *". . . only on the basis of the lowest responsive bid."* As such, the 1968 revision was written with the expectation that all federal-aid highway projects would be delivered using DBB. Thus, to permit delivery by another method required special authorization, which was provided by Special Experimental Programs 14 and 15. This meant that until 2004, a state that wanted to use DB had to apply for the authority through SEP-14, and states wishing to use CM/GC or PPP must still submit an SEP 14 or SEP 15 application if they are using federal-aid highway funding. As a result, the statutory underpinning of alternative QA views it as an exception to the established practice. Developing the necessary information to change alternative QA from an exception to the rule to a different set of recognized rules is the purpose of this particular research project.

In the past decade, the use of alternative project delivery methods has challenged the traditional quality management approach where the contractor performed QC while the owner conducted QA. Figure 2-2 is a graphical representation of the FHWA approach to the definition of QA in federal-aid highway projects.

A presentation at a recent FHWA "Every Day Counts" (EDC) Summit explained the federal alternative QA model in these terms:

> "The term Quality Assurance (QA) is a broad term that addresses all actions necessary to achieve project quality in both Design and Construction. QA is an umbrella term that includes Quality Control (QC) activities by the Contractor, as well as Acceptance activities by the Agency. Contrary to past misuse, QA is not *the activity performed by the Agency*." (Yakowenko 2010).

Figure 2-2 – Quality Assurance Concept as Described by the FHWA (adopted from Yakowenko 2010)

One can see that the major shift in perspective is the idea that QA is an umbrella under which all quality management activities take place and that the owner's primary QA role is one of acceptance. AASHTO R10-06 (2006) provides the following definition:

> **"**Quality Assurance (QA) **–** (1) All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service; or (2) making sure the quality of a product is what it should be [QA addresses the overall process of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA includes the elements of quality control, independent assurance, acceptance, dispute resolution etc. *The use of the term QA/QC or QC/QA is discouraged* and STA should use the term QA. QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities.]" (AASHTO 2006 italics added).

Additionally, the FHWA EDC presentation went on to state: "The Design-Builder cannot be assigned responsibility to perform any Acceptance (Verification) functions" (Yakowenko 2010). It is important to note that 23 CFR 637.207 (b) only applies to construction QA and not to design QA as shown in Figure 2-3. This not only validates the notion that the regulation was drafted contemplating DBB delivery, but it also creates a void with regard to federal guidance on design QA. The documents produced during the design process define a CM/GC or DB project's overall quality (Gransberg and Molenaar 2004). The construction QA program will use the construction documents as the standard for compliance of the constructed product. Another study found that only 17 of 75 DB RFPs required the submission of a design QA with the design-builder's proposal or after award of the DB contract (Gransberg and Windel 2008).

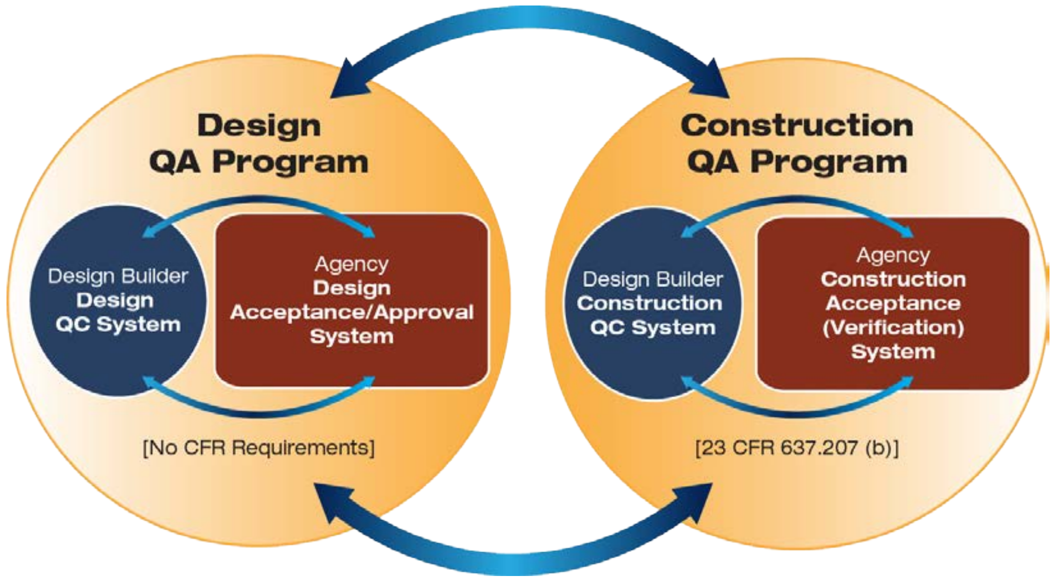

Figure 2-3 – FHWA Concept of the Relationship between Design QA and Construction QA (Yakowenko 2010)

A look at Figure 2-3 furnishes the answer to the rhetorical question: If the project's quality is defined in the design, why would it not be imperative to require a QA plan for design that is as robust as the construction QA plan? The answer is that currently there is no federal regulatory requirement to assure design quality. The same study also inferred that since many STAs have robust in-house design capability and complete much of their design using these resources, that "public sector owners have not seemed to make the philosophical transition from DBB to DB with regard to design quality management" (Gransberg and Windel 2008). The EDC presentation validates this understanding in one of the "Key Messages" developed to reinforce the initiative's purpose:

> "To ensure that goals for Project quality will be met, the Owner Agency should establish Quality Assurance (QA) requirements for DB projects. As outlined below, this includes a **Design QA Program** to address quality in the design process and a **Construction QA Program** to ensure the quality of construction. These QA Programs provide the skeleton or overall framework necessary for Quality Assurance implementation and clearly delineate the proper Agency and Design-Builder roles and responsibilities in achieving quality.

- **Design QA Program -** Research shows that many DB project RFPs totally ignore Design QA and focus only on Construction QA. While not explicitly required by Federal regulation, the Owner Agency is strongly encouraged to implement a Design QA

Program as a requirement of each DB project. The Design QA Program for DB projects includes the following two elements:

- Design Quality Control (QC) system by the Design-Builder
- Design Acceptance/Approval system by the Agency
- **Construction QA Program -** The Owner Agency should implement a Construction QA Program for each DB project. For Federal-Aid DB projects, this is a requirement (See 23CFR637.207 (b)). A complete Construction QA Program includes the following six core elements:
- Construction Quality Control (QC) system by the Design-Builder
- Construction Acceptance system by the Agency (or its Designated Agent)
- Independent Assurance (IA) by the Agency (or its Designated Agent)
- Dispute Resolution system established by the Agency
- Qualified/Accredited Laboratories (both Design-Builder and the Agency)
- Qualified/Certified Inspection & Testing Personnel (Design-Builder and the Agency)" (Yakowenko 2010)

Taking the FHWA quality management division of responsibilities detailed above and comparing it to the QM organizations found in NCHRP Synthesis 376 leads to the conclusion that the EDC presentation advocates a "Type 8" DB QA organization similar to the one used by the Minnesota DOT organization as outlined in the following RFP excerpt.

> "To ensure the quality of the Design-Build project, *MnDOT will manage and perform construction and design QA* and construction IA functions. *Construction QC and design QC plans and functions will be the responsibility of the Proposers*." (MnDOT 2001b italics added)

The NCHRP 10-83 Proposal contained Figure 2-4, the Integrated Quality Management Model (IQ2M). The FHWA alternative QA notion is that project acceptance is the ultimate goal of a QA program. Additionally, the universe of Project Quality Assurance (PQA) shown in Figure 2-4 corresponds with the QA umbrella in Figure 2-2 from the FHWA EDC presentation. Both models allow for QM activities separated by design and construction as well as independent assurance and owner verification. The only real difference, other than the artistic representation, is the IQ2M model adds two decision points that reflect the result of owner acceptance of the quality of the two major deliverables (final design and constructed facility). The first is the point in the project where the design or the design of a feature of work is released for construction. The second is the point where the constructed product is accepted and released for final payment. Therefore, one concludes that the IQ2M model complies with the spirit of QA expressed in the EDC presentation.

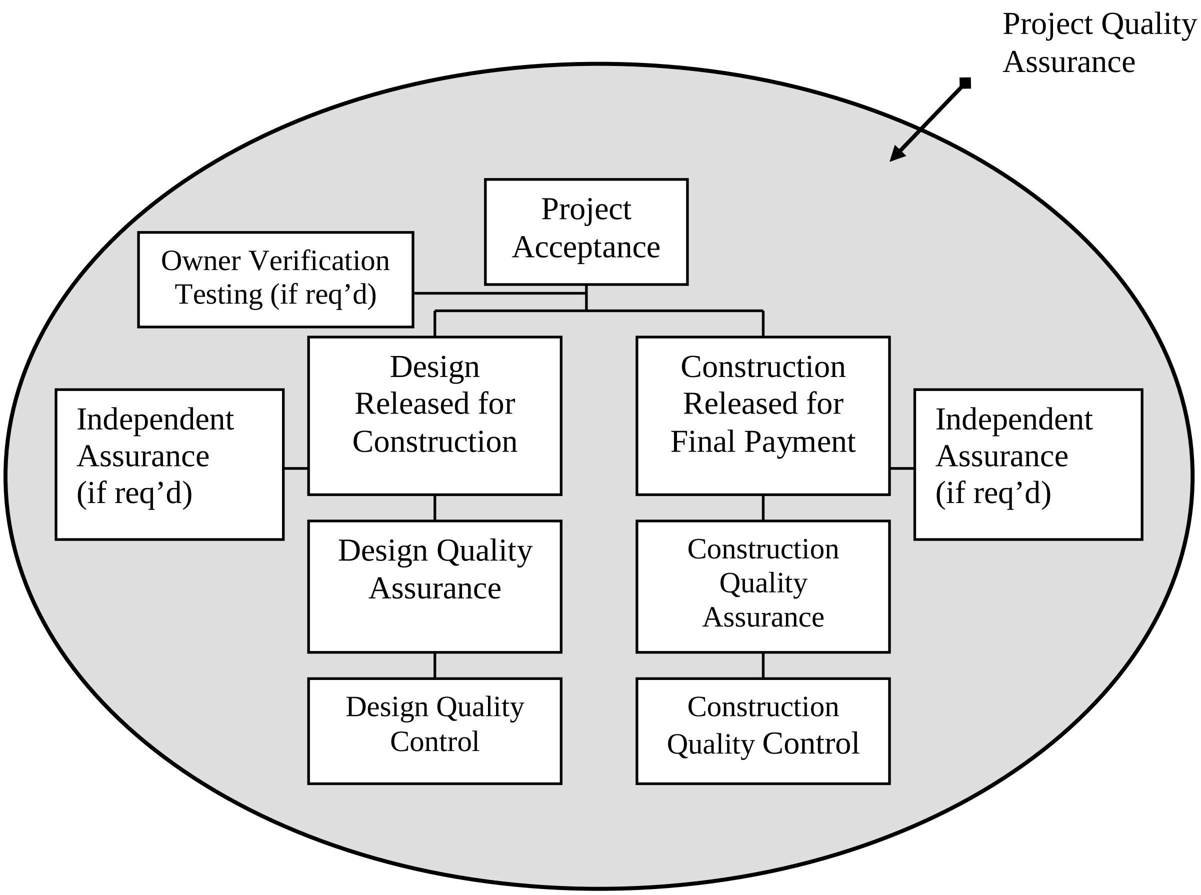

Figure 2-4 – Integrated Quality Management Model (IQ2M) [adapted from Synthesis 376 (Gransberg et al 2008)]

To be fully compliant with the FHWA EDC model, Figure 2-4 needs to be modified to indicate the distinction between QA/QC approach used by the agencies reviewed in the synthesis (i.e. "Contrary to past misuse, QA is not *the activity performed by the Agency*."). The modification is shown in Figure 2-5 and seeks to conform to the AASHTO R10-06 (2006) guidance that "*The use of the term QA/QC or QC/QA is discouraged*" by replacing the term "QA" shown inside the universe with "acceptance" and reorganizing the structure to show the acceptance decision points before the issuing of formal acceptance.

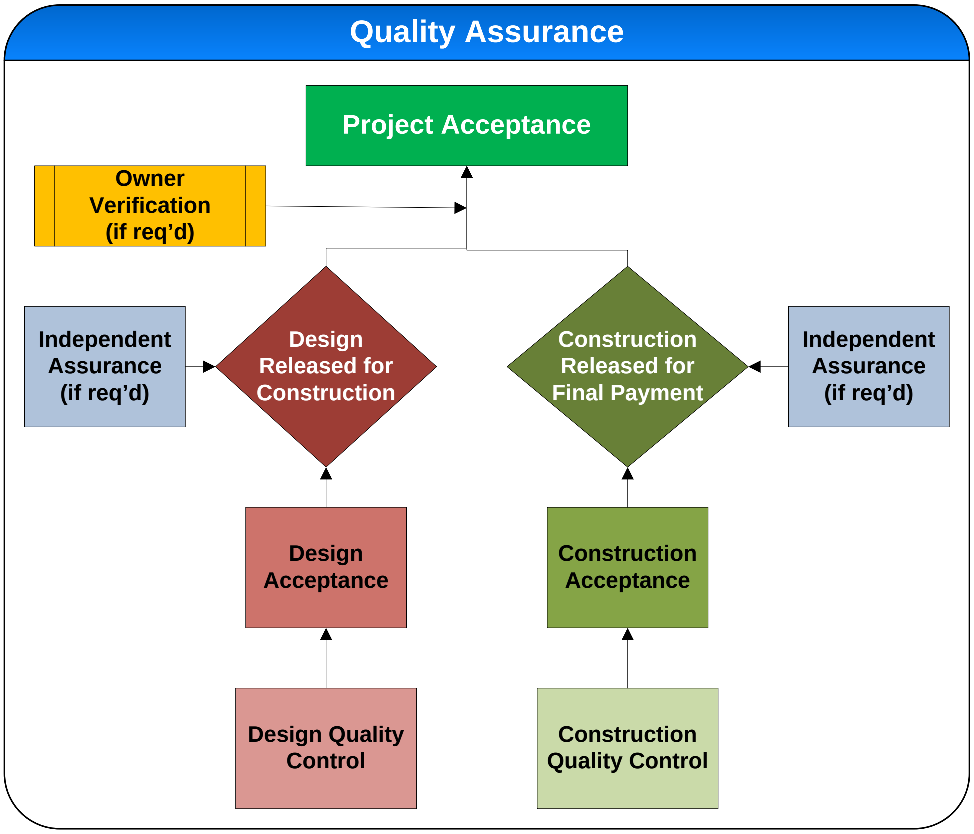

Figure 2-5 – IQ2M Model Adapted to Conform to the FHWA EDC QA Approach (after Yakowenko 2010)

2.4.2 USACE Quality Assurance Policy for Alternative Project Delivery

The US Army Corps of Engineers (USACE) has been using alternative project delivery methods since the 1980s (Henner 2007). USACE has a highly developed, detailed set of QM policies, regulations, and guidance documents for all project delivery methods. The overarching document is Engineer Regulation 1110-1-12 *Quality Management* (USACE 2006). This document describes the contents of what it calls "Project Quality Documents." It furnishes the following definitions for each component to the overall USACE QM program:

- "Project Management Plan (PMP)… a PMP is required for the execution of all work. The PMP identifies the scope, schedule, and resources needed to accomplish the work. It has sections that detail how to accomplish the project work items. The customer/local sponsor participates in development of the PMP and endorses it once completed.
- Quality Management Plan (QMP). The QMP is the quality component of the PMP. Its purpose is to document the project-specific quality control and quality assurance procedures appropriate to the size, complexity, and nature of the project. The QMP will identify customer quality objectives, and their thresholds, and project specific requirements determined by the command. The QMP will include Quality Control Plans and Quality Assurance Plans required for product deliverables and identify quality control and quality assurance requirements for the overall project, including work

performed by contractors. The QMP must be consistent with the organizational QM unless otherwise documented.

- Quality Control Plan (QCP). The QCP is the quality control component of the QMP and defines how quality control will be executed for products and services.
- Quality Assurance Plan (QAP). The QAP the quality assurance component of the QMP and defines how quality assurance will be executed for products and services that are completed by outside resources, including architect-engineer (A-E) contractors as well as other USACE Districts and Centers.
- Contractor Quality Control Plan (CQCP). The CQCP is a written plan, provided by an AE contractor that defines how quality control will be executed on products and services that are completed with A-E resources." (USACE 2006).

One can see that the USACE approach to QM is different from the approach described for the FHWA where "QA is not *the activity performed by the Agency*." (Yakowenko 2010). The references to QA in ER 1110-1-12 clearly assign the QA responsibility to the agency. Additionally, the USACE model sees QM as the "umbrella" that covers both QA and QC and it rolls the "acceptance" activities into the agency's QA role. Therefore, understanding the USACE approach entails carefully applying the USACE definitions for key terminology and not confusing it with the FHWA definitions for the same terms. The USACE model operates on Total Quality Management (TQM) principles laid down by Deming. Specifically, the model prescribes a "'Plan-Do-Check-Act' (PDCA) Cycle (commonly referred to in industry as the Deming (1986) Cycle) which is the guiding quality management procedure for USACE business processes" (Yakowenko 2010). The model is graphically presented in Figure 2-6. Each step in this process is defined as follows:

- "Plan – design the Project Management Plan to achieve customer requirements and provide for high-quality products and services.
- Do – implement the PMP, including the quality control and quality assurance procedures.
- Check – evaluate the project results.
- Act – identify and implement process changes for continual improvement" (USACE 2006).

Figure 2-6 – USACE QA Model for Alternative Project Delivery (USACE 2006)

USACE utilizes a systems approach to quality and does not break it out as a separate category of agency responsibility. As seen above, the QM plans are included as an integral part of the project management plan. The QM regulation goes on to develop further that concept by requiring the project management team to "ensure that other key PMP components are structured to optimize project quality." Those components are defined to include:

- "Production Schedule – All projects and associated technical documents will have a formal production schedule.
- Risk Management Plan – A Risk Management Plan is required for the PMP. The PM will effectively engage with the customer and other PDT members to identify risks to project scope, quality, schedule and cost. These risks will be clearly defined in the project Risk Management Plan. The PDT will ensure that the necessary work breakdown activities and resources are specified in the PMP to effectively address the defined risks. Starting with the PMP, Resource Providers and Independent Technical Review Team (ITRT) members will provide continuous review to ensure that the PDT has adequately defined and addressed project risks.
- Value Management Plan – A Value Management Plan is required for the PMP. The PDT will ensure that the Value Management Plan effectively applies VM/VE policies and procedures to provide the best value project for the customer.
- Change Management Plan – Change Management Plan is required for the PMP. The CMP will stipulate performance metrics for project scope, schedule, cost, quality and risk. PDT and ITRT members will evaluate all proposed project changes and report potential impacts to the performance metrics per the project Communications Plan. The

goal for the change management process will be to optimize project performance and customer satisfaction throughout the project life cycle.” (USACE 2006).

2.4.2.1 USACE DB QM Philosophy

After analyzing the USACE QM approach, one can see how it directly relates with the STAs’ primary reason for delivering a project using alternative methods: to compress the delivery schedule (FHWA 2006). USACE makes QM an integral part of project management rather than a separate process that requires specialized skills. To accomplish this aim, USACE specifically states its expectations in a chapter devoted to applying ER 1110-1-12 to DB project delivery. The following list contains selected excerpts that illustrate that philosophy shift from DBB to DB project delivery:

- “With D-B the contractor is the single point of responsibility for the design and construction services.
- The PDT [USACE Project Delivery Team] is responsible for the quality of the design performance criteria in the D-B solicitation. The D-B contractor is otherwise responsible for design quality. The PDT will ensure that appropriate design quality control provisions are included in the D-B contract.
- The PDT will develop and provide quality control review of the performance criteria and prescriptive requirements in the RFP. The PDT will review and evaluate D-B proposals for compliance with the contract requirements.
- Compared to an [DBB] A-E [architect-engineer design] contract, the D-B Contractor and its Designer-of-Record (DOR) are charged with a higher standard of care to correct construction associated with faulty design.
- The contract will have provisions for the contractor’s construction function to provide input during the design. The D-B Contractor’s construction function will address constructability, coordination, and ensure that the project cost is within the contract budget/price amount.
- The D-B contract will include “Warranty of Design” provisions that provide for an extended callback for design errors and omission, and for correction of construction related to faulty design.
- The D-B contract will address QC for design and design-related activities during construction. As a minimum, the design QCP must designate a qualified design quality control manager, incorporate independent peer reviews, utilize a design deficiency tracking system and develop procedures for design reviews, DOR reviews and approved construction submittals.
- The D-B Contractor, through its DOR, will ensure the project construction is in accordance with the accepted design and the contract. The DOR’s quality role during construction includes, but is not limited to, reviewing and approving shop drawings, correcting design errors and omissions, revising the design for official changes and approved deviations, resolving field questions or problems and approving final as-built drawings.

- The PDT remains responsible for the quality of the design criteria and for assuring that the construction conforms to the accepted design as well as to the contract requirements. The PDT's role is that of quality oversight by concurrence of the DOR and contract quality control activities, including spot-checking submittals to ensure that they conform to the contract and accepted design." (USACE 2006).

2.4.2.2 USACE DB QM Philosophy

USACE pioneered the use of CMGC project delivery as a method to bring the construction contractor onto the project that is faster than DBB and DB. Figure 2-7 shows the USACE perspective in relation to a given project planning year (PY) which begins when Congress authorizes planning and development (P&D) funding. USACE calls the project delivery method "Early Contractor Involvement" (ECI), which should not be confused with the ECI project delivery used by many international public transportation agencies that are structured similarly (Scheepbouwer 2010). Essentially, USACE sees ECI as a process that starts in planning with the construction contractor furnishing preconstruction services throughout the planning and preliminary design phases of an ECI project's life cycle. Presumably, procurement of the ECI contractor could happen before the project's designer-of-record, including both in-house and outsourced design resources. FAR 16.403-2 "Fixed Price Incentive Contract-Incentive Price Revision (Successive Targets)" methodology is used to procure the ECI contractor. The project delivery method allows the owner to determine whether to award the ECI contractor the construction contract based on the ability to negotiate a mutually agreed guaranteed maximum price (GMP).

Since CMGC project delivery has the owner holding separate contracts for design and construction, CMGC contractually falls between DBB and DB (Yakowenko 2010) and the need to promulgate new USACE QM regulations and policies is minimal. At this writing, USACE has not published any specific ECI QM guidance, and contacts with a senior USACE official indicate that none is forthcoming. ECI has been used extensively on nearly $7.0 billion worth of projects associated with Hurricane Katrina recovery effort. The project delivery teams merely applied the QM regulations (ER 1110-1-12) in much the same manner as discussed above for DB project delivery.

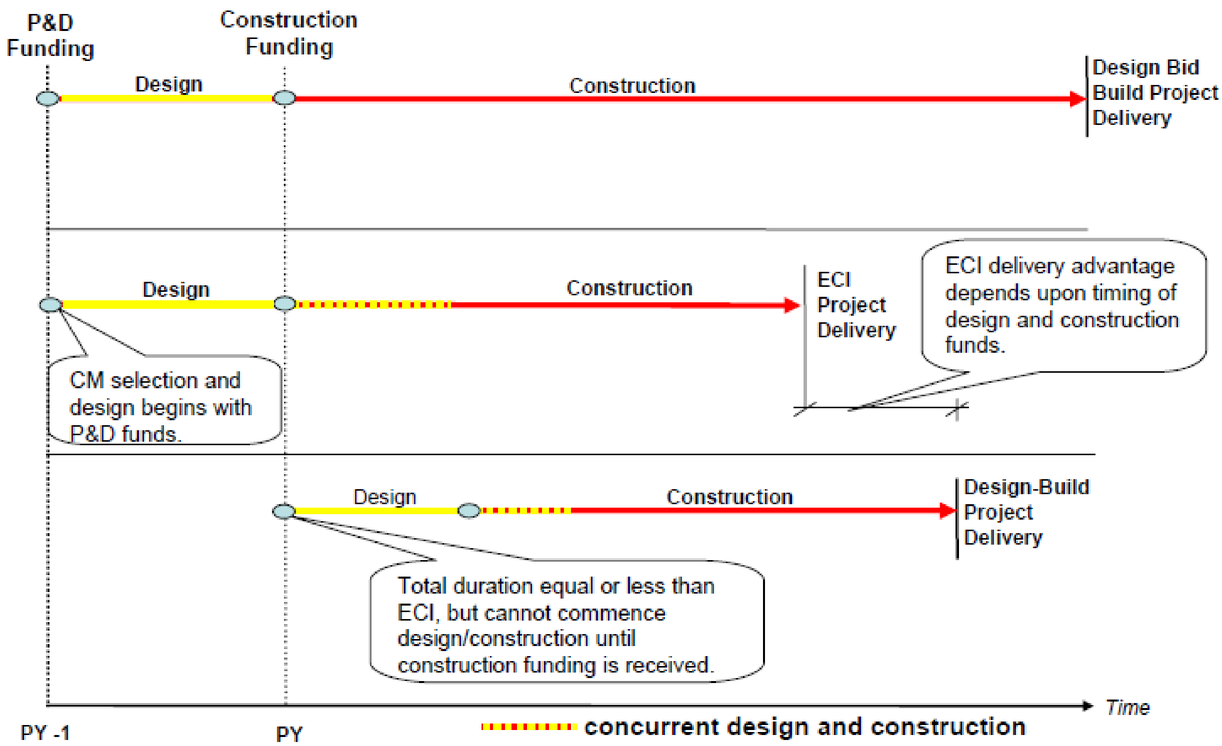

Figure 2-7 – USACE Relative Project Delivery Timelines (USACE 2009)

2.4.2.3 Summary of USACE Alternate QM

The USACE QM approach for projects delivered using alternative methods can be summarized as follows:

- USACE sees QA as the agency's role in QM.
- USACE uses a systems approach to QM and has detailed guidance for QA in each phase of life cycle of a CMGC (ECI) or DB project.
- USACE uses a standard series of QM plans to codify, quantify and assess quality performance on both design and construction quality.

2.4.3 ISO 9000 QA Principles Applied to Alternative Project Delivery

ISO 9000, promulgated by the International Organization for Standardization (ISO), offers a series of standards for an effective quality management program. The ISO 9000 requirements provide a common foundation to instill a quality culture in organizations that "embrace eight quality principles:

- Customer focus,
- Leadership,
- Involvement of personnel,

- Process-based approach,
- Systems approach to management,
- Continual improvement,
- Factual approach to decision-making, and
- Mutually beneficial relationships with suppliers" (Miron et al 2008).

ISO 9000's QM objective is to "break down communication barriers, change paradigms, and ensure that every department in an organization knows how its work affects other processes or areas in the organization. Aligning a quality management system with the organization's current management system facilitates planning, allocating resources, defining complementary objectives, and evaluating the organization's overall effectiveness" (Miron et al 2008).

At first glance, ISO 9000 appears to have no specific guidance with regard to highway design and construction. It does contain specific guidance for building construction that is directly applicable to the vertical projects that STAs may construct. The ISO web site contains no direct references to project delivery methods or highway construction. However, that fact does not mean there is nothing within the ISO body of knowledge that is not applicable to QM for highway projects delivered using alternative methods. ISO does provide a wealth of information on QM in design and manufacturing that has direct application to highway projects. For example, an article written in 1998 describes how an ISO 9002-certified Canadian contractor applies the fundamental principles of ISO 9000 to "produce, monitor and control its own concrete mixes, not only to ensure mix quality, but to more efficiently feed its continuous concrete paving operations" (Dufferin 1998).

The primary application of ISO 9000 was on the contractor's mobile concrete batch plant. This fits neatly into the manufacturing standards available from ISO. Since highway construction is equipment-intensive and becoming more highly automated, the opportunity to cross manufacturing standards to the appropriate construction system, such as GPS-driven construction machine guidance or in-place recycled asphalt paving trains is clearly transferable as shown by the ISO-certified Canadian batch plant. The FHWA used ISO 9000 principles to guide an initiative entitled: "Advanced Quality Systems (AQS)" (Miron et al 2008). The definition of AQS is:

> "An AQS is an integrated quality management system to fulfill the customer's expectations of pavement performance by making optimum use of the available tools and resources to continuously improve the system processes and the quality of the product delivered while fostering cooperative working relationships among all parties."

The term "integrated" is used in this definition in the same sense as it is used in project delivery method classification. An integrated project delivery method is one where the designer and the constructor work together during the design and construction phases. Thus, both CMGC and DB are integrated project delivery methods. Table 2-3 shows AQS tools developed by the FHWA and one can see that most of the tools are applicable across the project's life cycle. For example, the Construction Quality Database is used in planning, design, construction, and post-construction. Therefore, the application of this ISO 9000-based initiative to alternative project delivery requires little or no alteration to be able to implement.

Table 2-3 – FHWA Developed AQS Tools (Miron et al 2008).

Tool	PP	D	V	Ad	C	PC	Ac	M	As	CI	T
Construction Quality Database, www.fhwa.dot.gov/pavement/concrete/pubs/07019/index.cfm www.fhwa.dot.gov/pavement/concrete/pubs/07020	X	X	X	X	X	X	X	X	X	X	
PaveSpec, www.fhwa.dot.gov/pavement/pccp/pavespec/index.cfm	X	X	X	X	X	X	X				
SpecRisk, Available on CD only;	X	X	X	X	X	X	X				
Prob.O.Prof, http://dx.doi.org/	X	X	X	X	X	X	X				
HIPERPAV, www.hiperpav.com	X	X	X	X	X	X					
COMPASS, www.pccmix.com	X	X	X	X	X	X					
QA Program Effectiveness, http://dx.doi.org/								X	X	X	
Percent Within Limits: The Quality Measure of Choice (workshop)											X
Basic Pavement Warranty Workshop											X
SpecRisk Training (FHWA-NHI-134070) Web-based course currently under development.											X

PP = project planning; D = design; V = design verification; Ad = design adjustment; C = construction; PC = construction process control; Ac = construction acceptance; M = monitoring; As = assessment; CI = continuous improvement; T = Training

2.4.3.1 ISO 9000 Applied to Design QM in CMGC and DB

Design QM is the place where ISO 9000 principles may be most applicable. The principles of "involvement of personnel" and "factual approach to decision-making" personify integrated delivery methods. Both DB and CMGC bring the members of the project team together at early stages in the design and involve them in developing the facts regarding costs, time, and technical performance for design alternatives before making the final design decisions. The Oregon DOT lists the major services that the construction contractor can perform during the design phase of a CMGC project as follows:

- Cost Estimates
- Schedule analysis
- Work sequence
- Risk identification/mitigation/pricing
- Constructability reviews
- Develop work packages for bid
- Develop a GMP that meets owner requirements and budget restraints (Lee 2008)

A study of the delivery of a water treatment plant in Florida contained an interesting design QM role for the CMGC. The CMGC preconstruction services contract contained a clause that required the CMGC to include a licensed design professional on its preconstruction team to perform a technical peer review of the design at the 30%, 60% and 90% phases of design (Kwak and Bushey 2000). Water treatment projects are often rife with ISO 9000 process equipment design and manufacturing requirements and as such, often require both the designer and the construction contractor to be ISO 9000 certified (Battikha and Russell 1998). This requirement makes using an integrated method such as CMGC or DB an elegant way to an ISO 9000 certified team and ensuring the application of ISO 9000 QM principles from concept to ribbon cutting.

ISO 9000 advocates that a critical factor in achieving high quality design is free and open communication between all parties during the design phase (Miron et al 2008; Beard et al 2001), and DBIA's *Manual of Policy Statements* states: "DBIA advocates both formal and informal project partnering and considers the partnering philosophy to be at the foundation of design-build delivery" (DBIA 1998). During proposal preparation, the design-builder will make a number of design assumptions around which it will develop its proposed price. The FHWA AQS initiative recognizes this and prescribes: "Because the design and associated drawings and specifications define what the transportation agency wants, they all need to be consistent. Especially important: The design assumptions used to specify the quality of constructed pavement and predict its performance must be consistent with the quality and performance requirements called for in the specifications" (Miron et al 2008). Therefore, the ISO 9000 principles demand that the design-builder reconcile its design assumptions with the agency's technical criteria and ensure that the requisite level of quality is achieved on a performance basis.

2.4.3.2 ISO 9000 Applied to Construction QM in CMGC and DB

Construction QM in a CMGC project will not differ greatly from that found in a DBB project. The owner still occupies the same contractual position with respect to the designer and builder. Therefore, the ISO 9000 systems in use in DBB projects will directly apply to CMGC projects with little alteration. The key difference is the change in motivation of the constructor with regard to quality. In DBB, it has no input to the design and must build what is shown in the construction documents. In CMGC, the contractor assists in developing the final design and as a result assumes a significant degree of ownership in the design product. NCHRP Synthesis 402 (Gransberg and Shane 2010) described the idea of having "buy-in" to the design making the CMGC less prone to submit a claim for additional compensation for design problems in features of work for which the CMR had been paid to review and furnish input.

This notion was confirmed a Florida study of the delivery of a water treatment plant using CMGC (Kwak and Bushey 2000). In that project, much of the project's process equipment had ISO 9000 standards associated with it. Because of the rate at which water treatment technology is evolving and the constant threat of environmental standards changing, these types of projects often have need to implement "supplemental technology late in the design process and construction." The study concluded:

> "This method of delivery provides for flexibility in the implementation of design changes late in the design process without impacting construction schedules and final delivery dates. The ability of the CM [GC] to input constructability reviews, construction phasing, material availability, and cost estimating as well as technical peer review throughout the design process reduces the probable occurrences of change orders [due to design errors], project construction delays, and increased project costs due to contractor identification of these elements in the design phase instead of the construction phase…Costs in terms of

> initial, operational, and maintenance would tend to favor the CM [GC] quality and reject the low bid traditional method of project delivery” (Kwak and Bushey 2000).

STAs are accustomed to describing, in detail, the means and methods used to carry out the construction of their transportation projects in the standard specifications for construction. The use of prescriptive specifications for DBB projects has been proven over time to be successful in yielding a quality product. In DB, however, STAs have the opportunity to allow design-builders to use specific construction means and methods to differentiate themselves from their competitors and to provide efficiencies that may not have been contemplated by the project’s owner. This creates an opportunity to use ISO 9000 certification of construction companies as a mechanism to mitigate the risk that the construction means and methods used by the design-builder may not achieve the same quality as those prescribed in DBB contracts. Thus, ISO 9000 furnishes a criterion to articulate the amount of flexibility the design-builder will have over construction means and methods in a DB highway project (Battikha and Russell 1998).

2.5 Design Quality Management Tools

The design phase of a project is when STAs quantify and define the ultimate quality of the constructed facility through the production of construction documents. A previous study of DB quality management stated: “Quality cannot be assumed into the project. It must be designed and built into the project in accordance with the DB contract itself” (Gransberg and Molenaar 2004). It is intuitively obvious that there is a relationship between the final quality of the construction and the quality of the project’s design. Thus, design QM activities are necessary to assure the final quality of the products produced during design development as indicated by the following quote:

> “*Quality documents facilitate quality construction*… Review of the constructability of transportation facilities in the planning and design phases, specifically [for] deficiencies in quality and clarity of construction plans is critical…Constructability reviews…*are the key mechanism for insuring that plans and specifications fulfill these quality objectives*.” (Dunston et al 2002 italics added)

An important factor in producing a design that meets a high standard is free and open communication between all parties during the design phase (Beard et al 2001). Harking back to the I-35W bridge collapse, the investigators found, “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 2008). Although delivery of this bridge used DBB, the designer’s QM program and owner’s design QM program were both found lacking. This indicates a failure to communicate the requirements for quality in both directions.

2.5.1 Design Quality Management in DB Projects

As design details define construction quality requirements, it would follow that STAs who must commit themselves to the cost of construction prior approving the project’s final design, as happens in DB, would devote a significant portion of their DB solicitation packages to defining the required design quality management process, and that, in turn, would cue design-builders to prepare design quality management plans that detail their proposed process for each specific project that can be evaluated as a part of the selection process. Unfortunately, in practice this is not occurring.

A previous study of design quality management requirements in 75 DB projects across the nation found that only 18% of the DB solicitation documents required submission of a design quality management plan as part of the DB proposal (DeCorso 2004). Additionally, only 17 of these projects required a design QC plan after award and only two took the next step by requiring a complimentary design QA plan. Thus, the literature shows that design quality management is an area where the greatest potential for improvement is present. Perhaps this is due to a lack of policy guidance in the area of design management due to the DBB practice of public engineering agencies traditionally doing much of their design work using in-house professional engineers. Thus, STAs are not availing themselves of the opportunity to evaluate different design-builders' approaches to ensuring design quality by not asking for design quality management plans prior to award.

STAs give up control of the details of design by selecting DB project delivery, thus depending merely on the qualifications process to guarantee design quality, like in a pure design contract, may not be sufficient. With the dominant organizational type being a constructor-led DB team (Songer and Molenaar 1996), the designer's client is no longer the owner. Therefore, it would seem to be imperative that the DB teams' approach to producing a quality design be evaluated prior to award. Thus, having a clear definition of design quality management is imperative.

The Minnesota Department of Transportation (MnDOT) furnishes an excellent definition for quality management during the design phase of a DB project when it laid out the objectives of the Design Quality Management Plan. The intent of the plan is to:

- Place the primary responsibility for design quality on the design-builder and its designer(s).
- Facilitate early construction by the design-builder.
- Allow the Department to fulfill its responsibilities of exercising due diligence in overseeing the design process and design products while not relieving the design-builder from its obligation to comply with the contract. (Gonderinger 2001).

One can see that MnDOT's three-pronged approach not only satisfies its obligations for project oversight due to federal funding, but also ensures that the responsibility for the quality of the design is placed clearly on the design-builders' shoulders. It also speaks toward achieving a major benefit accrued by the owner when selecting DB project delivery: project schedule compression through overlapping design and construction activities. Thus, it becomes important to adopt not only a good definition for design quality management but to also define clearly the allocation of responsibilities between the STA and the design-builder after project award.

2.5.1.1 STA Guideline Approaches for Design QA

When reviewing the guidelines published by various STAs, there are three different policies established in determining the QC and acceptance roles in DB projects:

- Variable assignment of design QC and acceptance responsibilities on a project-by-project basis.
- Assigning design QC to the design-builder and the design acceptance to the STA.
- Assigning design QC and acceptance to the design-builder with the STA performing oversight and verification (i.e. design PQA).

Variable Approach

In the first approach, the assignment of design QC and acceptance roles can be varied from project to project. This recognizes that every project is different and that, depending on size, delivery speed and technical complexity, the optimum assignment of QC and acceptance responsibilities will be different based on individual project needs. This is shown in the Arkansas *Design-Build Guidelines and Procedures*:

> "The D/B package shall address any quality assurance requirements that the selected firm must follow in addition to those already in the referenced specifications, policies and procedures that will assure quality products (plans, materials, construction, etc.). Quality management criteria require at least three independent roles, including (1) quality control by the selected firm, (2) acceptance or verification by the Department's Resident Engineer (RE) office, and (3) independent assurance by the Department's central office staff. The responsibilities for all three roles and minimum sampling, testing and inspection frequencies shall be defined in the scope." (Arkansas HTD 2006).

STA Design Quality

In the second type of design QC and acceptance approach, the design-builder is responsible for the design QC and the STA is responsible for the design acceptance. This approach parallels the DBB assignment of responsibilities for construction quality management. The Colorado DOT, Massachusetts Highway Department and the Florida DOT use this method and an example of this comes from the Arizona *Design-Build Procurement and Administration Guide:*

> The Design-Builder shall be required to submit a design quality management plan, which describes how the Design-Builder will control the accuracy and completeness of the plans, specifications, and other related design documents produced by the Design-Builder. …ADOT will retain a quality verification role as it does for other quality management issues. For design work, quality verification will be accomplished by design reviews led by the PM and performed by ADOT's technical groups or the general consultant, if one is used. (Arizona DOT 2001)

Design-Builder Design Quality

Finally, the third approach assigns the design-builder both design QC and acceptance and the STA steps back from active participation and responsibility and, instead, only performs oversight and verification of design quality. The New York State DOT follows this approach.

> The contractual requirements for design management and QA/QC [*quality control and quality acceptance*] are the primary responsibility of the Design-Builder rather than the

> Department…The Department's project staff Oversight role during design and Design Review consists of monitoring and auditing design progress, interpreting contract requirements, and verifying design compliance with contract requirements. (NYSDOT 2005).

Regardless of how the design QM responsibilities are assigned they must be performed. When the STA will perform the design acceptance activities, the contract documents (i.e. the RFP) need not further explain design acceptance activities. However, when the design-builder is assigned the design acceptance responsibilities, it is imperative to lay out the requirements in the RFP so that confusion is eliminated and the STA understands exactly what services they will receive with the proposal as well as how to integrate their QM activities during design.

<u>Reviews of the DB Design Deliverables</u>

One of the traditional ways that STAs have ensured quality design is by being able to fully review the design before it is advertised for bids. In DB, STAs do not have this same opportunity. One of the major advantages of DB is schedule compression, which happens by being able to start construction before the full design is finalized. In fact, in the survey 85% of STA respondents to the general survey indicated this as a reason for implementing DB. Another advantage of DB is the transfer of risk from the STA to the design-builder, and in the survey, 53% of STA respondents also indicated this as a reason for implementing DB. In a DB contract, the design-builder is responsible for the adequacy of the design in relation to the contract documents. STAs must be aware that "increased control over project design might not only reduce potential design-build benefits but might also carry with it the risk of liability for the entire project" (Wichern 2004).

Thus, many states that do place the responsibility for design QC and acceptance on the design-builder use specified design review checkpoints, a design PQA activity, to ensure that the design is proceeding according to contract requirements. This also fulfills the STAs' responsibility to the public to deliver projects designed and built in accordance with public law and good engineering practice. These checkpoints exist so that the design-builder's final design is acceptable to the STA and is in accordance with the performance criteria contained in the contract documents.

<u>Design Review Checkpoints</u>

The NCHRP Synthesis 376 RFP content analysis found that there are two general ways to determine design review checkpoints. These are summarized in Table 2-4. The first method defines them in the RFP. The STA states in the RFP when to conduct reviews and what to include in the review. The design-builder must then account for the required reviews in their proposal and schedule of the project. This is by far the most common way to identify the required reviews. In the solicitation document analysis, 41 projects had design reviews as a requirement of the contract. Of these 41 projects, 83% told the design-builder at what point to review the design.

Table 2-4 – General DB Design Review Categories

Type	Design-builder responsibility	STA responsibility	Comments	% of Projects in Content Analysis
Defined Reviews	To be responsive, must follow defined reviews in contract documents	Defines reviews in the RFP	Reviews may be performed by design-builder, STA or 3rd party	83%
Proposed Reviews	Propose design reviews for project as part of proposal or after award of contract	Accepts or rejects proposed design reviews	Reviews may be performed by design-builder, STA or 3rd party	17%

The second approach, proposed reviews, is to allow the design-builder to propose the schedule of design reviews in their response to the RFP or during negotiations after the award of the contract. This is the stated policy of the Arkansas DOT: "There will be no pre-defined reviews scheduled by the Department. The selected firm and the Department will decide on the appropriate timing of reviews during execution of the contract" (Arkansas HTD 2006).

2.5.1.2 Appropriate Number of Design Reviews

In addition to how the design reviews are defined, the number of required design reviews by the STAs varies from state to state. However, the content analysis identified three main trends:

- No formal review prior to final (release-for-construction) design review,
- One review prior to the final design being released for construction,
- Multiple reviews prior to the final design review.

Also, in many instances the design-builder is encouraged to request informal reviews that are not required but allow the STA to provide frequent input. This helps to ensure that the final design will meet the contract requirements. These reviews are often called "over-the-shoulder" or "oversight" reviews to indicate that the design process will not stop proceeding to wait for comments that result from these informal reviews. Table 2-5 provides a summary of the different categories of required number of design reviews and the corresponding percentage of occurrences in the RFP analysis.

Table 2-5 – Required Number of Design Reviews

	% of Projects in Content Analysis	Comments
No review prior to final	15%	STA still provides oversight and comments informally
One review prior to final	56%	Can be anywhere from preliminary design until just before the final design review
Multiple reviews prior to final	29%	The exact number of reviews can range from two reviews total to one review for every major feature of work

No Mandated Reviews

When there is no STA-mandated design review checkpoint required before final design, the burden of design compliance is fully placed on the design-builder. In theory, this is one of the benefits of utilizing DB project delivery. However, the STA must still provide assurance that the contract will be completed with all the requirements met in a timely manner. In the RFPs analyzed for this project, 41 mentioned the design review requirements. Fifteen percent used the approach of no STA-mandated design review checkpoints before the release-for-construction design review. The Minnesota DOT detailed its design QA approach in one RFP as follows:

> The Department will participate in oversight reviews and reviews of early construction as part of its due diligence responsibilities. If the Department, in its review, observes that the Design-Builder is not complying with contract requirements and/or that the QC/QA [*quality control and quality acceptance*] checks are not complete, it will notify the Design-Builder in writing that construction may not proceed until the noted items are corrected. The Department's oversight review and comments will not constitute approval or acceptance of the design or subsequent construction. (MnDOT 2001b)

This QA activity (sometimes termed as due diligence) must be accomplished through an oversight approach as stated in the Minnesota RFP referenced above or by via a formal audit approach such as used by the Utah DOT (2005). The Utah RFP goes on to discuss the design review process for the final design deliverable.

> When the designer has completed a design package to 100% and the package has been checked and audited, a formal design submittal is assembled and distributed for review, including plan sheets, calculations, specifications, and other pertinent data. The Designer shall prepare for these reviews a full set of drawings and other documents stamped "Checked and Ready for Review."…After the 100% comments have been addressed and the design documents have been checked and audited, a "ready to be released for construction" submittal package is assembled and distributed to the Design-Builder and the Department for release for construction. (UDOT 2005)

To preserve the definition of design liability, Utah also requires the design-builder to complete a certification process on the final design package and specifies the time limit to which the STA must adhere to furnish timely acceptance.

Single Design Review

The second category of DB design review is where the STA requires a single official review of the design before the review of the final design deliverable. This gives the STA an intermediate point at which to verify that the design development is proceeding in accordance with the contract requirements and to ensure that it is progressing according to the schedule. The Mississippi DOT uses this type of design review for their DB projects. An example is listed below.

> The CONTRACTOR will prepare and submit a single preliminary design submittal for the entire project. Preliminary design shall include roadway plan and profile, bridge type, selection layout, drainage, erosion control, signing, architectural and traffic control plans. MDOT will review Preliminary Design Submittals within 21 Days of the submittal…. (MissDOT 2005a)

The requirement of only one official review by the STA is, by far, the most popular design review process currently used as found in the RFP analysis. Fifty-six percent of the RFPs analyzed for NCHRP Synthesis 376 used this type of design review process.

Multiple Design Reviews

In the final category of design reviews, the STA requires more than one official agency review before releasing the design for construction. This process was found in 29% of the RFPs that included information about design reviews. The Maine DOT required in one RFP that "formal design package submittals shall be made…at the 50% and 80% design development stage of any design package intended to be RFC [released-for-construction]" (Maine DOT 2003).

Two variations on this category that were found and require mentioning in this section. The first is when the STA requires an independent design quality assurance firm to do the design reviews with the STA only providing limited oversight. This is the current situation with the SH 130 project in Texas. The RFP states:

> DQAM [design quality assurance manager] will conduct a formal over-the-shoulder review presentation to the TTA [Texas Turnpike Authority] at the TTA's office. The over-the-shoulder review presentation will be held, following the DQAF's [design quality assurance firm's] approval of: the Corridor Structure Type Study Report; the Preliminary (30%) Design Submittal; the Intermediate (65%) Design Submittal; and the Final (100%) Design Submittal….Developer's designer shall furnish to the DQAF at least five (5) mandatory design submittals, and if necessary, any resubmittals. (TTA 2001)

The second variation is when the STA requires certain design reviews, attends the reviews, but is not the responsible party for the review. In the following example, the DB firm was responsible for the formal design reviews with the STA in attendance.

> The DQA [design quality assurance] Manager will conduct formal milestone reviews at the 30%, 60%, and 90% (or as otherwise agreed by the WSDOT and Design-Builder) stage of project elements to determine whether the Contract requirements and design are being followed and that QC/QA [quality control and quality acceptance] activities are following the approved QMP…The DQA Manager shall compile and maintain documentation of the review. The Department will be invited to attend these reviews. (WSDOT 2004)

In the vein of deciding the appropriate number of STA design reviews for a given project, it is interesting to note that the US Army Corps of Engineers (USACE) changed its policy for DB design reviews, reducing the number of reviews from four (30%, 60%, 90%, and final) to two (intermediate and final) (USACE 2006). The reason for the change was to reduce the potential for delays due to waiting for government reviews. In a personal communication with the author, Joel Hoffman of USACE explained the rationale as: “Philosophy is that once the designer-of-record approves construction and extension of design submittals, the builder can proceed - don't wait on us, unless there is a specific government approval required.” Thus, one critical issue regarding determining the appropriate number of design reviews is the need for the design-builder to maintain an aggressive schedule. If the project is not schedule-constrained, the DOT can afford to inject more design review points. Whereas, design reviews can be minimized on a fast-track project.

Over-the-Shoulder Reviews

In addition to the design reviews outlined above, another noticeable trend is the inclusion in the RFP of a statement inviting the design-builder to request informal “over-the-shoulder” reviews to ensure that the design is progressing according to the contract requirements without the need to prepare a specific design submittal package and to provide owner input to the design where it will be both desired and helpful. These statements are included in RFPs regardless of the number of required design reviews. Usually, however, a statement is also included that removes liability from the STA for any comments that may be incorporated from the informal reviews.

Design reviews are an integral part of any design QM program. They ensure the constructability of the project, and they ensure that the design meets the contract requirements. Even though the design-builder is responsible for both of these in DB, STAs must provide themselves with assurance that the design-builder is carrying out its responsibility.

Design Review Responsibility

Communicating who is responsible for the design reviews is also essential to the smooth execution of these quality activities. This can be done in various ways, including lists, charts, diagrams, or designating responsibility in contract clauses. Table 2-6 is an example from a Louisiana DOTD DB RFP that provides a good example of how to communicate effectively design review responsibility.

Table 2-6 – Communicating Design Review Responsibilities (Louisiana DOTD 2005).

Stage Of Design Development	Design Check And Certification To Design-Builder	Design Review
Definitive Design	Designer and Design Quality Control Manager	Design Quality Control Manager
Interim Review	Designer and Design Quality Control Manager	Design Quality Control Manager
Readiness for Construction Design	Designer and Design Quality Control Manager	Design Quality Control Manager
Final Design	Designer and Design Quality Control Manager	Design Quality Control Manager
Working Plans and Related Documents	Designer and Design Quality Control Manager	Design Quality Control Manager
As-Built Plans	Designer and Design Quality Control Manager	LA DOTD's designated representative
Major Temporary Components	Designer and Design Quality Control Manager	Design Quality Control Manager
Temporary Components	Designer and Checker	Not applicable

2.5.2 Design Quality Management in CMGC Projects

CMAA commissioned a study in 2005 (Doren et al) to survey owners about their perceptions on how project quality can be improved. The study's top five responses all relate to enhancing the project's quality during design by collaboration between the designer and builder.

- A/E teams [designers] need to be more conscious of the cost to build their designs
- More coordination/collaboration among team members
- Need quality reviews from CMs
- There needs to be a thorough review of the technical design details
- Need to bring contractors, subs, and suppliers on board in the design phase (Doren et al 2005)

The UDOT CMR report confirmed the same notions specifically for design quality. It also indicated agreement from both the design and construction industries in Utah. The report stated:

> The program managers and AGC representatives agree that contractor participation in design minimized risk and improved schedule. Design consultants preferred this method because UDOT controlled the design and innovations selected for the project. This gave them a *greater ability to develop a quality design* (Alder 2007).

Another public agency report on its CMR project found that "[d]esign and peer review of the 30%, 60%, and 90% detail designs are required to ensure quality and constructability" (Kwak and Bushey 2000). This agency points to constructability as a measure that goes hand and hand with quality. Design reviews are an integral part of any design QA program. They ensure the constructability of the project, and they ensure that the design meets the contract requirements (Dunston et al 2002). A survey on the benefits of constructability reported the following responses regarding its impact on a project:

- Minimizes contract change orders and disputes,
- Reduces project cost,
- Enhances project quality,
- Reduces project duration,
- Increases owner satisfaction,
- Enhances partnering and trust among project team (Pocock et al 2006).

2.6 Construction Quality Management Tools

In DBB, STAs make their standard set of specifications for bridges and roads a contract requirement and then use the agency's QM program to assure meeting the standards for construction quality expressed in the construction documents. Since the CMGC contractual structure is virtually the same as DBB, one would expect that there would be no significant change with regard to construction QM and there is no functional reason to make a change if the agency is comfortable with its traditional QM process. Such is the not the case in DB project delivery.

DB project delivery inherently changes the traditional QM roles merely because the design-builder (i.e. the agency's single prime contractor) produces the design and thus writes its own construction quality standards (FHWA 2012). DB project delivery is usually chosen to accelerate project delivery and that aspect in itself creates a greater demand on the QM system to be well defined and be designed to function at a pace of work not often seen in DBB or CMGC projects.

2.6.1 Construction Quality Management in DB Projects

NCHRP Synthesis 376 (Gransberg et al 2008) used a content analysis of DB RFPs to identify trends regarding construction QA and QC functions on DB projects. It specifically sampled four major components of the construction QM process, normally retained by the agency, and identified the change in responsibilities for the following QA and QC activities:

- Performance of submittal, shop and/or working drawing review and approval,
- Performance of routine QC inspections,
- QM testing,
- Nonconforming work (punchlist).

Table 2-7 shows the results of that analysis. With the exception of preparing and verifying the report of nonconforming work, the responsibility for construction QA was delegated to the design-builder. This may because the designer-of-record now works for the design-builder and many of the traditional QA activities are performed by the agency that either completed the design in-house or holds a design contract with a design professional (Gransberg et al 2008). Nevertheless, the table clearly illustrates the shift in quality culture that is demanded by the employment of DB project delivery.

Table 2-7 – NCHRP Synthesis 376, Quality Assurance in Design-Build Projects (Gransberg et al 2008)

DB Construction QM Task	Agency Only	Design-builder Only	Independent Consultant	Combination of 2 or more
Submittal approval	15%	62%	12%	11%
Routine inspection	13%	51%	31%	5%
QM testing	0%	95%	5%	0%
Nonconforming work	64%	32%	0%	4%

The central aspect of construction QM is QC testing. This is also an instance where the NCHRP Synthesis 376 content analysis found that STAs have overwhelmingly given responsibility to the design-builder. In fact, in the 39 projects that specifically mentioned construction QC testing in the DB RFP, the STA did not retain control in any of them. In all but two cases, the design-builder was assigned direct control. In the two exceptions, a third party was required to perform part of the testing. STAs, however, did not give up the right to make further inspections or to perform their own verification and acceptance testing. The following example from an RFP issued by the Mississippi DOT illustrates how they gave the responsibility of construction QC testing to the design-builder while retaining verification and acceptance testing responsibilities.

> "The CONTRACTOR is required to conduct concrete and asphalt sampling and testing in accordance with MDOT Standard Specifications for Road and Bridge Construction ... The CONTRACTOR may elect to conduct other sampling and testing for his own benefit ... [MDOT] or its duly authorized representative may conduct QA inspections, verification sampling and testing for concrete and hot mix asphalt, all other acceptance testing, and independent assurance testing." (MissDOT 2005b)

The Texas DOT utilized an independent consultant in their DB RFP for State Highway 130, a mega-project with its own unique characteristics. Because of the magnitude of the project, TxDOT chose to rely on an independent QA firm. The RFP indicated the independent firm's responsibilities as follows:

> For quality assurance purposes, the department shall provide or contract for, independently of the design-build firm, any inspection services or verification testing services necessary for acceptance of the transportation project. (Koch et al 2010).

The above discussion leads to the conclusion that that the STA must ultimately ensure that the construction QM system *supports rather than constrains project progress.* It can accomplish this by either giving the design-builder full responsibility for construction QM or by inserting an independent quality firm to furnish full-time, on-site resources. In doing so, the STA is ensuring that it has clearly delineated the requirement for QC testing during the course of construction.

2.6.2 Construction Quality Management in CMGC Projects

Establishing construction phase quality management relationships occurs in the procurement phase, nurtured during the design phase, and applied when work begins on the project. Before starting work, the contractor needs to know and understand the roles of the agency's QA personnel as well as the designer's responsibilities during the construction of a CMGC project. "It is also recognized that, because of constrained staffing and budgets, it is not possible for state agencies to 'inspect' quality into the work. Therefore, a procurement process is needed that considers value-related elements in awarding contracts" (Scott et al 2006).

The value found in CMGC is the in-depth knowledge of the design that the constructor gained during the preconstruction when it starts construction. Additionally, the presence of contingencies further ameliorates the motivation to cut corners on quality as a means of recovering financial losses due to contractor or subcontractor error (Trauner 2007). Finally, the issue of remaining competitive for future work with the agency is a strong motivator to achieve the requisite construction quality and satisfy the owner. "CM At-Risk is still largely a position of representing the Owner's interests, and if it is pursued as simply a negotiated general contract it will leave the Owner dissatisfied and the CM without future work" (Strang 2002). NCHRP Synthesis 402 found that 80% of the STAs studied made no changes to their traditional DBB QM system. The ones that did were all delivering projects that were nontraditional STA projects with strong vertical construction content.

The synthesis found four possible entities to which these responsibilities were assigned are shown in table 2-8. The independent consultant is not the same as the designer. The Alaska, Florida, Michigan, and Utah DOTs as well as the Utah Transit Authority and the Memphis Airport all retained consultants to perform construction quality assurance services. The sum of the number of times a given entity was assigned a task is at the bottom and gives an indication of the distribution of construction quality management responsibilities in the case study CMGC projects. The agency and its independent consultant share the most responsibility, then the design consultant and finally the CMGC firm.

The CMGC's assigned roles appear to line up almost with what one would expect to see in a DBB construction QC plan. The only anomalies are one instance of shop drawing review and two instances of verification testing. The shop drawing review occurred in Michigan where the CMGC was required to conduct joint reviews with the designer of certain subcontractor submittals. The CMGC verification testing was done jointly with the agency's staff in the Pinal County project and the Utah Transit Authority assigned this responsibility to the CMGC exclusively. The Utah project put 4% the construction fee at risk on each monthly progress payment (Touran et al 2009). The decision as to how much was awarded was made by a panel and included the evaluation of construction quality performance.

Table 2-8 – Distribution of Construction Quality Management Tasks in Case Study Projects

Construction Quality Management Tasks	Assigned Responsibility*				
	Does not apply	Agency	Designer	CMGC	Independent consultant
Technical review of construction shop drawings	0	1	9	1	6
Technical review of construction material submittals	0	2	7	0	7
Checking of pay quantities	1	4	3	0	6
Routine construction inspection	0	3	3	4	4
Quality control testing	0	0	2	10	1
Establishment of horizontal and vertical control	0	0	3	6	2
Verification testing	0	3	3	2	4
Acceptance testing	0	7	2	0	3
Independent assurance testing/inspection	0	3	3	0	5
Approval of progress payments for construction	0	9	0	0	3
Approval of construction post-award QA/QC plans	0	8	1	0	2
Report of nonconforming work or punchlist.	0	7	1	0	4
Total responses	**1**	**47**	**37**	**23**	**47**
*Can total > 10 as some agencies assign dual responsibility for same QM task.					

2.7 Independent Assurance

The *Glossary of Highway Quality Assurance Terms* (TRB 2005) defines independent assurance (IA) as follows:

> "A management tool that requires a third party, not directly responsible for process control or acceptance, to provide an independent assessment of the product or the reliability of test results, or both, obtained from process control and acceptance. [The results of independent assurance tests are not to be used as a basis of product acceptance.]" (TRB 2005).

The joint Australian/New Zealand Standards Committee (A/NZS 1996) terms the independent assurance process a "configuration audit." That group defines configuration as: "Functional and physical characteristics of a product as defined in technical documents [i.e. the design] and achieved in the product [i.e. constructed facility]. The definition of a configuration audit is "examination [by an independent entity] to determine whether a configuration item conforms to its configuration documents." The operating verbs in this approach are "functional" and "physical." As a result this approach is uniquely qualified to be adapted to alternative project delivery in the US, since DB project by definition are performance-based and CMGC projects furnish the agency an ability to verify/validate the physical constraints of the design before committing to construction.

The A/NZS configuration audit has two parts. First, the auditor completes the "functional configuration audit" by verifying that the project's contractual functional characteristics perform as designed. Secondly, a "formal examination of the 'as-built/produced' configuration" is completed and verifies that physical requirements are met. The one fundamental difference between this definition and the one from TRB is that projects in these two countries often contain a contractual requirement for a configuration audit as part of the project acceptance process. The A/NZS approach externally validates the IQ2M model proposed in Figure 2-5 in the previous section. In fact, it allows the independent assurance aspect of the model to be further defined by adding the functional and physical components to the model as shown in Figure 2-8.

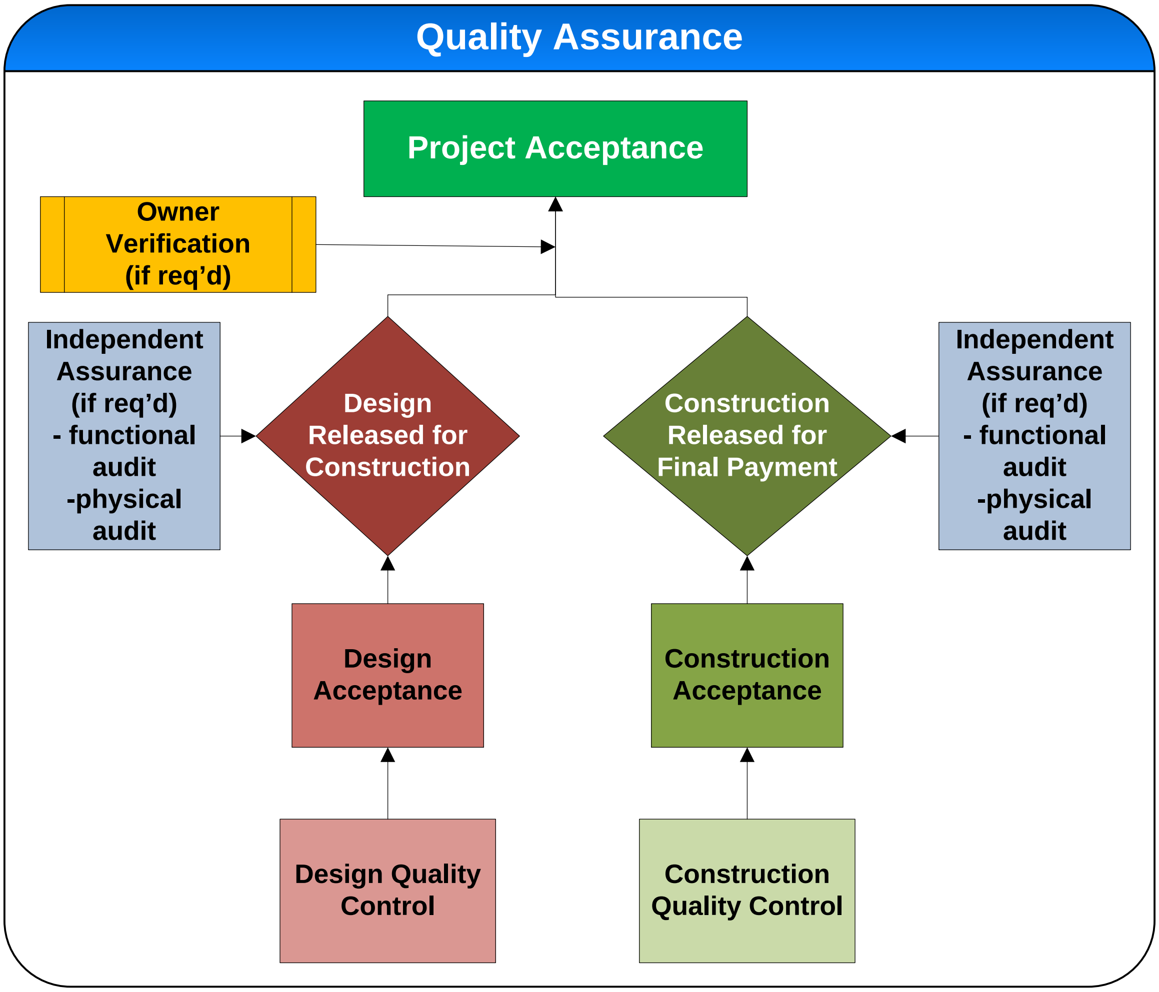

Figure 2-8 – Expanded IQ2M Model to Further Define Independent Assurance Activities

2.7.1 Independent Assurance in DB Projects

The Washington State DOT (WSDOT) provides a comprehensive definition of what it includes for independent assurance in its DB projects. WSDOT includes the following IA activities:

- "Observation of initial qualification, annual re-qualification of sampling and testing procedures for quality verification (QV) testing staff.
- Monthly initially then moving to Quarterly review/audit observations of the qualifications of the Design/Builder's QA testing staff, with Non-conformance issues documented for Design/Builder—WSDOT resolution.

- Monthly initially then moving to Quarterly review/audit observations of verification records of the testing equipment used to perform WSDOT QV and Design/Builder's QA testing activities.
- Initially month by month then moving to Quarterly review/audit observations of the Design/Builder's QA tester training records.
- Practical guidance for specification interpretation and procedural technique for WSDOT QV oversight personnel" (WSDOT 2007).

WSDOT believes that the IA program can be used to "validate the:

- WSDOT QV oversight of the Design-Builder QA sampling and testing processes.
- WSDOT QV sampling and testing processes.
- QA/QV statistical abnormalities ..."(WSDOT 2007).

The WSDOT document states that "this work may include:

- Auditing QA/QV testing records.
- Observing the Design/Builder's QA testing technicians.
- Taking independent split samples with the Design/ Builder on a random basis for verification of Design/Builder's QA testing procedures and equipment.
- Taking independent split samples with the WSDOT on a random basis for verification of WSDOT QV testing procedures and equipment.
- Act as a third party for analysis and recommend resolution of statistical abnormalities between Design/Builder's QA and WSDOT QV." (WSDOT 2007).

The notable feature of the WSDOT IA program for DB projects is the use of audits in much the same manner as the A/NZS configuration audit approach.

2.7.2 Independent Assurance in CMGC Projects

Since the contract structure in CMGC closely matches that of DBB contracts, one would expect that most agencies would feel comfortable using the same approach to CMGC IA activities as they do for DBB projects. NCHRP Synthesis 402 found this to be true for 80% of the case study agencies. It also found that the IA role was assigned to an independent third party consultant in only half the cases. In the others, either agency itself or the designer-of-record was given the responsibility for conducting IA. The Utah Transit Authority connected the quality of on-going construction with its progress payment clause and put 4% the construction fee at risk on each monthly progress payment (Touran et al 2009). The decision as to how much of the at-risk fee was awarded for each monthly pay application was made by a stakeholder panel and included the evaluation of quality performance. Thus, it created a de-facto IA body that essentially validated the QA information produced for each month's construction progress as well as a disincentive for the constructor if it was not diligent in executing the approved QA plan. In nearly 3 years of construction, there was only one month where the CMGC did not receive the full amount of fee, and the panel refunded the penalty amount the next month based on the speed and effectiveness of the corrective actions taken to remedy the problem.

2.8 Validation, Verification and Acceptance Activities

It is important to remember the differences between the three terms to be able to understand how these concepts are applied in DB and CMGC projects. The Glossary of Highway Quality Assurance Terms (TRB 2005) offers the following definitions:

- "Validation - The process of confirming the soundness or effectiveness of a product (such as a model, a program, or specifications) thereby indicating official sanction. [The validation of a product often includes the verification of test results.]
- Verification- The process of determining or testing the truth or accuracy of test results by examining the data and/or providing objective evidence. [Verification sampling and testing may be part of an independent assurance program (to verify contractor QC testing or agency acceptance) or part of an acceptance program (to verify contractor testing used in the agency's acceptance decision).]
- Acceptance - The process of deciding, through inspection, whether to accept or reject a product, including what pay factor to apply" (TRB 2005).

One can see that the three terms are both interrelated and distinct. Essentially the three forms of QM activities compose the tasks for necessary to release the design product for construction and to justify final payment for construction and project acceptance.

2.8.1 Validation, Verification and Acceptance Testing for DB Projects

To support final project acceptance, the responsibility for final inspections as well as any verification or acceptance testing must be determined. The Synthesis 376 content analysis looked to see who was responsible for the verification and acceptance testing. As with the report of nonconforming work, STAs have generally retained this quality function. In fact, of the 40 projects that listed who was responsible for verification and acceptance testing, 88% assigned the responsibility to the STA. Another 5% required an independent firm that worked directly for the STA to accomplish this. Interestingly, three RFPs assigned this responsibility to the design-builder. The synthesis survey responses support these findings by indicating that 88% of the time the STA or a third party hired by the STA performs verification and acceptance testing while the design-builder is responsible only 12% of the time. While the majority of the states retained the verification and acceptance testing responsibilities, this does not mean that they will perform the actual tests with their own forces. Some STAs indicated in the RFP that the STA reserved the right to appoint a representative to perform the tests (see the example from the Florida DOT below). Standard RFP clauses are represented below.

- Arizona: The design-build firm shall be responsible for the quality of the construction and materials incorporated into the project and is responsible for most QC actions. The Department has the responsibility of determining the acceptability of the construction and the materials incorporated into the project. The Department will use the results of the firm's inspection, sampling and testing, and the Department's surveillance inspection, and verification sampling and testing to determine the acceptability of completed work items and for final project acceptance. Verification Sampling and Testing will be performed by the Department to validate Design-builder Sampling and Testing as well as the quality of the material produced. (Arizona DOT 1997)

- Florida: The Department or Department's representative will perform independent assurance, verification and resolution testing services in accordance with the latest Specifications. The Design-Build Firm will provide quality control testing in accordance with the latest Specifications. (FDOT 2003)
- Minnesota: The Department, through its owner quality assurance (QA), will have the primary responsibility for verification of the quality of both the design and construction work. The Department reserves the right to conduct inspection, sampling, testing, and evaluation associated with QA and IA [independent assurance]. (MnDOT 2002)
- Mississippi: [Mississippi DOT] or its duly authorized representative may conduct QA inspections, verification sampling and testing for concrete and hot mix asphalt, all other acceptance testing, and independent assurance testing. (MissDOT 2005a)
- Utah: The Department will be responsible for construction QA. The Department will perform the same inspections and tests it performs on a standard design-bid-build project. (UDOT 2005)

In three of the Synthesis 376 case study projects, the design-builder was made responsible for the verification and acceptance testing. One of these, the RFP for the Eastern Transportation Corridor in California, was for a toll collection and revenue management system where the verification and acceptance testing was based on a 60-day trial period after completion. For projects involving highway construction, however, the two projects that used design-builder verification and acceptance testing were a mega-project, the Colorado South East Corridor (SEC) Multi-Modal Project, and a major urban interstate makeover, I-64 in Missouri. Excerpts from the RFP are given for both projects.

- Colorado: In cases where inspections are to serve as the basis for compliance verification, the Contractor shall prepare detailed inspection procedures and submit these to the SEC Representative for review. The Contractor shall conduct each inspection in accordance with the inspection procedures reviewed by the SEC Representative; no inspection shall be performed prior to obtaining the SEC Representative review of such inspection procedures. The Contractor in a suitable inspection report clearly showing if the inspection passed or failed based on the "pass/fail criteria" established in the procedure, shall document the results. (CDOT 2000 italics added)
- Missouri: The following quality planning aspects shall be included in the Quality Manual…the Quality Assurance staff position responsible to perform the verification responsibilities including inspection, checking and testing…the method of performing Quality Assurance verification responsibilities including inspection, checking and testing. (MoDOT 2006 italics added)

In another mega-project, the San Joaquin Hills Transportation Corridor, an independent firm was to be retained for the acceptance and assurance responsibilities. The RFP states:

> The Construction Engineering Manager [employed by an independent firm] shall be responsible for coordinating and directing all Acceptance and Assurance inspections, sampling and testing to he conducted hereunder. (San Joaquin Hills 1991)

Finally, in Utah's I-15 mega-project, UDOT specifically listed a third party specifically to assist in fulfilling verification and acceptance testing responsibilities. (UDOT 1997)

2.8.2 Validation, Verification and Acceptance Testing for CMGC Projects

Once again, the typical CMGC project's validation, verification and acceptance testing program would not vary much from that found in typical QM in DBB projects. In Synthesis 402, only two of 10 case study projects assigned the role of verification testing to the CMGC and none released control of acceptance testing. In about half the cases, the agency retained an independent consultant to conduct validation, verification and acceptance tests. A concern found in the literature was that the faster pace of CMGC projects would create an environment where validation, verification and acceptance test results might be compromised and hence the quality of the ultimate project would suffer. NCHRP Synthesis 379 (Anderson and Damnjanovic 2008) evaluated the potential for and impact of alternative construction method to accelerate completion. The authors found that quality was not reported to be degraded by the use of nontraditional contracting methods such as CMR and also made this observation:

> "The majority of respondents stated that quality was the same for the contracting methods evaluated as compared with typical projects. This result seems to counter the perception that accelerating project completion negatively impacts quality, which was cited as a perceived disadvantage for some contracting methods." (Anderson and Damnjanovic 2008)

2.9 Benchmarking Survey

2.9.1 Purpose

The purpose of this survey was to define the state-of-the-practice with regard to the use of alternative quality management systems. The survey was designed not only to benchmark STA practices on projects delivered using alternative project delivery methods, such as CMGC, DB, and PPP, but also to uncover alternative quality management systems that are in use on traditional DBB projects. The survey questionnaire was prepared based on the principles prescribed by Oppenheim (1992) for survey questionnaire design. The survey contained the following four sections (See Appendix B for survey details):

1. General Information: This section captured the data necessary to identify the agency and quantify its experience with alternative QM systems.
2. Agency Quality Management Policy/Procedures Information: This section sought to identify the responding agency's approach to QM is the following phases of the project life cycle:
    a. Procurement phase: Actions taken regarding the quality management process that are reflected in the agency's contractor prequalification requirements and/or

solicitation documentation such as in the Invitation to Bid (IFB), Request for Qualifications (RFQ) and the Request for Proposals (RFP).

b. Design Phase (in-house): Actions taken after approval to start design work regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements. ***OR***

c. Design Phase (out-source): Actions taken after design contract award regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements.

d. Construction Phase: Actions taken after contract award regarding the quality of the final constructed product to ensure that it complies with both the completed design and other contractual requirements.

3. Quality Management Planning: This section for information regarding how the agency planned QM operations on typical projects.
4. Quality Management Program Effectiveness: This section asked the respondents cogent questions regarding the effectiveness of the agency's QM program in a variety of typical situations.

2.9.2 Survey General Information Results

The survey drew 22 responses from 19 states. Figure 2-9 shows the respondents, which also shows each state's experience with various project delivery methods. The map shows that the responses were not only from a cross-section of STAs but also from a group with varied experience with alternative project delivery methods. One fact that was important to the analysis of survey responses was the amount of experience each respondent had with various project delivery methods. Table 2-9 shows the results for this question. Since the roles and responsibilities for various QM tasks are often assigned based on type of project delivery method (Gransberg et al 2008) and research has documented a learning curve as public owners become familiar with a new project delivery method (Gransberg and Molenaar 2004), it is important to analyze the survey responses in light of the context of a given agency's experience with a specific project delivery method.

Since DB is the most often used alternate project delivery method, the population was split into those with greater than 5 years of experience with DB and those with less than 5 years of experience. The idea that since DB requires an owner to delegate design and construction QM tasks to the design-builder, STAs with significant DB experience will have developed an approach to QM based on lessons learned that might be different than the ones used by STAs that are new to alternative project delivery and STAs with only DBB experience (Ernzen and Feeney 2002).

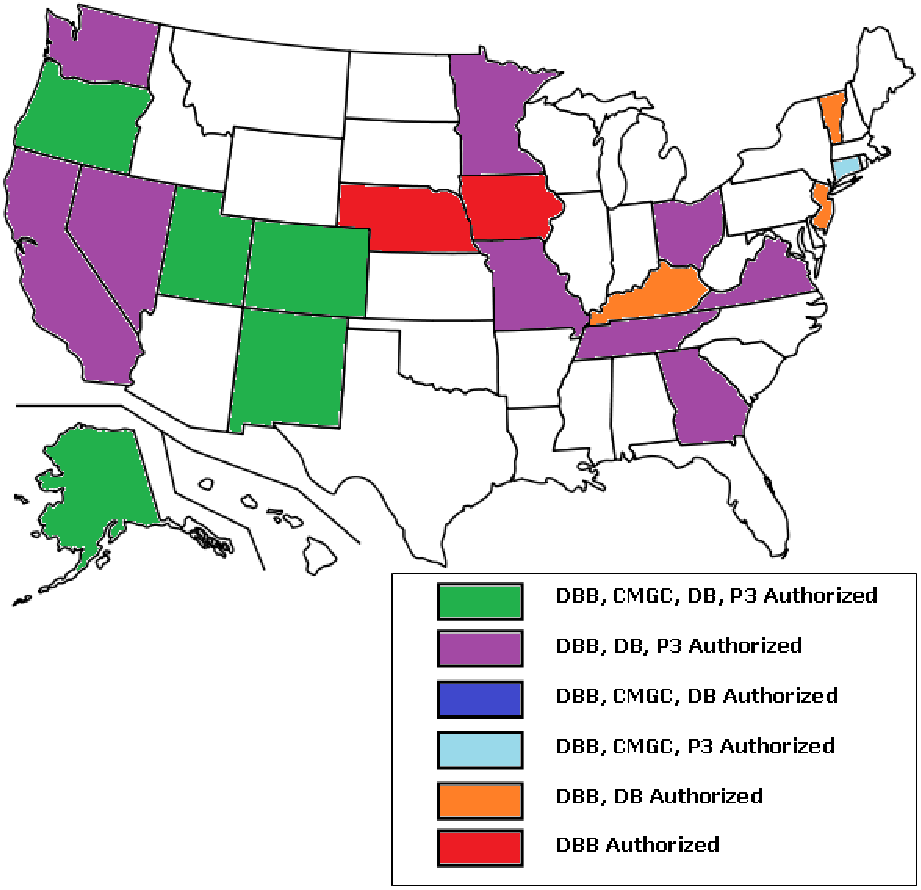

Figure 2-9 – Survey Responses

Table 2-9 – Survey Respondents' Experience with Each Project Delivery Method

Project Delivery Method	**Years of Experience with Given Project Delivery Method**		
	1-5	6-10	>10
DBB	0	0	22 All
CMGC	4	1	0
	AK; CO; CT; OR	UT	-
DB	5	3	9
	CA; MO; NV; TN; VT	AK; KY; NM	CO; GA; MN; NJ; OH; OR; UT; VA; WA
PPP	9	1	2
	AK; CO; GA; MN; MO; NV; OH; OR; TN	UT	CA; VA

To ensure that Table 2-9 is not misinterpreted, it should be noted that based on the wording of the survey question, a state with authorization to use a given project delivery method but no experience would be forced to answer "1-5 years." Tennessee is an example of an agency with the authority to use PPP but with no actual project experience. Additionally, the questionnaire instruction directed a state that has not completed a project using a given method but has one or more projects under development to also answer "1-5 years." California is an example of this having only received DB authority within the past two years. In spite of these two special cases, the impact on the survey analysis is nil since the two subpopulations were split between those with five or less years of DB experience and those with more.

Respondents were also asked to differentiate alternative project delivery authority between authority for only pilot projects or only specific project types (i.e. PPP only allowed for tolling projects) and general authority to use the given methods without constraint. Table 2-10 shows the results of that query.

Table 2-10 – Legislative Authority for Alternative Project Delivery Use

Project Delivery Method	Pilot/Specific Projects Only	General Authorization
DBB	0	22
CMGC	4	1
DB	7	10
PPP	7	5

2.9.3 Agency Quality Management Policy/Procedures Information

The survey sought to identify the state-of-the-practice regarding agency QM policy and procedures for all project delivery methods. Alternative project delivery methods require the alteration of QM policies and procedures used in DBB and thus are inherently classified as alternative QM systems (Arditi and Lee 2004; Blanding 2006; Drennon 1998; Lee 2008; Scheepbouwer 2010; VDOT 2006; Yuan et al 2007). However, the survey and literature review found alternative QM systems, such as contractor acceptance testing, in use of DBB as well (Hughes 2005; Turochy et al 2007; Qaasim 2005; Parker and Turochy 2006; Miron et al 2008).

Since QM is a concept that permeates the entire project's life cycle, the survey attempts to differentiate QM policies and procedures by project phase: procurement, design, and construction. "The design phase . . . is the phase where the ultimate quality of the constructed facility is quantified through the production of construction documents . . . the point of the project where quality is defined . . . it is imperative that the design quality management responsibilities be clearly defined in the [procurement phase] solicitation documents" (Gransberg et al. 2008).

Hence, CMGC, DB, and PPP project delivery requires adjusting the linear QM approach commonly used in DBB and sometimes called the "catch and punish method," (Postma et al 2002; Koch et al 2010) where the management of project quality is transferred at the end of each phase. This notion gains confirmation through the survey results shown in Figure 2-10. Two-thirds of the respondents retain traditional QA roles in DBB and CMGC, the two methods where the owner retains control of the design (Koch et al 2010). Whereas, 75% of the respondents outsource QA on PPP projects and 71% do not retain traditional QA roles on DB projects. Also, one-third of the respondents delegate traditional QA tasks to the contractor on CMGC projects, which corresponds to the FHWA policy shown in Figure 2-2.

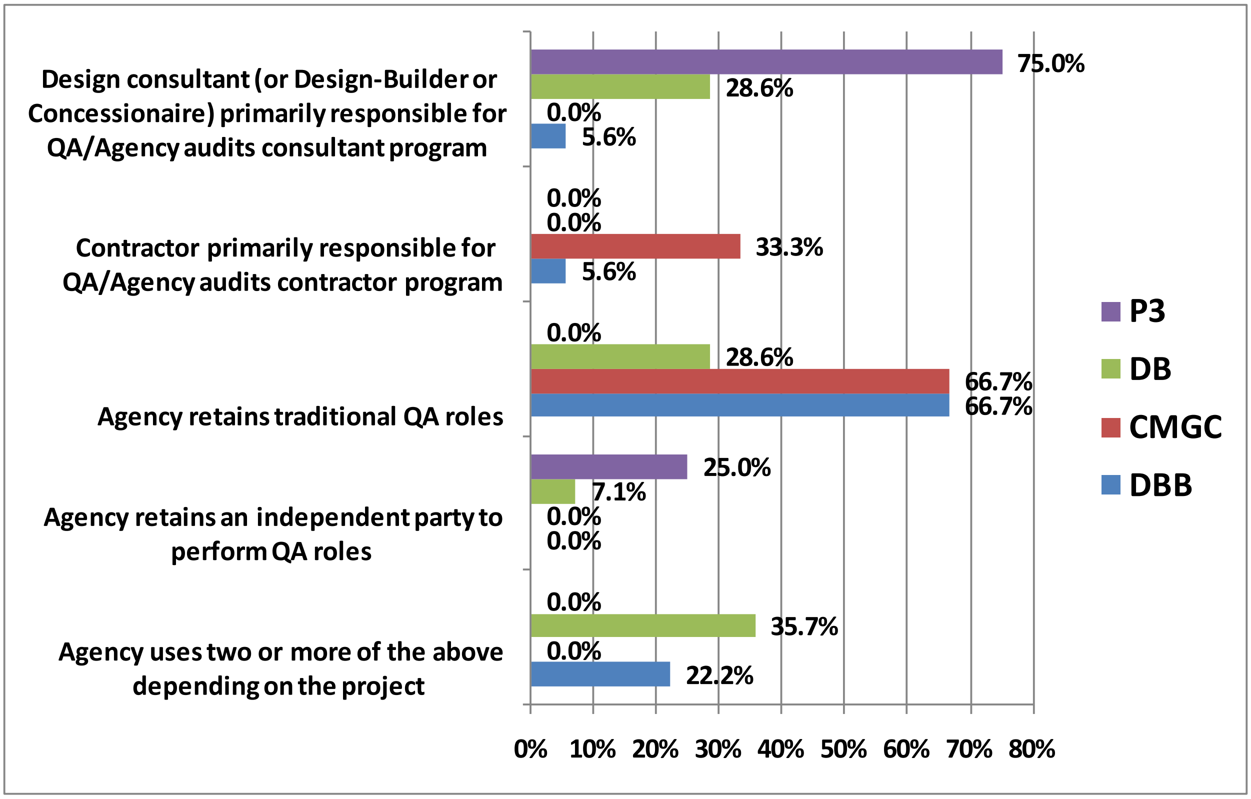

Figure 2-10 – Agency Quality Management Approaches by Project Delivery Method

Finally, the survey asked if the QM system used on projects delivered using alternative methods was different than the one used for DBB projects and 64% responded that they were the same. Based on the responses shown in Figure 2-10, this is inferred to mean that the agency's QM policy does not change.

2.9.3.1 Procurement Phase Agency Quality Management Policies

NCHRP Synthesis 402 (Gransberg and Shane 2010 italics added) states: "Construction phase quality management relationships are *established in the procurement phase*, nurtured during the design phase, and applied when work begins on the project." As such, articulation of agency policies regarding QM requirements occurs before any work actually begins or any design or construction product is produced. Put another way: "It is also recognized that, because of constrained staffing and budgets, it is not possible for state agencies to 'inspect' quality into the work. Therefore, a *procurement process is needed that considers value-related elements* in awarding contracts" (Scott et al. 2006 italics added). The survey sought to identify procurement policies that related to QM systems for each project delivery method.

The first procurement phase decision deals with whether to complete the design or to procure a design consultant. Table 2-11 shows the survey responses regarding the amount of outsourced design completed by each respondent. The response ranged from a low of 10% in California to a high of 90% in Utah. The relative percentage of outsourced design is important to design quality because it creates an enforceable contractual relationship between the STA and the design consultant. It also permits the STA to require certain specific design personnel qualifications and experience requirements that impact design quality.

Table 2-11 – Level of Design Outsourcing Survey Responses

Percent of Design Program that is Outsourced	State
0-20%	CA, MO, NV, OR
21-50%	AK, CO,MN, NE,NM, OH, VT, WA
51-70%	NJ, VA
>71%	CT,GA, KY, UT

While in-house designs are in no way inferior to those completed by design consultants, STA project managers have less control over work assigned to agency design professionals (Alder 2007). Additionally, a STA's internal design staff is a fixed entity with regard to professional qualifications and past experience, increasing the possibility that the design will be completed by a design professional with little experience in a given project. An analysis of the responses from those STAs that outsourced design percentages of >20%, >30%, and >40% versus the respondents that fell below those thresholds was conducted to determine if there were discernible differences in QM approaches was conducted as the amount of outsourced design increased. No trends were identified, which leads to the conclusion that quality is not affected by whether or not the project's design is outsourced.

The procurement phase furnishes the owner an opportunity to influence the "quality" of project design and construction personnel by establish criteria for individual qualifications and corporate experience with specific types of projects. Table 2-12 details the response to a survey question that asked respondents to articulate the content of their project solicitation documents. In DBB and CMGC projects, the solicitation documents included RFQs for the designer. For the reason discussed in the previous paragraph, it is unrealistic to sample projects that are designed in-house since there are no solicitation documents to procure the design services. The table ranked ordered the possible responses from the most used to the least used. The table shows that factors that related to design quality were more often cited than those related to construction quality. In fact, all the responses that had more positive than negative answers were design quality related. This indicates a shift in perspective from the results of earlier studies that found that design quality was rarely mentioned in DB solicitation documents (Gransberg and Windel 2008; Gransberg et al 2008).

Table 2-12 – Procurement Solicitation Document Content

Do your project advertising/ solicitation documents contain the following?	Required proposal/bid package submittal? (of 18 responses)		If YES: Is it evaluated to make the award decision?		If NO: Is it a required submittal after contract award?	
	Yes	No	Yes	No	Yes	No
Qualifications of the Design Quality Manager	14	4	10	4	0	4
Qualifications of other Quality Management Personnel	12	6	8	4	3	3
Design quality management plan	11	7	11	0	3	4
Design quality assurance plan	11	7	11	0	2	5
Design quality control plan	11	7	10	1	3	4
Qualifications of the Construction Quality Manager	8	10	6	2	2	8
Quality management roles and responsibilities	8	10	6	2	3	7
Construction quality management plan	7	11	5	2	6	5
Construction quality assurance plan	6	12	5	1	4	8
Construction quality control plan	6	12	5	1	7	5
Construction testing matrix	5	13	1	4	2	11
Design criteria checklists	4	14	0	4	6	8
Quality-based incentive/ disincentive features	4	14	1	3	0	14
Warranties	2	16	0	2	1	15
Optional warranties	0	18	0	0	2	16

Table 2-13 contains a comparison of those STAs with less than five years of experience with alternative project delivery methods and those with more than that amount of experience. The table breaks the various solicitation factors into three categories:

1. Qualifications of Key Personnel
2. QM Plans
3. Contract Content

The difference between the two subpopulations is striking. The experienced respondents' solicitation documents contain more criteria than the less experienced agencies in all but one category, qualifications of other QM personnel. There is also a clear trend to more heavily emphasize QM planning during the procurement phase and inclusion of contractual constraints, incentives, and warranties. In addition, the experienced group emphasizes design QM more heavily than construction QM in their solicitation documents, which confirms the notion that ultimate project quality is defined the construction documents prepared in the design phase. This leads to the conclusion that QM starts in the procurement phase and that important QM issues can successfully be addressed through the evaluation of competing design and construction proposals before awarding a DBB design contract, a CMGC preconstruction contract, or DB contract. It also lends weight to the conclusion that experienced STAs use the procurement phase as a tool to articulate project quality requirements and constraints.

Table 2-13 – Comparison of Inexperienced Respondents with Experienced Respondents

Do your project advertising/ solicitation documents contain the following	**<5yrs exp** (% of subpopulation)	**>5yrs exp** (% of subpopulation)
Qualifications of Key Personnel		
Qualifications of the Design Quality Manager	75%	82%
Qualifications of the Construction Quality Manager	20%	55%
Qualifications of other Quality Management Personnel	75%	55%
QM Plans		
Design quality management plan	25%	73%
Design quality assurance plan	25%	73%
Design quality control plan	25%	73%
Construction quality management plan	20%	45%
Construction quality assurance plan	0%	45%
Construction quality control plan	0%	45%
Quality management roles and responsibilities	25%	55%
Contract Content		
Design criteria checklists	0%	18%
Construction testing matrix	0%	36%
Quality-based incentive/disincentive features	0%	27%
Warranties	0%	18%
Optional warranties	0%	0%

2.9.3.2 Design Phase Agency Quality Management Policies

Defining the construction quality requirements takes place during the design phase. As a result, agency QM policies and procedures during the design phase create the environment in which the design is delivered and ultimately accepted by the STA. Central to the process of alternative project delivery is the definition and assignment of responsibilities for the suite of QM tasks that must be accomplished before the final design is released for construction (Gonderinger 2001; Arditi and Lee 2008; Pantazides 2005; Yakowenko 2010; Yuan et al 2007). To assess the state-of-the-practice in this phase, the survey asked a number of specific questions including the STAs' policies for distribution of QM roles and responsibilities on project delivered using alternative quality systems. Table 2-14 and table 2-15 contain the output from that portion of the survey showing the total population and the two subpopulations.

Table 2-14 – Design Phase QM Responsibilities for Design Process

Who performs the following design quality management tasks?	RANK	%	RANK	%	RANK	%
Technical review of design deliverables	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	64%	1	60%	1	77%
Agency project management staff	3	41%	2	40%	3	46%
Project design consultant	2	50%	2	40%	2	69%
Independent quality consultant	4	32%	5	20%	4	38%
Project constr. staff in CMGC, DB, PPP	6	14%	6	0%	5	23%
Other	5	18%	2	40%	6	15%
Checking of design calculations	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	50%	1	40%	2	62%
Agency project management staff	3	14%	3	0%	4	15%
Project design consultant	2	45%	2	20%	1	69%
Independent quality consultant	3	14%	3	0%	3	23%
Project constr. staff in CMGC, DB, PPP	5	9%	3	0%	4	15%
Other	5	9%	3	0%	4	15%
Checking of quantities	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	59%	1	60%	1	62%
Agency project management staff	4	14%	3	0%	4	23%
Project design consultant	2	45%	2	20%	1	62%
Independent quality consultant	3	23%	3	0%	3	31%
Project constr. staff in CMGC, DB, PPP	6	9%	3	0%	5	15%
Other	4	14%	3	0%	5	15%
Acceptance of design deliverables	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	64%	1	40%	1	85%
Agency project management staff	2	36%	2	20%	2	46%
Project design consultant	3	14%	3	0%	3	23%
Independent quality consultant	5	5%	3	0%	5	8%
Project constr. staff in CMGC, DB, PPP	5	5%	3	0%	5	8%
Other	4	9%	3	0%	4	15%
Review of specifications	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	68%	1	60%	1	85%
Agency project management staff	2	55%	2	40%	2	69%
Project design consultant	4	32%	4	20%	3	46%
Independent quality consultant	3	41%	4	20%	3	46%
Project constr. staff in CMGC, DB, PPP	6	5%	6	0%	6	8%
Other	5	23%	2	40%	5	15%
NOTE: The percentages will not add to 100% because respondents were permitted to check all that applied. So if the agency design staff and a consultant shared a responsibility it would checked twice. Hence the important data is the ranking for each category.						

Table 2-15 – Design Phase QM Responsibilities for Design Close-out

Who performs the following design quality management tasks?	**RANK**	**%**	**RANK**	**%**	**RANK**	**%**
Approval of final construction documents	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	55%	1	40%	1	69%
Agency project management staff	2	45%	2	20%	2	62%
Project design consultant	5	5%	3	0%	5	8%
Independent quality consultant	3	14%	3	0%	3	23%
Project constr. staff in CMGC, DB, PPP	6	0%	3	0%	6	0%
Other	4	9%	3	0%	4	15%
Approval of payments for design progress	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	2	32%	1	40%	2	31%
Agency project management staff	1	59%	1	40%	1	77%
Project design consultant	4	0%	2	0%	4	0%
Independent quality consultant	3	14%	2	0%	3	23%
Project constr. staff in CMGC, DB, PPP	4	0%	2	0%	4	0%
Other	4	0%	2	0%	4	0%
Approval of post-award design QM/QA/QC plans	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	2	27%	1	20%	2	38%
Agency project management staff	1	41%	1	20%	1	62%
Project design consultant	4	5%	2	0%	4	8%
Independent quality consultant	3	23%	2	0%	3	31%
Project constr. staff in CMGC, DB, PPP	4	5%	2	0%	4	8%
Other	4	5%	2	0%	6	0%
NOTE: The percentages will not add to 100% because respondents were permitted to check all that applied. So if the agency design staff and a consultant shared a responsibility it would checked twice. Hence the important data is the ranking for each category.						

Looking at the rankings in Table 2-14 and table 2-15, STAs retain the responsibility for design QM in most instances. The agency staff is ranked either first or second in every category of design QM task except checking quantities. There is also no difference in the assigned responsibilities between the experienced and inexperienced agencies. This leads to the conclusion that design QM is the primary responsibility of the owner regardless of project delivery method.

2.9.3.3 Construction Phase Agency Quality Management Policies

Construction QM is “a domain once strictly held by the agency… [the] combination of increased pressure to perform faster along with decreased numbers of personnel and an increased dependence on outsourcing of the quality function has some in the transportation community concerned” (Ernzen and Feeney 2002). Table 2-16 and table 2-17 portray the responses to survey questions regarding construction phase QM roles and responsibilities.

Table 2-16 – Construction Phase QM Responsibilities for Routine QM Tasks

Who performs the following construction quality management tasks?	RANK	%	RANK	%	RANK	%
Technical review of construction shop drawings	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	1	59%	1	60%	1	54%
Agency project management staff	3	36%	2	40%	4	38%
Project design consultant	2	45%	2	40%	3	46%
Independent quality consultant	4	32%	4	0%	1	54%
Project constr. staff in CMGC, DB, PPP	5	9%	4	0%	5	15%
Other	6	5%	4	0%	6	8%
Technical review of construction material submittals	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	3	32%	1	40%	3	31%
Agency project management staff	1	45%	1	40%	2	46%
Project design consultant	3	32%	1	40%	3	31%
Independent quality consultant	1	45%	5	0%	1	62%
Project constr. staff in CMGC, DB, PPP	6	9%	5	0%	5	15%
Other	5	18%	4	20%	5	15%
Checking of pay quantities	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	5	5%	3	20%	5	0%
Agency project management staff	2	50%	1	60%	2	46%
Project design consultant	6	0%	5	0%	5	0%
Independent quality consultant	1	55%	3	20%	1	62%
Project constr. staff in CMGC, DB, PPP	4	9%	5	0%	3	8%
Other	3	18%	2	40%	3	8%
Routine construction inspection	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	5	9%	3	20%	6	0%
Agency project management staff	2	45%	1	60%	2	38%
Project design consultant	5	9%	3	20%	5	8%
Independent quality consultant	1	55%	3	20%	1	62%
Project constr. staff in CMGC, DB, PPP	3	23%	6	0%	3	23%
Other	3	23%	2	40%	4	15%
Quality control testing	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	6	0%	4	0%	6	0%
Agency project management staff	3	23%	2	20%	3	23%
Project design consultant	5	5%	4	0%	5	8%
Independent quality consultant	1	55%	4	0%	2	31%
Project constr. staff in CMGC, DB, PPP	4	14%	4	0%	4	15%
Other	2	41%	1	40%	1	46%
NOTE: The percentages will not add to 100% because respondents were permitted to check all that applied..						

Table 2-17 – Construction Phase QM Responsibilities for Acceptance and Close-out

Who performs the following construction quality management tasks?	RANK	%	RANK	%	RANK	%
Verification testing	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	3	18%	2	20%	6	8%
Agency project management staff	1	41%	1	40%	2	38%
Project design consultant	5	9%	2	20%	5	8%
Independent quality consultant	1	41%	5	0%	1	46%
Project constr. staff in CMGC, DB, PPP	5	9%	5	0%	3	15%
Other	3	18%	2	20%	3	15%
Acceptance testing	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	4	18%	3	20%	5	8%
Agency project management staff	1	41%	1	40%	2	38%
Project design consultant	6	9%	3	20%	5	8%
Independent quality consultant	1	41%	5	0%	1	46%
Project constr. staff in CMGC, DB, PPP	4	18%	5	0%	3	23%
Other	3	23%	1	40%	4	15%
Approval of progress payments for construction progress	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	5	5%	3	20%	5	0%
Agency project management staff	1	59%	1	80%	1	54%
Project design consultant	6	0%	4	0%	5	0%
Independent quality consultant	2	45%	4	0%	2	46%
Project constr. staff in CMGC, DB, PPP	4	14%	4	0%	3	15%
Other	3	18%	2	40%	4	8%
Approval of construction post-award QM/QA/QC plans	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	3	23%	3	0%	2	31%
Agency project management staff	1	45%	1	60%	1	46%
Project design consultant	5	9%	3	0%	4	15%
Independent quality consultant	2	32%	3	0%	2	31%
Project constr. staff in CMGC, DB, PPP	6	0%	3	0%	6	0%
Other	4	18%	2	20%	4	15%
Report of nonconforming work or punchlist	**Total**		**<5yrs exp**		**>5yrs exp**	
Agency design staff	4	9%	2	20%	4	8%
Agency project management staff	2	50%	1	60%	2	46%
Project design consultant	4	9%	2	20%	4	8%
Independent quality consultant	1	55%	5	0%	1	62%
Project constr. staff in CMGC, DB, PPP	4	9%	5	0%	3	15%
Other	3	14%	2	20%	4	8%
NOTE: The percentages will not add to 100% because respondents were permitted to check all that applied.						

A glance at table 2-16 and table 2-17 confirms the assertion made by Ernzen and Feeney (2002) with regard to “increased dependence on outsourcing of the quality function.” The majority of the experienced agencies delegated the construction QM authority to an independent quality consultant for every QM task, achieving a rank of either first or second for all possible categories. There is also greater disparity between the experienced and inexperienced agencies in construction QM than there was in design QM. The rankings show inexperienced agencies retain the construction QM responsibility in most instances. The lone exception is QC testing, where most experienced and inexperienced agencies selected “other” as their answer. The explanation for all other responses indicated that the construction contractor was assigned this responsibility and is consistent with the FHWA policy shown in Figure 2-3.

The difference between the two subpopulations in the construction QM area infers that the experienced agencies advanced on the alternate QM system learning curve and are successfully outsourcing traditional construction QM responsibility to an independent quality consultant. Federal Regulation 23 CFR 637.207(b) mandates agency oversight (sometimes termed “due diligence”) of QM on federal-aid highway projects. The experienced agencies have satisfied this requirement by augmenting the STA personnel with consultants that specialize in QM. The Arizona DOT is one of these experienced agencies and a case study of a major urban freeway construction project found the following:

> “The reconstruction of Interstate 17 in Phoenix, Arizona, used two innovative concepts: design–build and a contractor-led quality management program… [the study found that] though the material quality is marginally higher with traditional design–bid–build contracting and agency controlled QA, the differences are very small and the results are very encouraging for other state highway agencies that are considering moving in this direction and that are concerned about project quality” (Ernzen and Feeney 2002).

The survey also asked for information regarding the use of contractor QA test results. Figure 2-11 shows the output. Of the agencies that indicated the use of contractor tests, only one was an inexperienced agency. The major difference between DBB and the various alternative project delivery methods is the ability to select the constructor on a basis of qualifications rather than on a low bid. Adding qualifications to the award method apparently permits the experienced agencies to select contractors to whom they are willing to delegate QA acceptance testing. This may be necessary to achieve the aggressive schedules that justify the implementation of alternative project delivery. This notion is confirmed by the Arizona DOT I-17 DB project where “[d]espite the constraints of working on one of the most heavily traveled roads in the state, the design–build team… completed the project in 30% less time than Arizona DOT had originally estimated” (Ernzen and Feeney 2002).

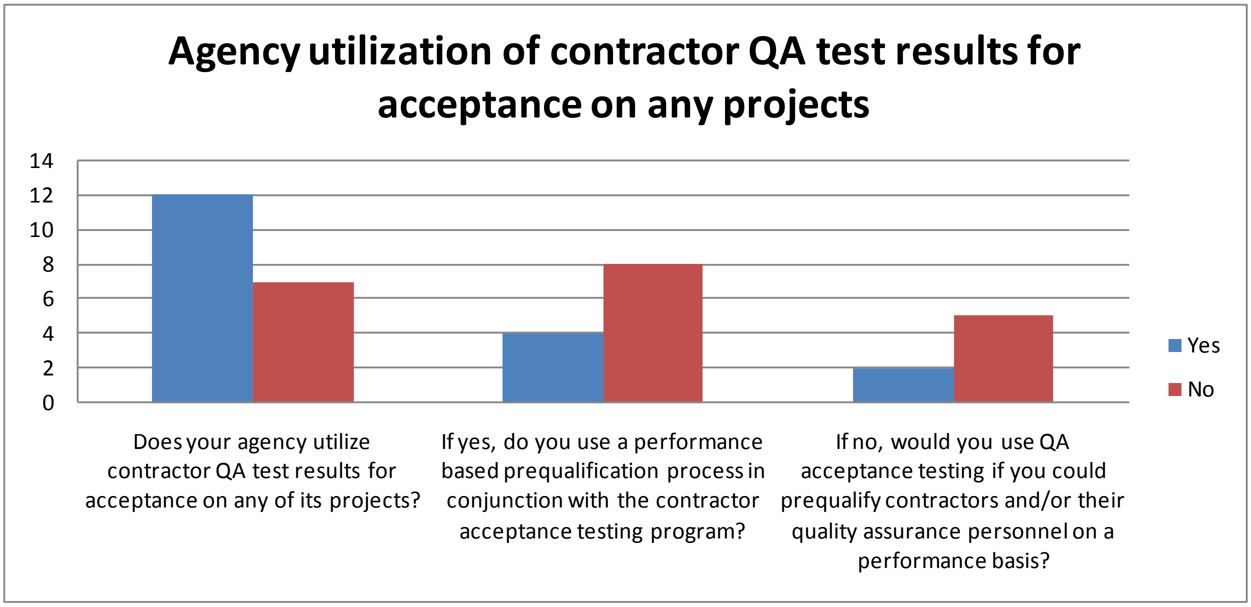

Figure 2-11 – Contractor QA Test Usage

2.9.4 Quality Management Planning

QM planning spans the entire life cycle of the transportation project. Ensuring that the requirements for alternative design and construction QM systems are clearly defined is critical to their successful execution (Gransberg and Windel 2008). The survey specifically sought to determine how prescriptive the responding STAs were in the alternative QM planning process. Table 2-18 illustrates the output from a series of questions regarding this specific topic. The responses were aggregated using a weighted average technique so that they could be ranked. The two highest ranked QM plan elements are very prescriptive with all agencies mandating the use of standard specifications and design details. This permits greater agency control over the final design.

Research has found that the loss of control over the details of design is a major barrier to the implementation of alternative project delivery methods (Smith 2001; Lee 2008; Gransberg and Molenaar 2008; Scheepbouwer 2010; Touran et al 2010). The next highest ranked elements are procedures that allow the STA to customize its design and construction QM planning based on the requirements of a given projects. When combing the flexibility of the third ranked elements with prescription of the first two, one finds that agencies that utilize alternate QM systems are able to control design quality issues by mandating tried and true details and specifications while allowing their contractors the flexibility needed to achieve aggressive project delivery schedules with minimal agency interference.

The Minnesota DOT, an experienced agency, is a typical example of this prescriptive yet flexible approach to alternative QM. Minnesota is one of the agencies that requires no formal design reviews. Its DB design QM policy is synopsized as follows: "The Department will participate in oversight reviews and reviews of early construction as part of its due diligence responsibilities" (MnDOT 2001a). It also uses an innovative process to control design details by meeting with each competing design-builder before proposals are due to confidentially and individually approve alternative technical concepts as well as lock down the content of the design before awarding the contract (MnDOT 2010). The ability to influence design decisions before award then allows MnDOT to be flexible during design and construction and minimize its potential interference with progress while satisfying its statutory obligations under 23 CFR 637.207(b).

Table 2-18 – Quality Management Plan Components.

Elements of the QM Plan	Always	Some-times	Never	Weighted Average	Rank
Agency mandate the use of standard agency specifications?	14	4	0	16.67	1
Agency mandate the use of standard agency design details?	10	5	0	13.33	2
Construction QM plans used on CMGC/DB/PPP projects significantly different from the QM plans used on traditional DBB construction projects?	5	8	6	12.33	3
Design QM plans used on CMGC/DB/PPP projects different from the QM plans used on traditional design projects?	4	10	5	12.33	3
Agency mandate the use of standard agency construction means and/or methods?	3	11	3	11.33	5
Agency mandate the use of its own standard QM plans?	6	5	4	10.67	6
Agency specify what must be included in the CMGC/DB/PPP QM plans?	6	4	3	9.67	7
Agency mandate a specific set of qualifications for the QM staff of design consultants and construction contractors in DBB projects?	3	7	5	9.33	8
Agency mandate a specific set of qualifications for the design-builder/PPP concessionaire's design QM staff?	4	5	2	8.00	9
Agency mandate a specific set of qualifications for the design-builder/PPP concessionaire's construction QM staff?	3	6	1	7.33	10
Agency mandate a specific set of qualifications for the QM staff of design consultants and construction contractors in CMGC projects?	1	2	7	4.67	11

2.9.5 Quality Management Program Effectiveness

The final topic covered in the survey was the effectiveness of alternative QM systems. The survey asked the respondents to rate the impact on quality of a number of different factors found in the literature (Gransberg et al 2008) to identify trends between the two subpopulations regarding perceived effectiveness of those factors. The factors are organized from least to most impact based on the inexperienced agency responses. A glance at Figure 2-12 confirms that there are indeed differences in the two groups.

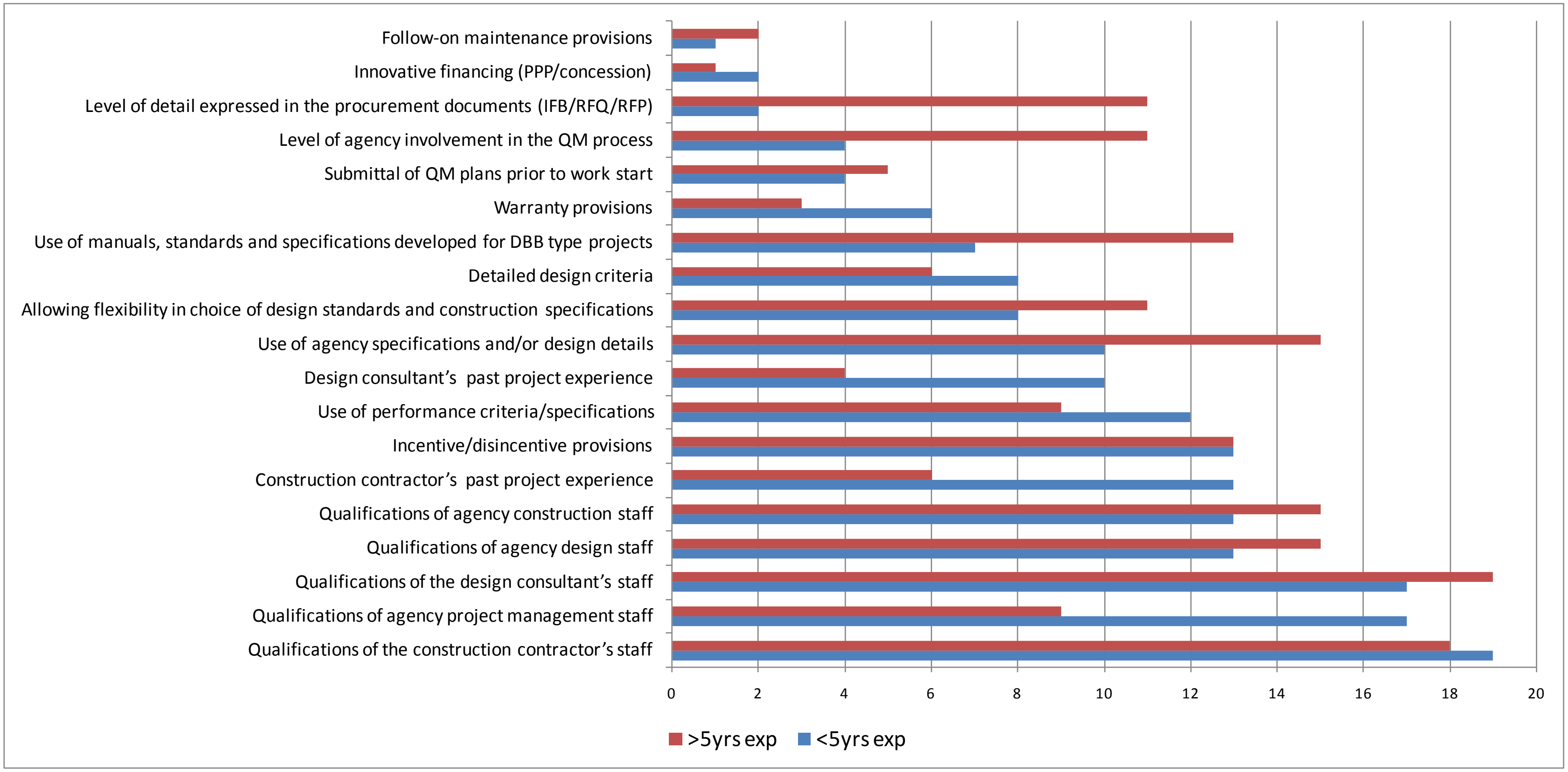

Figure 2-12 – Rated Impact on Final Quality of Various Factors

2.9.6 Impact on Quality

To understand better the differences in the perceived impact on quality, the absolute value of the difference between the rank assigned by the inexperienced agencies and the experienced agencies was calculated and listed in table 2-19. Combining these with the information in Figure 2-12 allows one to infer the trends in this data. The greatest difference was the impact of the information contained in the procurements documents (IFB/RFQ/RFP). Experienced agency ranked this having high impact whereas the inexperienced agencies ranked it very low. This comparison shows the value of dividing the two groups to benchmark the state-of-the-practice. In DB and PPP projects, the technical scope of work contained in the procurement documents becomes an operating part of the final awarded contract (Loulakis and Shean 1996; Yakowenko 2010). Hence, the high rank assigned by the experienced agencies is justified and the low rank assigned by the inexperienced agencies demonstrates a lack of understanding that QM begins in the procurement phase and scoping decisions expressed in the solicitation documents ultimately impacts final project quality.

Table 2-19 – Difference in Ranking of Experienced and Inexperienced Respondents

Factor	$\lvert\in\rvert$	Factor	$\lvert\in\rvert$	Factor	$\lvert\in\rvert$
Level of detail expressed in the procurement documents	9	Use of agency specifications and/or design details	5	Qualifications of agency construction staff	2
Qualifications of agency project management staff	8	Use of performance criteria/specifications	3	Detailed design criteria	2
Construction contractor's past project experience	7	Allowing flexibility in choice of design standards and construction specifications	3	Qualifications of the construction contractor's staff	1
Level of agency involvement in the QM process	7	Warranty provisions	3	Submittal of QM plans prior to work start	1
Design consultant's past project experience	6	Qualifications of the design consultant's staff	2	Innovative financing (PPP/concession)	1
Use of manuals, standards and specifications developed for DBB	6	Qualifications of agency design staff	2	Follow-on maintenance provisions	1
$\lvert\in\rvert$ = Absolute value of the difference in impact rank				Incentive/disincentives	0

The next big differences are in the perceived impact of the agency's project management staff and the constructor's past project experience on quality. The inexperienced agencies rated these higher than the experienced agencies. The experienced agencies felt that the qualifications of the agency's design and construction staffs as well as the qualifications of the designer had more of a significant impact. The experienced group placed relatively high ratings on the use of standard specifications, design details and allowing flexibility in choosing which of these to use on a given project. This reinforces the conclusion drawn in Section 2.8.2 that experienced agencies control project quality by mandating the use of proven design details and specifications while allowing their contractors flexibility to make decisions in a manner that facilitates the increased speed when using alternative QM systems.

2.9.7 Challenges to Achieving Quality

The final section of the survey asked the respondents to relate their experience with respect to achieving project quality. Again, it provided a list of factors found in the literature (Yuan et al 2007) that had been cited as creating a challenge to a project manager's ability to achieve the desired levels of final project quality. Figure 2-13 shows the output from that exercise. Again, there are perceptional differences between the two groups. Both agreed that documenting the quality aspects of a project was the greatest challenge and in a similar vein, rated getting complete design documentation from their contractors as the next largest challenge. The opinions diverged after that with the experienced agencies rating misunderstood roles and responsibilities and the use of DBB contract language without regard to project delivery method much higher than the inexperienced group. This probably reflects a frustration with internal contracting policies and procedures where agency contracting personnel lag behind the agency project delivery personnel on the alternate QM learning curve. Koch et al (2010) describe this particular phenomenon as "creative tension" between process-oriented entities who prefer to standardize procedures and product-oriented entities that see each project as a different product demanding procedures customized to fit project requirements.

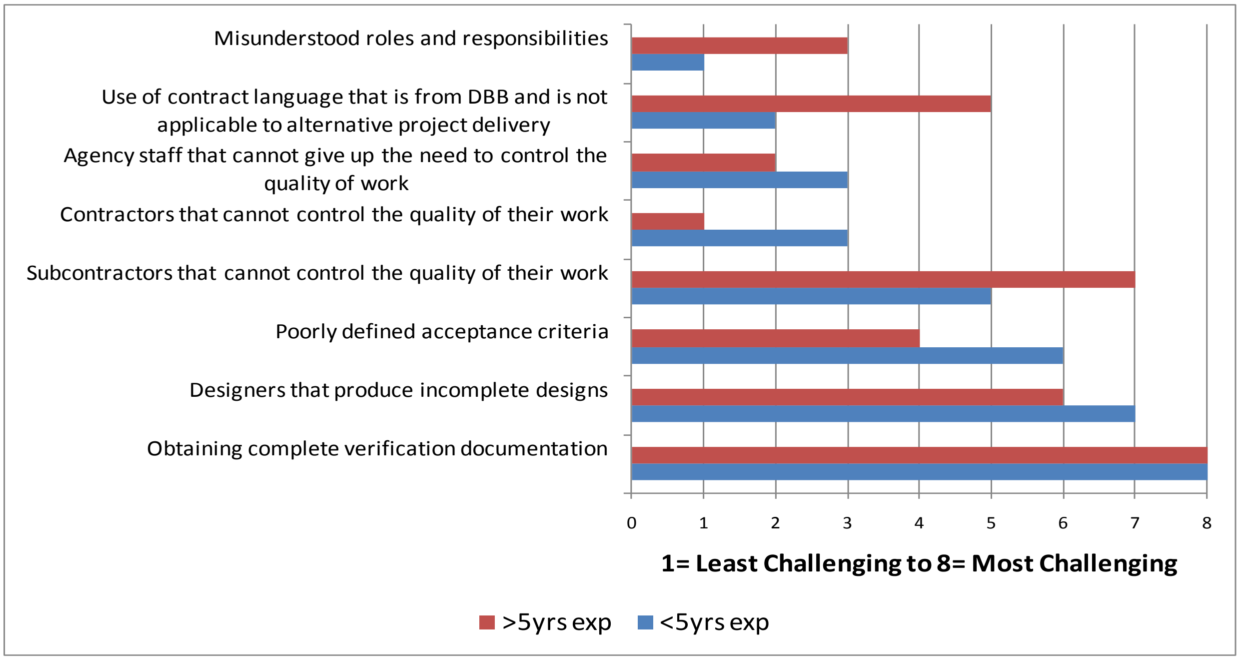

Figure 2-13 – Challenges to Implementing Effective QM Using Alternative Project Delivery

The experienced group also rated subcontractor quality control as a bigger challenge than the inexperienced agencies. This may reflect the fact that the agency has no privity with the project's subcontractors and must make demands on the prime contractor to promulgate QM standards, policies, and procedures to its subcontractors. This also may be a challenge because the subcontractors often are new to alternative project delivery methods and are unfamiliar with the changes inherent to the move from traditional DBB to another delivery method. The reasons for both the differences rating discussed in this paragraph are conjecture and no conclusions can be drawn.

2.10 Summary

NCHRP Synthesis 379 comment by Anderson and Damnjanovic (2008) aptly points out the "popular mythology" that surrounds the culture shift from traditional project delivery and its "catch and punish" QM system to something different. There are always champions that promote the new method with evangelistic zeal and opponents that can see all sorts of unsolvable problems being spawned by the change in contractual relationships. Degraded quality is usually one of the disadvantages cited by opponents to change and the champions cite reasons why quality is in fact enhanced. The *real issue with regard to quality is not how to guarantee that it will improve but rather to ensure that the change does not create a set of circumstances that causes it to decline.* The FHWA Design-Build Effectiveness Study (FWHA 2006) effectively debunked this quality issue. The FHWA study team found that:

> "On average, the managers of design-build projects surveyed in the study estimated that design-build project delivery reduced the overall duration of their projects by 14 percent, reduced the total cost of the projects by 3 percent, and *maintained the same level of quality as compared to design-bid-build project delivery"*(FHWA 2006 italics added)

Strang (2002) holds that public owners who "are not bold enough" to implement DB will be drawn to CMGC as a more palatable alternative to DBB. Design consultants that work for UDOT have indicated a preference for CMGC over DB because UDOT controls the details of the design (Alder 2007). Other agencies have found that CMGC furnishes a good option to both DBB and DB project delivery. "The performance to date of Tri-Met's [Portland, Oregon] two major CMGC contracts for the Interstate MAX light rail line is exemplary from the perspective of keeping the project on schedule and maintaining good quality" (FTA 2003). The same report goes one to say:

> "With a more cooperative working partnership between the owner, the designer and CMGC contractor—Tri-Met calls these entities the CMGC team—work quality should improve. The contractor has been selected on factors other than just price, many of which are strong indicators of ability to complete the job successfully. Also, the CMGC contractor has increased responsibility for quality control over all aspects of the job under this method." (FTA 2003)

This critical review of the literature on QM as applied to alternative project delivery methods can be summed up as a success with regard to furnishing project delivery methods that "improves quality and value… [by keeping the] focus on quality and value – not low bid" (Ladino et al 2008). Thus, the notion that quality must be "engineered" into the project from the very start is confirmed and that using project delivery methods that don't have a bias to minimize construction costs in fact reap the benefits of enhanced quality while controlling both cost and schedule of badly needed highway projects. This conclusion was confirmed by the survey results where experienced respondents reported success using alternate QM systems on projects delivered using alternative delivery methods. These agencies have struck a balance between prescriptive requirements to control design quality to allowing maximum flexibility to their contractors to facilitate aggressive schedules.

CHAPTER 3 : QUALITY ASSURANCE ORGANIZATIONS

3.1 Introduction

Quality Assurance Organizations (QAOs) in the highway industry have been evolving since the 1960s. They have moved from a recipe of prescriptive quality specifications, to developments in materials inspections and testing, implementation of statistical process control (SPC), and ultimately towards performance-based quality management (Hughes 2005; Smith 1998; Halstead 1979).

While the bulk of the research, innovations, and strategies of highway project quality acceptance have been focused on the construction phase of the project (Hughes 2005; Halstead 1979), there is recognition that design has to be an integral part of the discussion of highway project quality (Burati Jr. 1992). The importance of including design into the QAO has been made increasingly evident due to introduction of alternative delivery methods and changing philosophies about the use of consultants in roles historically filled by transportation agency staff. In practice, highway projects QAOs have been adjusting to the needs of the alternative delivery methods and other changing conditions on a project-by-project basis.

This chapter provides guidance for development of QAOs on future projects by identifying a set of fundamental QAOs and a proposed approach for applying each. Five QAOs have been developed through a triangulation of literature review, contract document analysis and case study evaluation, yielding a consistent and efficient approach to QAO planning in the highway sector.

3.2 Methodology

Identification of the five QAO models consisted of three distinct phases. A thorough literature review and national survey were used to identify a theoretical framework with 14 potential QAOs. The second phase employed a content analysis of 66 contract and policy documents to identify the QAO's that are currently in use by industry. The QAOs identified in phases one and two were analyzed based on the agency's quality roles and responsibilities within each QAO. If the agency shared a role, directly contracted the role out to an independent firm, or had sole responsibility, it was considered an agency project quality role and responsibility. Many of the initially identified QAOs were variations of the fundamental QAOs, depending on how the agency performed the role and/or if the non-agency quality roles and responsibilities were contracted to a single party or multiple parties. These variants were consolidated into five fundamental models. The five fundamental QAOs presented that follow are based on agency roles for the traditional and three of the most common alternative project delivery methods: DB, CMGC and PPP.

3.3 Quality Assurance Organization (QAO) Presentation

Each QAO is graphically represented using the generic QAO framework, shown in Figure 3-1. The generic framework shows all of the project quality roles, their relationships, and the surrounding project quality activities. The generic framework includes both design and construction. Design quality has not been traditionally included in highway QA discussions, but is required for the alternative delivery methods that are becoming prevalent in the industry. A dotted line is used to indicate whether the agency, contractor, designer, concessionaire, or design builder is responsible for each project quality role. Items above a dotted line are the responsibility of the agency. A vertical dotted line below a horizontal dotted line separates the responsibilities between the designer and the contractor.

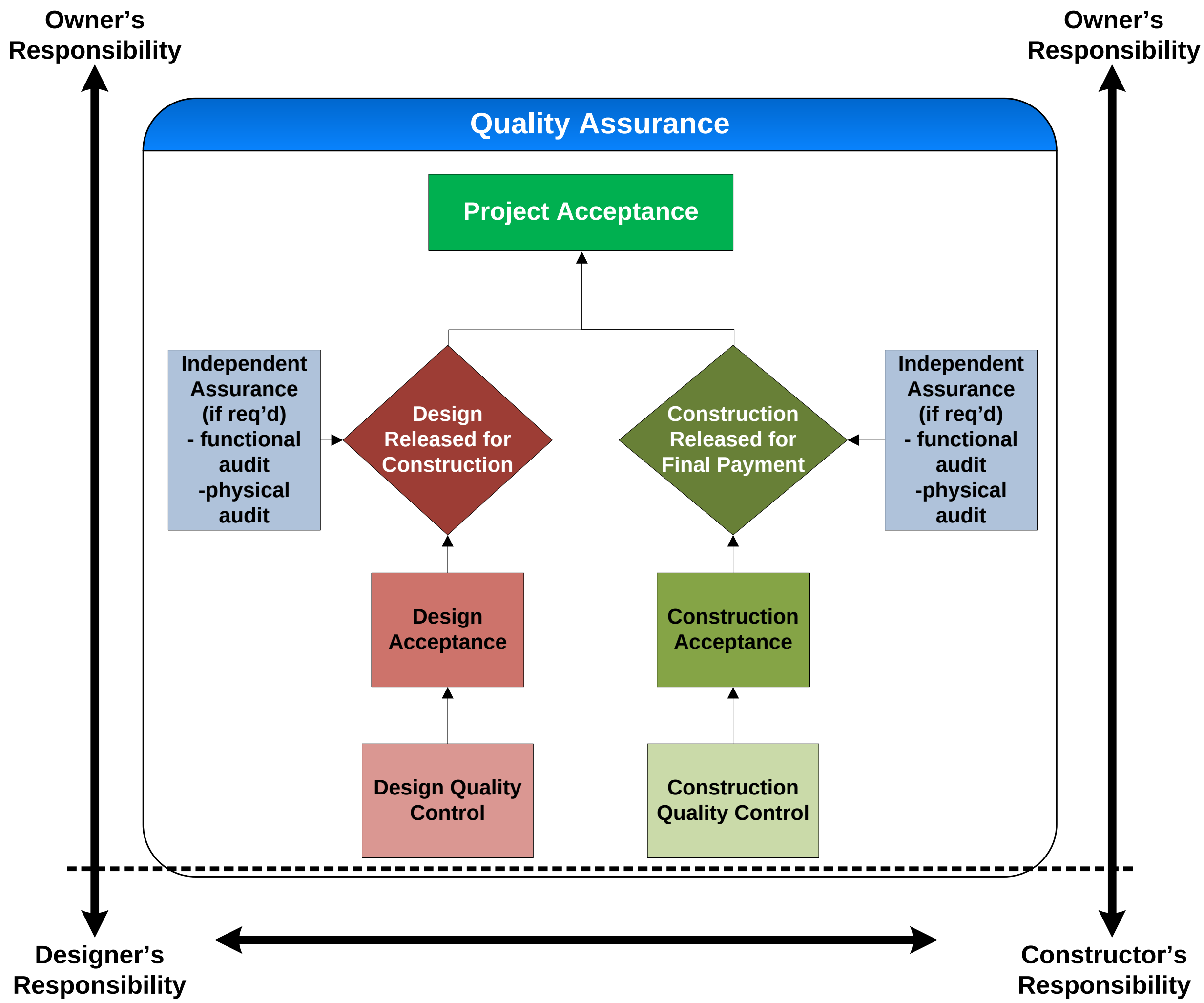

Figure 3-1 – Generic Quality Assurance Organization (QAO) Model

3.4 Fundamental Highway QAOs

The five fundamental QAOs for the highway construction and design industry identified by this research are listed below:

- Deterministic – The traditional approach to quality within the highway industry. The agency retains all project quality roles, responsibilities and activities.
- Assurance – The agency is responsible for all aspects of the quality except for design and construction QC.
- Variable – Design and construction take different approaches to quality. For example, the STA may assign both design phase QC and acceptance to an outside party, while the construction phase QC only may be assigned to an outside party. This approach was found on DB projects.
- Oversight – the agency takes on an oversight role by assigning design QC, design acceptance, construction QC and construction acceptance to outside parties.
- Acceptance – The agency is responsible for verification testing and final acceptance. All other quality roles and responsibilities are assigned to the concessionaire. This approach was found only in PPP arrangements.

Figure 3-2 shows a summary of the five QAOs in respect to both the level of agency control and the approach to quality management.

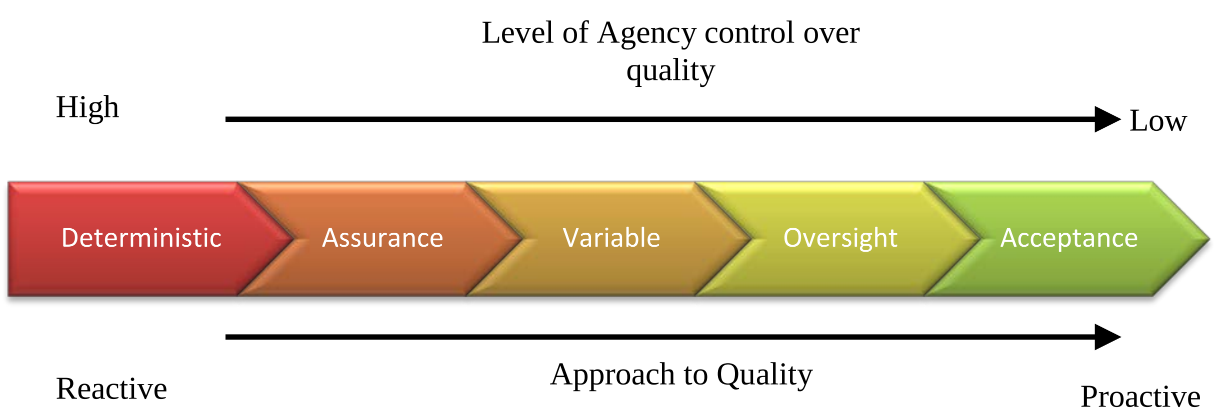

Figure 3-2 – Fundamental highway industry QAOs based on approach to control and quality

There are two distinct approaches to managing quality: reactive and proactive. The reactive approach aims to detect and correct existing problems, "in other words, the designer of a product/process/service incorporates a system of checks and measures that serves to isolate and catch defects as and when they occur. By their very nature, reactive quality assurance strategies are better suited to identify problems and resolve them and as such are clearly defensive in nature" (Desai and Mital 2009) . The reactive approach inspects the quality into the final product. Conversely, the proactive approach to managing quality aims at preventing problems, defects and/or errors before they occur. The proactive approach provides the project team with the ability to build quality into the final product beginning at the design stage instead of inspecting it at a later stage. (Desai and Mital 2009)

The sections that follow present each of the five QAOs with a description of the assignment of the roles and responsibilities, the approach to managing quality, the applicable project delivery methods, and the existing variations on the fundamental QAO. The description of the assignment of the roles and responsibilities clearly identifies the team member responsible for each task. It also discusses the level of owner control for that QAO. The approach to quality indicates if the QAO results in a reactive or proactive approach to quality. The discussion identifies the project delivery methods where the QAO has been implemented in the industry as well as the feasibility of the application of the QAO to other project delivery methods. Lastly, the discussion identifies the variations of the QAO.

3.4.1 Deterministic

The Deterministic quality management organization, as shown in Figure 3-3, is the traditional quality organization on highway construction projects and the primary parties of STA, designer and contractor understand this QAO well. The agency's roles in the Deterministic QAO include design QC, design acceptance, and construction acceptance. The agency can use third party consultants to perform any of their roles, but the agency is ultimately responsible for ensuring these roles are successfully completed on the project. The STA provides guidelines to the contractor as to possible necessary tests and inspections appropriate for the project, but the contractor is responsible for creating the construction QC plan.

"The STA's role is to approve the QC program, monitor contractor procedures, test results, perform independent tests and determine acceptance" (Smith 1998). Project acceptance is not required because the agency is responsible for all quality acceptance (design and construction) on the project. The Deterministic QAO represents the baseline for alternative QAO discussions and comparisons for the remainder of this paper.

Because of the controlling role of the owner in the deterministic this organization, it is considered a reactive approach to quality (Postma et al. 2002). In this QAO, the agency develops the designs, specifies the materials to be used, and watches over the construction (Gransberg et al. 2008). In the Deterministic QAO, "the contractor works within a very controlled environment like that in a method specification project. Assurance, using method specifications is based on the owner having complete control of the process and enumeration of contractor means and methods. Detailed owner-directed inspection is the primary control process and final acceptance of the work is essentially automatic" (Smith 1998).

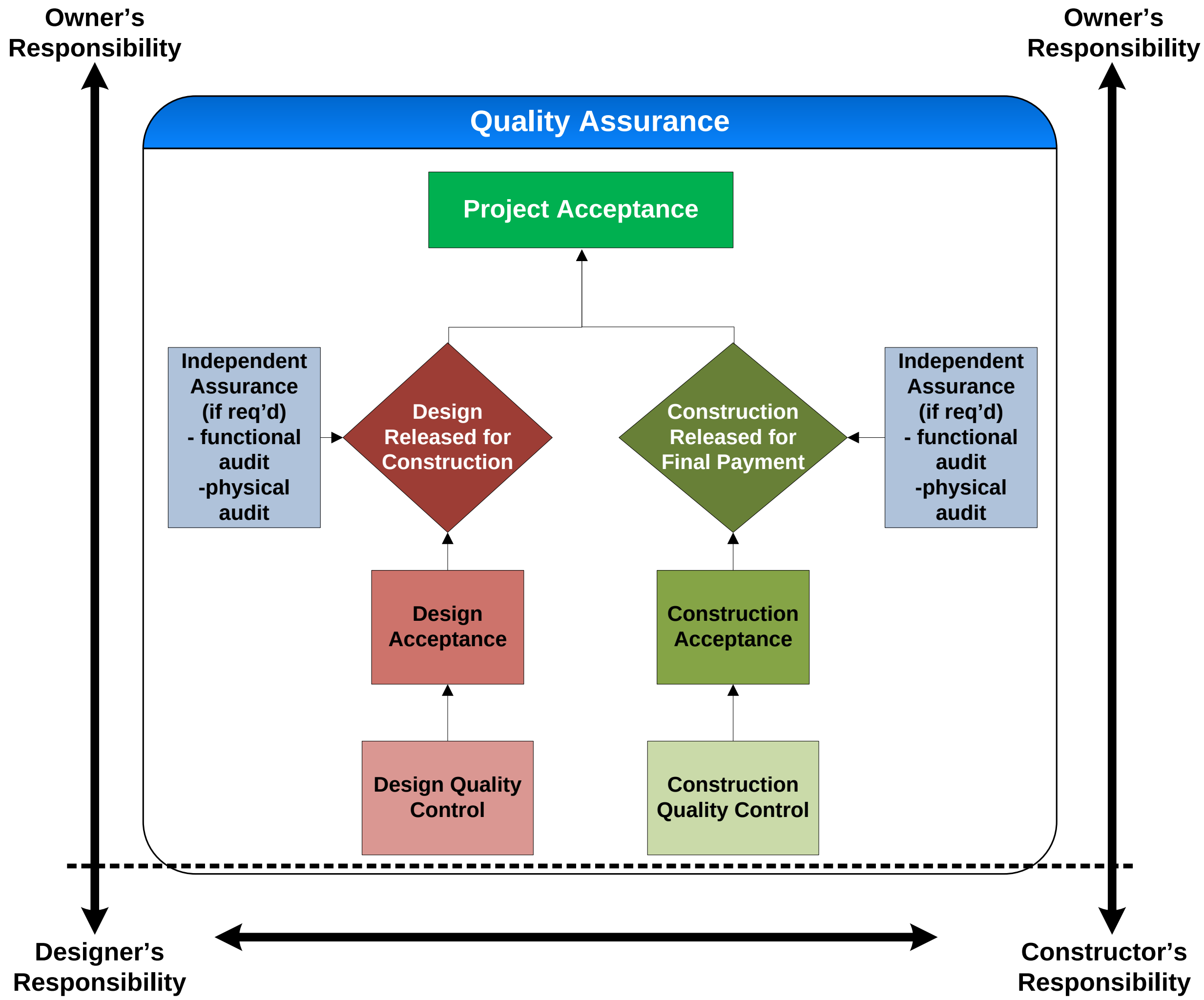

Figure 3-3 – Deterministic QAO

The lack of any sort of collaboration in the Deterministic approach contributes to the frequently contentious relationship between the owner and the contractor. This adversarial relationship is so pronounced that the Deterministic QAO is sometimes referred to as the "catch and punish" method (Postma et al. 2002). There is no place for collaboration because the contractor and the designer have no input in the acceptance of their own product, they are merely responding to what the agency dictates within the RFP, plans, specifications, and bidding documents. Difficulties can arise when there are conflicts because the quality expectations are not explicitly called out by the bidding documents and/or when contract change orders are needed.

The Deterministic QAO implementation commonly occurs on DBB projects, especially when the STA internally performs the design, rather than outsourcing the design to a consultant. Gransberg and Shane (2010) concluded that the quality systems used in DBB pertain to CMGC because the owner still occupies the same contractual position with respect to the designer and builder (Gransberg and Shane 2010). The Deterministic QAO would be most appropriately applied to CMGC if the scope of preconstruction work for the contractor was limited to items not directly relating to the design: cost estimates and project scheduling. In contrast, the Deterministic QAO is not well suited for a DB project. This is because one of the benefits of the DB delivery method is that the agency can transfer some of the risks associated with the quality of design and construction, which requires a shift in authority for each of these tasks. Applying the Deterministic QAO to a DB project would mean the agency would retain the quality authority for design and construction which no longer allows the design builder to manage and assume the risks associated with those tasks (Gransberg et al. 2008).

3.4.2 Assurance

In the Assurance QAO, the agency has the responsibility for acceptance in design and construction and the decisions to release the design for construction and to release construction for final payment. These responsibilities can be performed in-house or by an independent consultant/engineer.

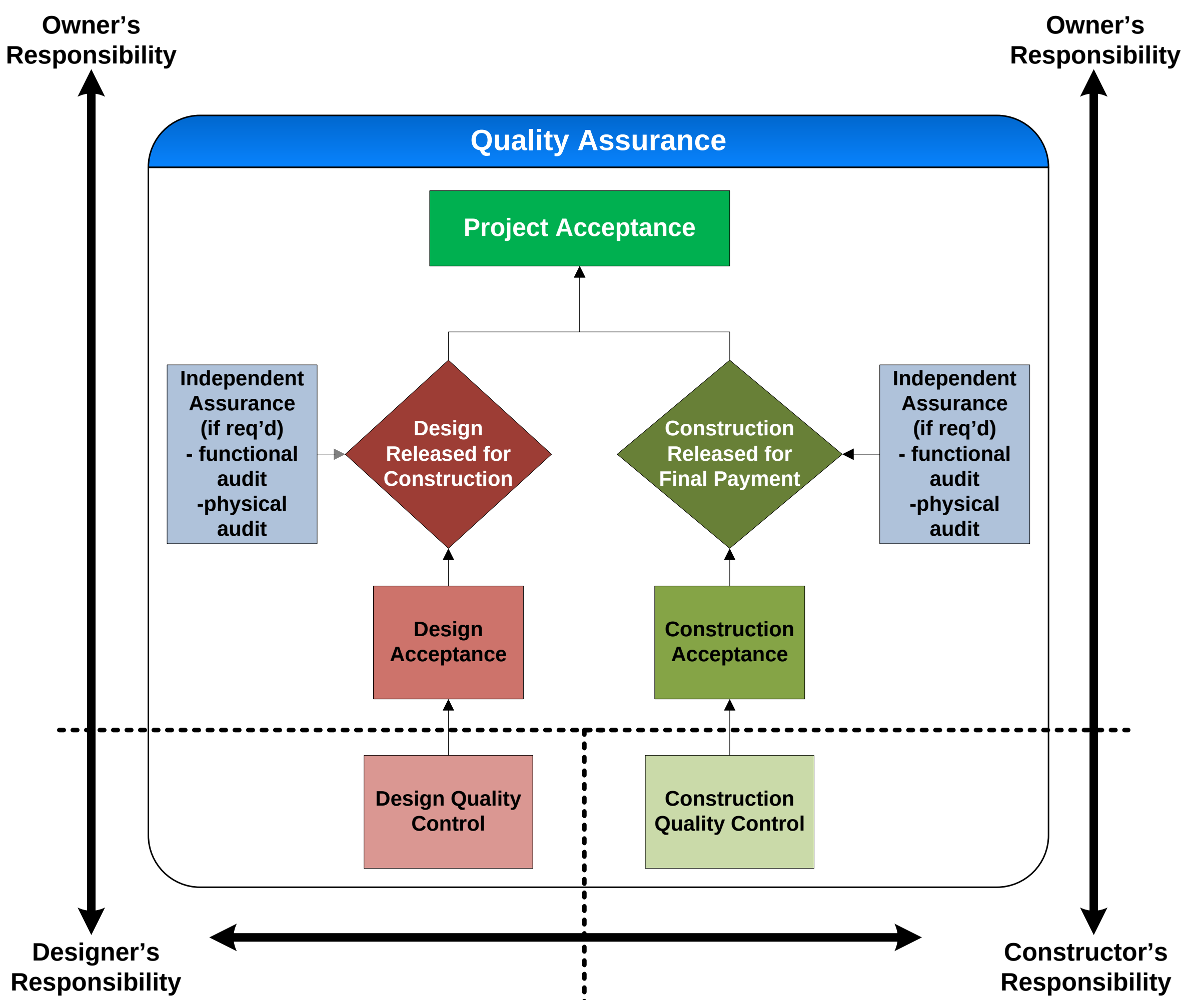

Figure 3-4 – Assurance QAO

Figure 3-4 graphically depicts the Assurance QAO as applied to a dual contract project (separate contracts for the designer and the contractor). The designer and the contractor are responsible for performing QC of their respective fields. Because the agency is still responsible for all quality acceptance on the project, project acceptance is not necessary. While the contractor and the designer are perform their own QC, typically the agency will perform independent assurance and testing to verify the QC tests results (Gransberg et al. 2008).

The Assurance QAO is a small step beyond the Deterministic QAO. Because the agency is still responsible for all design and construction quality acceptance on the project without input from either the designer or contractor, the owner still has a very controlling role in the project. The quality responsibilities have not shifted very far from the Deterministic method and there is still a focus on inspections and materials testing as the way to assure quality, rather than an emphasis on building quality in. Additionally, because the owner is so heavily involved in dictating the quality of the project, the designer and the contractor have minimal accountability for quality. The high level of agency control over the quality on the project also prohibits collaboration between the agency and the designer and contractor regarding quality. The lack of collaboration along with the strong emphasis on assuring quality through inspections of the final products makes the Assurance QAO a reactive approach to quality.

The Assurance QAO has been applied to both DBB and DB projects. When applied to DBB projects as shown in Figure 3-4, everything above the dotted line is the agency's responsibility and the vertical dotted line represents the separate design and construction contracts. When applied to the DB delivery method, with a single contract for design and construction, all QC activities are the responsibilities of the design builder, as shown in Figure 3-5. Gransberg et al. (2008) speculated on reasons this method would be applied to DB projects. They suggested that agencies, which have limited experience with the DB method, apply quality management policies and procedures that are still evolving from the DBB method where the contractor controls construction QC and the STA has control over all QA functions and over design QC (Gransberg et al. 2008).

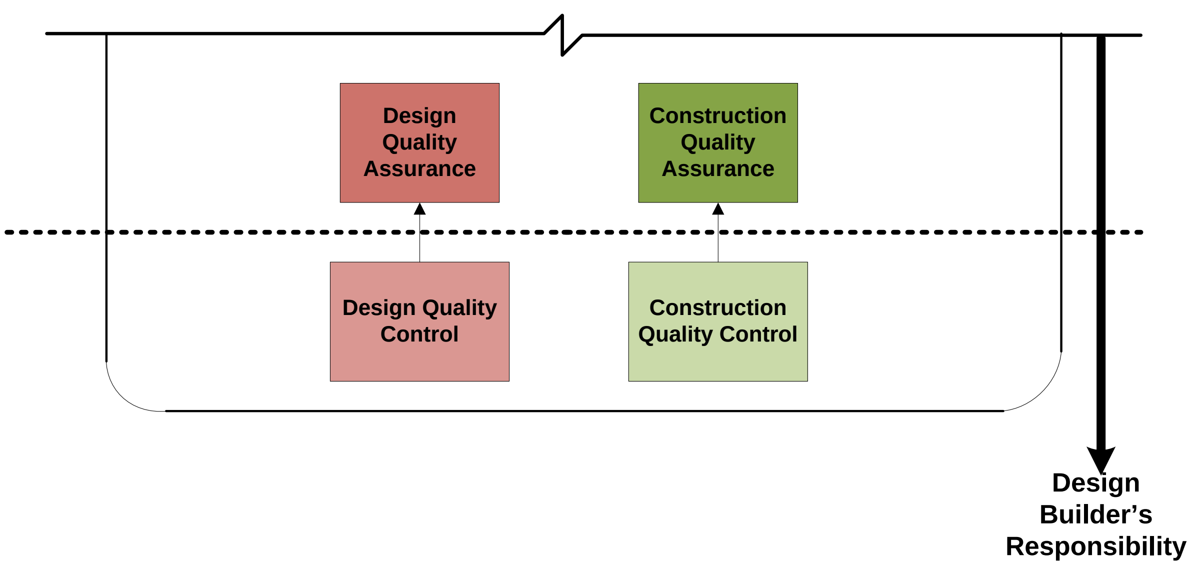

Figure 3-5 – Assurance QAO, single contract

Another variation on the Assurance QAO used DB projects is the shared variation. This variation shares the responsibilities for design acceptance and construction acceptance between the owner and the design builder, shown in Figure 3-6. This organization still falls into the Assurance QAO because the owner still has a role in the assurance on the project and as a result, no project acceptance is necessary. When sharing roles between stakeholders on a project, it is critical that a clear identification of all roles in the shared task are specifically addressed and assigned to prevent confusion on the project. The shared variation of the Assurance QAO could also be applied to the CMGC delivery method but the contractor would be responsible for construction acceptance and the designer would be responsible for design acceptance.

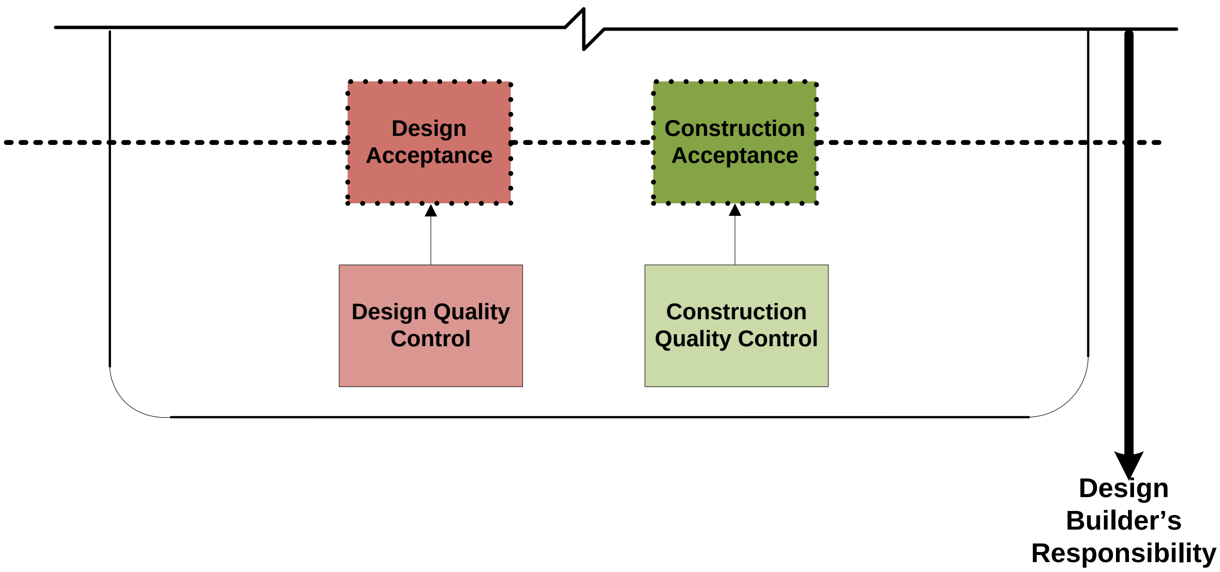

Figure 3-6 – Assurance QAO, shared assurance variation

3.4.3 Variable

The Variable QAO differs from the four others because it is described by the function of the model rather than by the role of the agency. The defining characteristic of the Variable QAO is that the approach to quality between design and construction is different. An example of this method has been found on a DB project when the agency is responsible for the construction acceptance but not design acceptance, as shown in Figure 3-7. Because the agency is no longer responsible for design acceptance, the agency must perform project acceptance on the design side of the project (Gransberg et al. 2008). As a result, the design phase of the project is considered to be a proactive approach to quality. On the construction side however, the agency still maintains control of construction acceptance, resulting in a reactive approach to quality on the construction side. For the DB example considered in Figure 3-7, the agency is taking a different approach to quality on the design phase from the construction phase. This results in implementing two different approaches to quality across not only the agency but also the design builder, which can complicate attempts at creating continuity across the project.

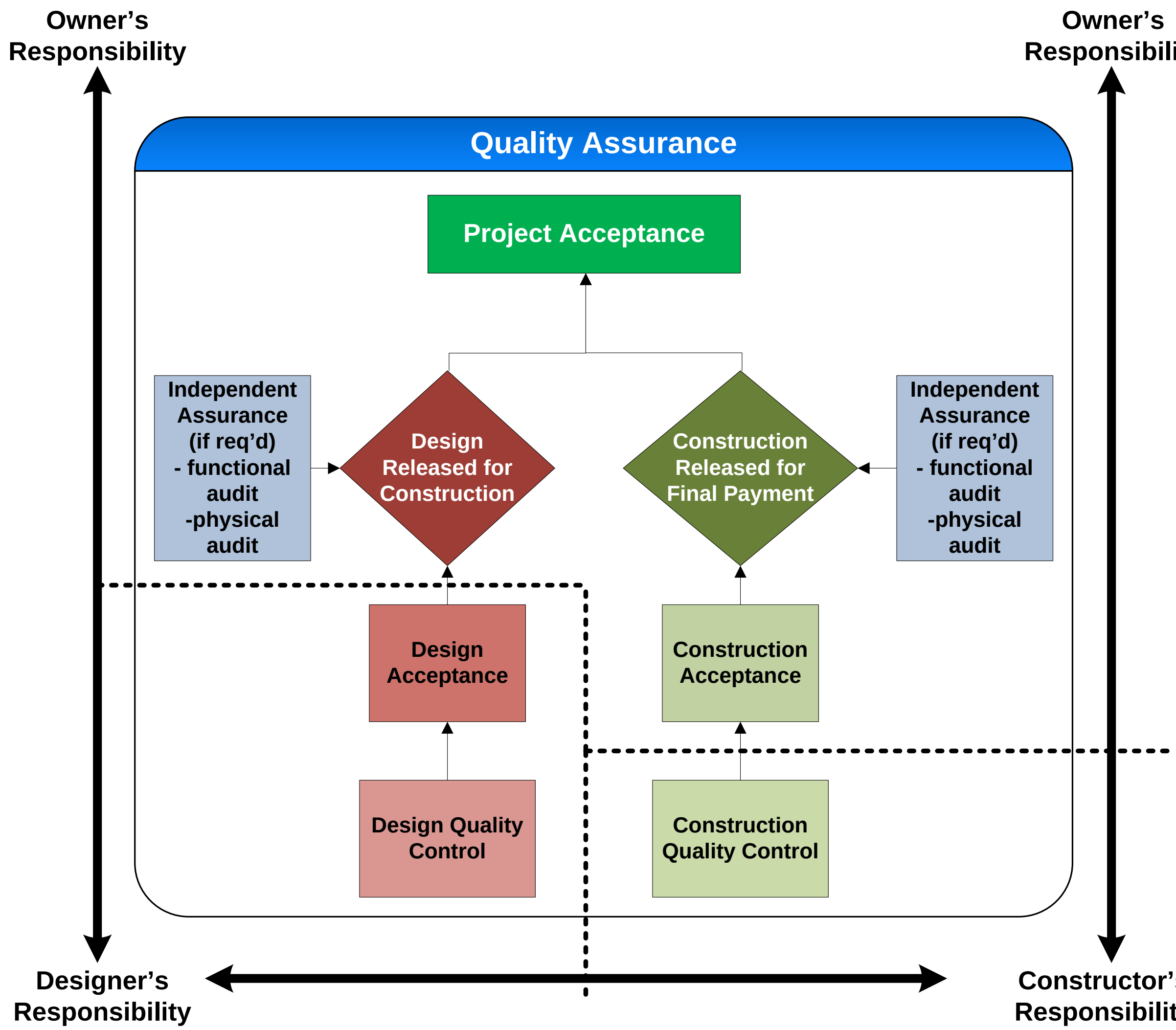

Figure 3-7 – Variable QAO, construction assurance single contract

The Variable QAO is a mixed approach to quality between the design and the construction phases. Figure 3-8 illustrates another variation on this QAO. Here, the STA has the responsibility for design acceptance, and is not responsible for the construction acceptance or construction QC. In this case, the design phase of the project is a reactive approach to quality and the construction phase is a proactive approach requiring the owner to perform project acceptance for construction activities. Again, this version of the Variable QAO has a mixed approach to quality between the design and construction phases, complicating efforts to have a single quality philosophy across the entire project.

A critical element of a proactive approach to quality and successfully shedding the acceptance responsibility from the agency is the agency's identification of the quality requirements to be included in the RFP. Agencies must provide enough guidance so that respondents can include the appropriate services and approach to quality in their proposals (Gransberg et al. 2008). While this arrangement requires fewer agency resources over the duration of the project, these resources must then be focused on the quality requirements within the contract not on the detailed technical details of the project. While the variation in Figure 3-8 results in a proactive approach to construction quality, it results in a reactive approach to design quality by the agency maintaining control of the design acceptance function. The reactive approach forces the agency to focus on the testing and inspections required to perform design acceptance. This requires the traditional skills possessed by a transportation agency, focused on checking all the technical details of the project. The Variable QAO can be difficult for an agency to manage because the project team must have the abilities to manage both proactive and reactive quality approaches within one team.

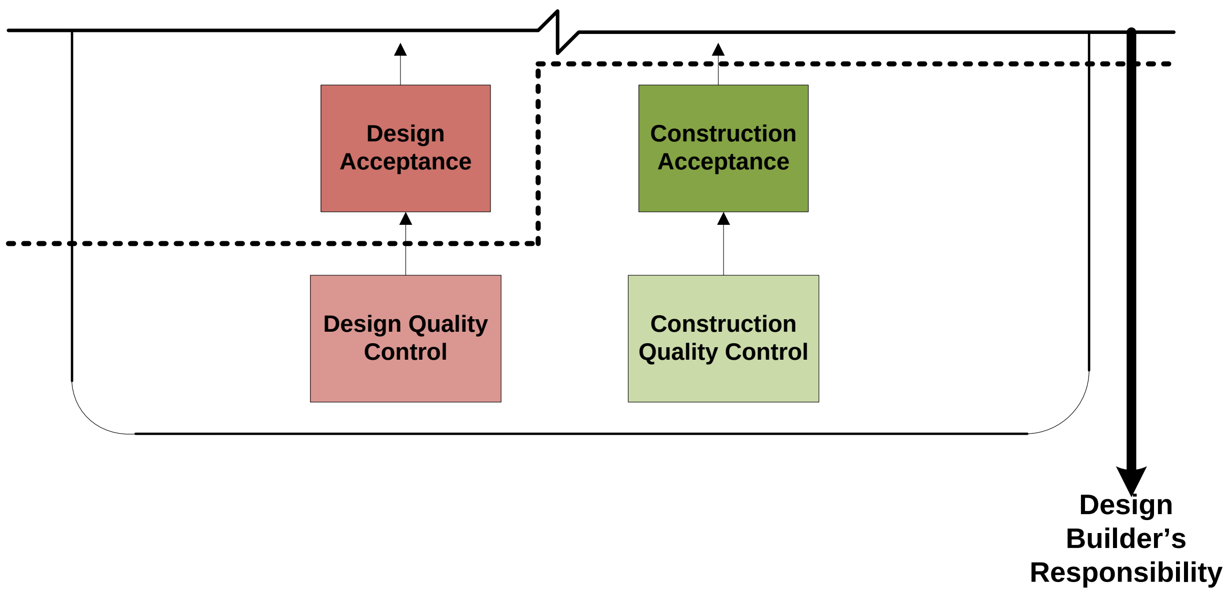

Figure 3-8 – Variable QAO, design assurance variation single contract

As with the previous model, the last variation of the Variable QAO that would be feasible also occurs when the design phase quality management is reactive and the construction phase is proactive. In this case, the agency is responsible for both design acceptance and design QC, while the contractor/design-builder is responsible for construction acceptance and construction QC. This variation is shown in Figure 3-9. This organization has not occurred in industry at this point, but it does still possess the mixed approach to quality between design and construction phases, so it is a valid variation of the organization. The reverse of this variation, in which the agency is responsible for construction acceptance and QC while the designer is responsible for design acceptance and QC, would not occur because construction QC always resides with the contractor.

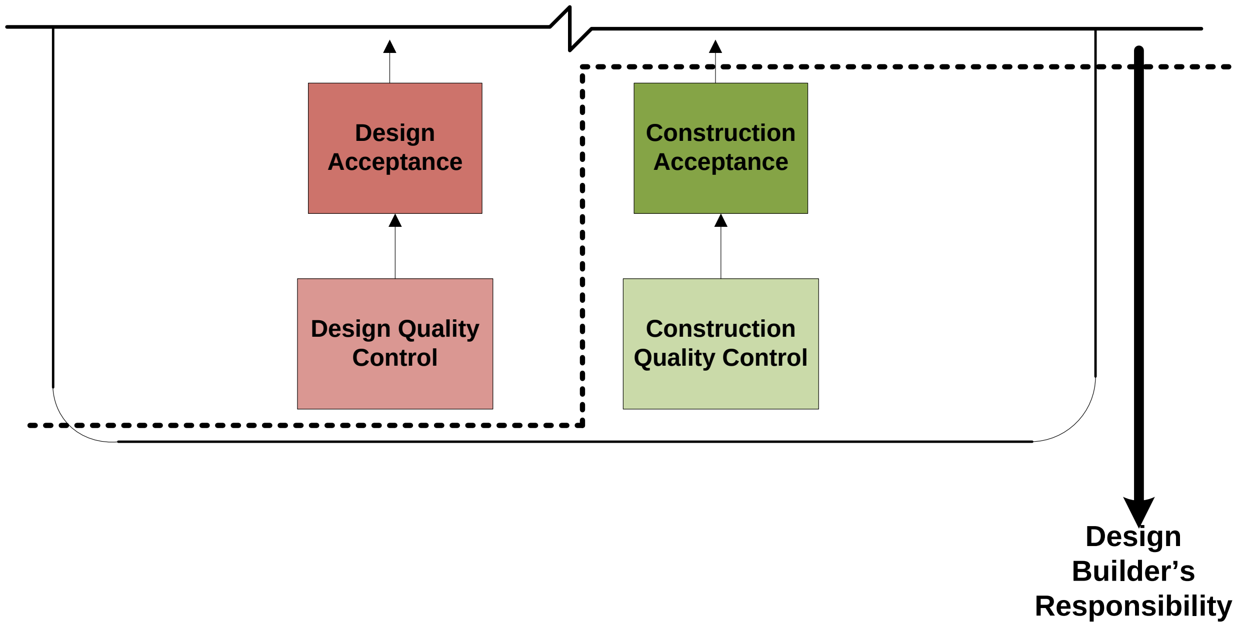

Figure 3-9 – Variable QAO, agency has complete design quality responsibility

The Variable QAO construction assurance variation has been implemented on Design-Build projects as shown in Figure 3-7. Currently there are no examples from the data showing that the design assurance variation is in use in the industry. No examples have been found of this variation of the Variable QAO being applied to either DBB or CMGC projects; however, there is nothing within the variation itself, which would prevent it from being implemented on a dual contract (DBB or CMGC) project.

3.4.4 Oversight

In the Oversight Quality Assurance Organization, shown in Figure 3-10, the agency is responsible for the decisions to release the designs for construction and to release construction for final payment. The designer is responsible for design acceptance and design QC, while the contractor is responsible for construction acceptance and construction QC. Because the agency does not have any responsibility for the design or construction acceptance, it is responsible for performing project acceptance. In the Oversight QAO the agency no longer has direct control over the day-to-day quality management of the project and is no longer dictating how to produce the quality required by the project; rather the agency's role is to ensure that both the designer and contractor quality management plans are effective at meeting the agency's quality requirements stipulated in the contract and that the plans are being implemented.

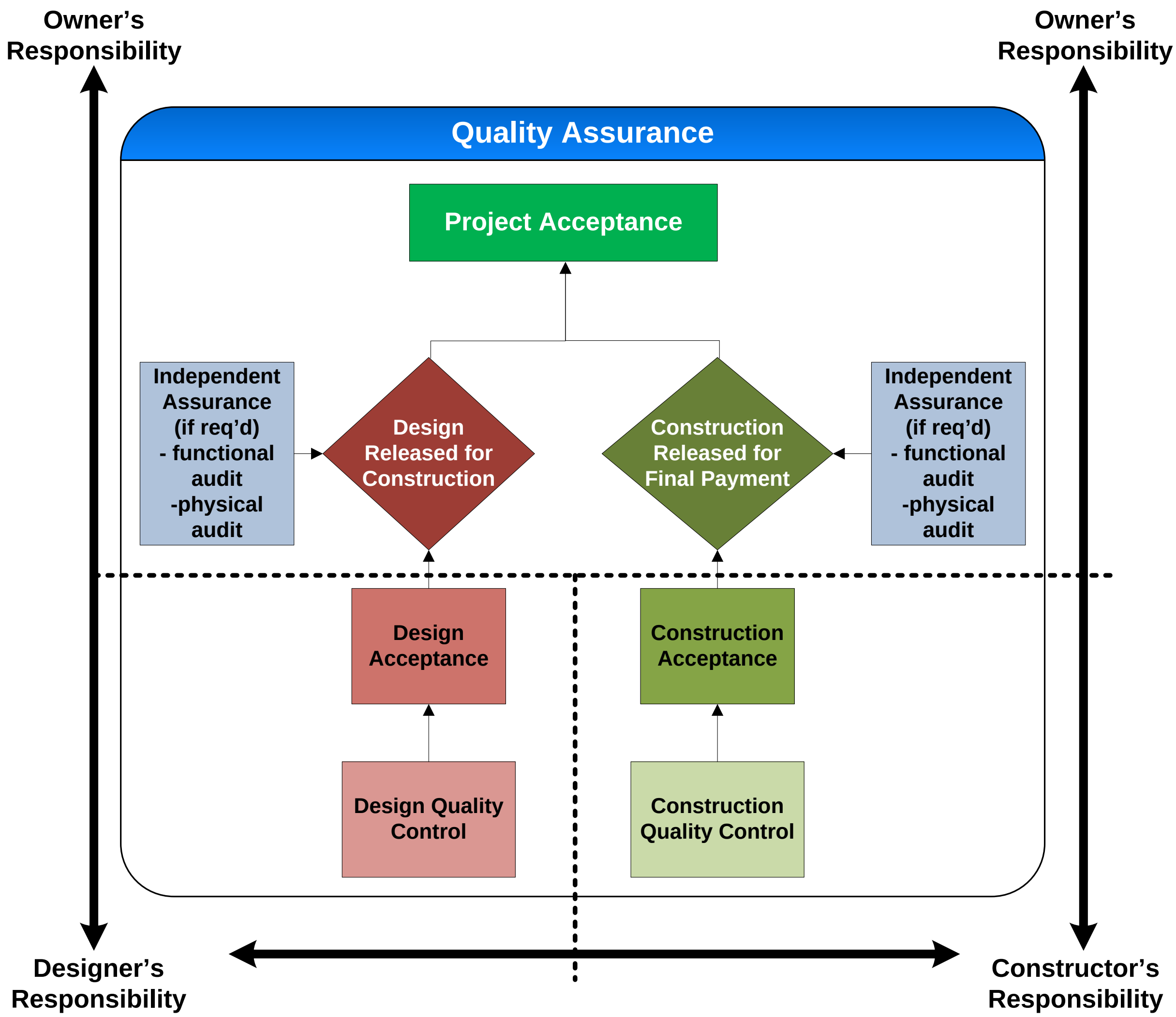

Figure 3-10 – Oversight QAO

The Oversight QAO is a proactive approach to quality, at least as far as the agency's role in quality is concerned. The producers, the designer and the contractor, are responsible for all aspects of the quality for the products that they produce for the agency. The Agency's primary responsibility in the Oversight Organization is oversight of the quality of the project, which is conducted through project acceptance. The agency can conduct project acceptance either with in-house staff or with an independent quality firm contracted directly to the agency. To perform the project acceptance role in-house effectively, the agency will have to teach its staff the different skill set required to be successful. The designer and contractor's approach to quality does not have to be proactive, unless required by the agency's contract. The designer and/or contractor can create a quality acceptance plan in which their approach to managing quality is reactive (focused on inspecting final product rather than finding the defects before they are implemented). Either way, designers and contractors have not historically had much responsibility for the acceptance aspects of a project and may need specific acceptance training to learn how to perform this function.

While the agency always ultimately has the risk for quality on a project, in the Oversight QAO, quality risk shifts to the designer and the contractor. Shifting the risk results in both the designer and contractor having to "buy-in" into the quality assurance of the project because they are each responsible for creating their respective quality acceptance plans which ensure that the quality goals and requirements of the project are met. Because the Oversight QAO shifts the responsibility for acceptance to the designer and the contractor, the level of integration between the agency, designer and contractor increases and requires a higher level of collaboration among the three in order to meet the quality requirements for all parties. In this QAO, all parties are involved in the quality management of the project and the designer and contractor have contractual accountability for not only the quality of the final product that they deliver to the agency, but also the actual processes of delivering that product.

Because of the high level of collaboration required by the Oversight QAO, it would be difficult to implement on a project with a linear approach where the designer and the contractor are not involved early in the project; as a result, the Oversight QAO would not be a good choice for a DBB project. However, in project delivery methods when the designer and contractor are brought in early on a project, such as DB and CMGC, the Oversight organization would be complimentary to the collaborative nature of these methods. In a design-build project, all acceptance and QC for the project would fall to the design-builder, as shown in Figure 3-11.

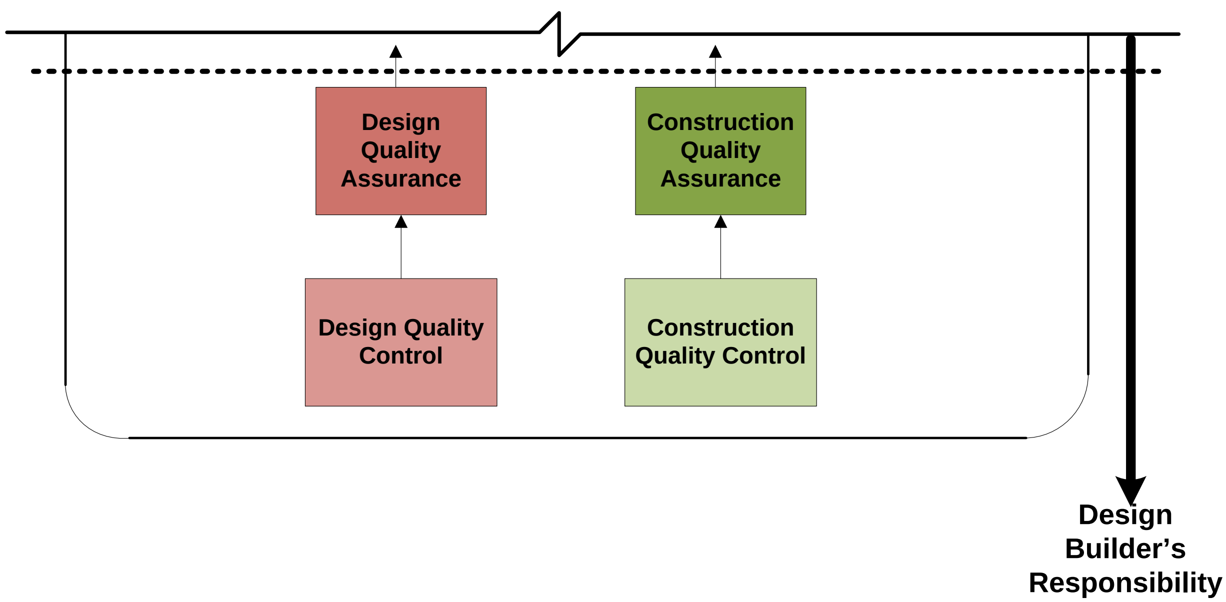

Figure 3-11 – Oversight QAO, single Contract Variation

3.4.5 Acceptance

The Acceptance QAO is specific to PPP projects. In this organization, the owner only has responsibility for final project acceptance and owner verification testing while the party contracted to complete the project is responsible for all other quality responsibilities on the project as shown in Figure 3-12. Since the agency is no longer providing 100% of the financing for design, construction, operations, and maintenance, there is a shift in financial liabilities, which also pertains to the shift of the quality responsibilities (Gransberg et al. 2008). Since the United States has not fully embraced the PPP delivery method, there were limited projects to include in this research. The Acceptance QAO is based on several Texas DOT projects that are using the PPP delivery method. There are some variations of the PPP method across the globe, but because they are not implemented within the business environment of the United States, they were not included in the document review, or the survey responses.

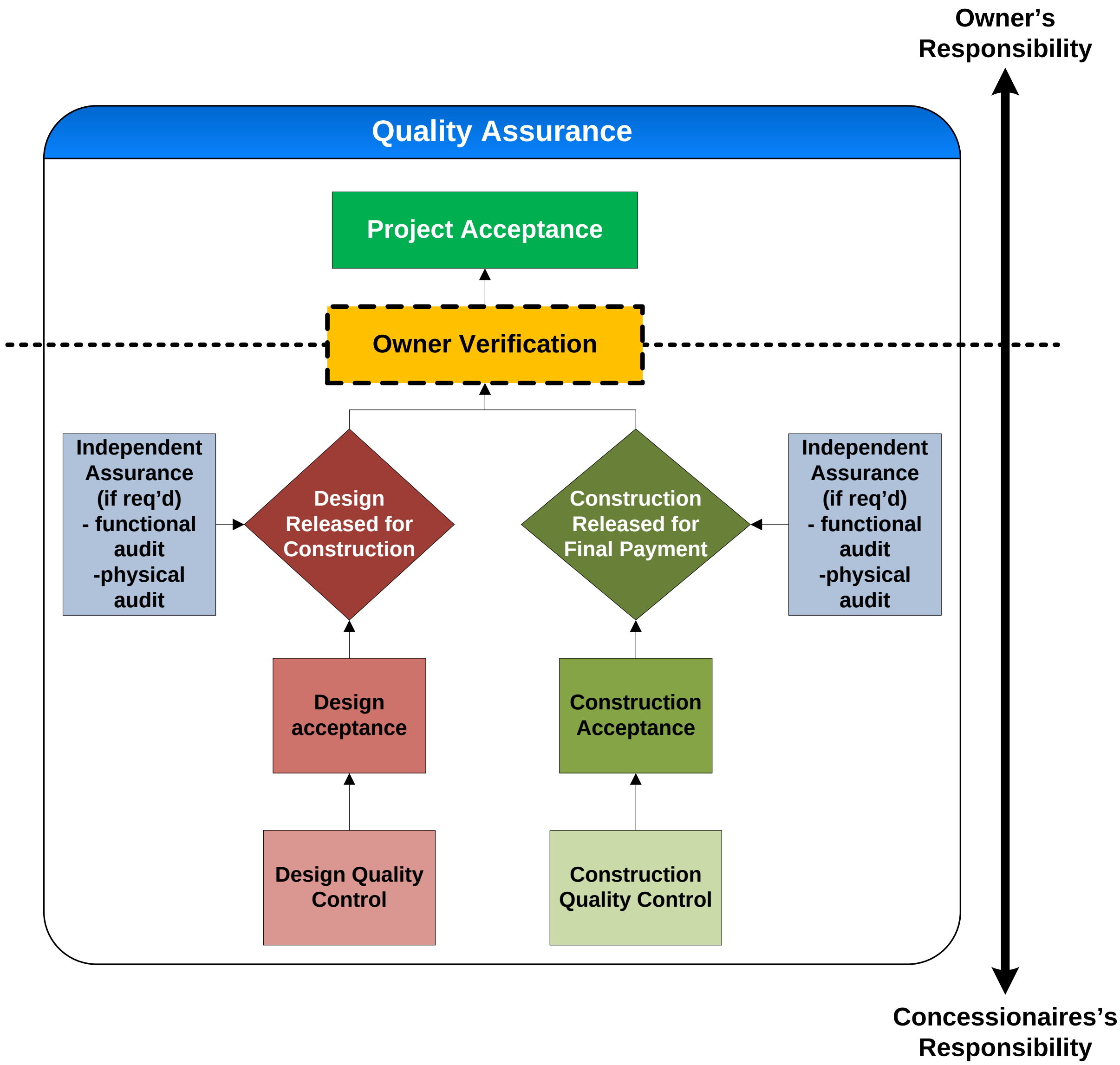

Figure 3-12 – Acceptance QAO

Out of the all project QAOs, the agency has the least amount of direct control over the QM of the project in the Acceptance QAO. The agency's primary focus, as required by FHWA Technical Advisory 6120.3, is to perform design and construction quality oversight to satisfy their legal responsibilities to the public (Gransberg et al. 2008). This requires the agency to perform owner verification testing commonly performed by an independent engineer. The independent engineer is hired jointly by the concessionaire and the agency to perform not only owner verification testing but also independent assurance and any other quality acceptance activities that are now part of the concessionaire's responsibility, but the agency pays for 100% of owner verification testing. Notice that even the decision of accepting design for construction and accepting construction for final payment is a responsibility of the concessionaire due to the financial liability of the concessionaire to correct any design or construction deficiencies during the operations and maintenance period (Gransberg et al. 2008).

Because the agency's involvement in the quality of the project is establishing the quality requirements, approving submitted quality management plans and ensuring that quality plans are being implemented, the Acceptance QAO is a proactive approach to quality management. The agency will have some oversight responsibilities to meet the due diligence requirements for federal funding, but these responsibilities are not considered to dominate the overall quality management of the project. This oversight is usually conducted through agency verification by either in-house staff or an independent engineering consultant contracted to the agency. The designer, contractor and/or concessionaire create the quality plans required by the contract and as long as they meet the requirements of the contract, the agency approves them. In the Acceptance approach, succinctly stating the quality requirements in the contract with the project team is the primary responsibility of the agency for creating successful quality on the project.

Collaboration for the Acceptance QAO is low because after stating the quality requirements within the contract documents for the Concessionaire, the agency is minimally involved in the project. As a result the meeting the quality requirements for the project is placed in the hands of the concessionaire, while the agency performs enough of an oversight role to ensure that they are meeting the federal requirements for due diligence and making sure the concessionaire is following their own project quality management plan

3.5 Summary

The quality roles and responsibilities on a project are shifting on highway projects due to the use of different project delivery methods, the needs of the industry for faster and better projects, and the growing acceptance of the utilization of consultants by STAs. The five fundamental QAOs for the highway design and construction industry range from the agency having sole responsible for all quality functions except construction QC, to the agency only being responsible for final acceptance and meeting federal requirements. Table 3-1 summarizes the roles and responsibilities of the five QAOs. When DB is the project delivery method, all of the non-agency quality responsibilities become the responsibility of the design-builder. The Acceptance QAO has only been found in PPP projects, so the concessionaire is the party performing all non-agency quality roles and responsibilities.

Table 3-1 – Roles and responsibilities of the five fundamental QAOs

Quality Assurance Organization	Design Acceptance	Design QC	Construction Acceptance	Construction QC
Deterministic	Agency	Agency	Agency	Contractor
Assurance	Agency	Designer	Agency	Contractor
Variable	Designer	Designer	Agency	Contractor
Oversight	Designer	Designer	Contractor	Contractor
Acceptance	Concessionaire	Concessionaire	Concessionaire	Concessionaire

Further investigation of each of the organizations was conducted to identify the approach to quality, the level of owner control, and the delivery methods for which it is applicable. The approach to quality was expressed as reactive, heavily focused on final product inspections; or proactive, building quality into the process. The level of owner control was expressed as high, medium, or low. It was found that as the level of owner control moved from high to low, the approach to quality moved from reactive to proactive. Lastly, the applicable delivery methods were identified. These were identified through actual examples in industry or if the QAO could align with the project delivery method based on the timing of the parties' involvement, the level of collaboration involved in the QAO, and the level of owner control. A summary of all of these results is shown in table 3-2.

Table 3-2 – Characteristics of the five fundamental quality assurance organizations

Quality Assurance Organizations	Quality management approach	Level of owner control	Identified delivery methods	Potential delivery methods	Example States and Agencies using QAO
Deterministic	Reactive	High	DBB, CMGC	None	All
Assurance	Reactive	High	DB	CMGC, DBB	NM, SD, LA, MS, NC, AK, FL
Variable	Mixed	Medium	DB	CMGC	NC, FL, MN, VA, UT, ME, CA
Oversight	Proactive	Low	DB	CMGC	CA, CO, MN, MO, NV, OR, TX, UT, VA, WA, WASH DC, FHWA Eastern Federal Lands Highway Diversion, Alberta Canada
Acceptance	Proactive	Low	PPP	None	TX, FL

During the reduction process there were some common traits/factors observed among all of the QAO models.

1. Construction QC is the responsibility of the contractor. "The contractor is, as is any manufacturer, the only one who can control the quality of his work." (Shilstone 1992)
2. Project quality acceptance is always performed by the agency.
3. Final project acceptance is always performed by the agency.
4. The contract verbiage regarding the roles and responsibilities for quality has to be very concise and documented to be successful.
5. The decision as to the QAO of a project has to be determined at the time of the first request for proposal, whether it is design, construction, or both at the same time. The quality management responsibilities have to be clearly laid out in the Request for Proposals in order for the designer and/or the contractor to be able to appropriately provide for the amount of risk they will be assuming on the project.

CHAPTER 4 : CASE STUDIES OF ALTERNATIVE QUALITY MANAGEMENT

4.1 Introduction

Previous chapters focused on the historic and current state of quality management practice and identified the most common quality management models in use in the highway industry. The focus of this chapter is on the ten case studies conducted by the research team and the relevant analyses and observations of those case studies. Case studies formed the bulk of the original research conducted in Phase I of this research project and offered examples of quality management practices delivered under a variety of project conditions, which may serve as models for the organization of quality management systems for future projects.

This chapter begins with a discussion of the protocol and methodology used to conduct the case studies and secure the relevant information from each in a justifiable manner. Included in this section are a breakdown of the case study demographics and an explanation of how the case studies were chosen. Following the section on methodology are truncated versions of the case study summaries. The full case study summaries are presented in the appendices in full detail. A large amount of information is contained in the summaries. In order to assist with comparing among the various studies, tabular summaries of relevant details are presented at the end of the summaries section.

The case study summaries include a description of the general trends observed when comparing the case studies. The cross-case analysis produced a list of potential alternative QM system tools. These tools are associated with applicable QAOs, which furnishes a mechanism by which agencies can determine which tools will be more valuable to a given project's QM requirements. The tools are discussed in detail in in chapter 5.

4.2 Case Study Protocol

While the survey conducted in Task 2 provided some useful insights into the overall state-of-the-practice, the case studies were the primary source of practical applications of innovative quality management techniques in Phase I and for the practices recommended by the guidebook in Phase II. As a result of the central role in the research project, the research team gave serious consideration to how best to conduct the case studies and capture their valuable information.

While researchers may differ in their preference for which research techniques and strategies to use in various situations, case studies represent a valuable tool in the arsenal of any researcher. Case studies are particularly useful in answering questions about how things are done in detail, especially when examining a number of different cases (Yin 2003). In this project, the use of the case study method was essential in capturing not only the unique nature and methods of each project but also understanding questions of why projects were conducted a certain way and how successful those methods were.

One of the traditional arguments against the use of case studies has been their perceived lack of rigor. Recognizing this common criticism, the authors sought to generate a defensible, repeatable method to guide the case study process. This method was formalized and recorded in the case study protocol for the project, which Appendix C presents in detail. Yin (2003) provided guidance in creating the case study protocol.

The case study protocol serves a number of purposes. Primarily it establishes the purpose of the case studies and the questions to be answered by them. While this information was later useful for the case study participants (albeit in a shortened form), clearly stating this information at the start of this crucial document ensured that all researchers who were conducting case study interviews understood the ultimate goals of the research. The background information for the protocol included key sections of the project proposal and work plan like the explicit research objectives and key questions and also included relevant readings which are fundamental to this research.

The most important component of the protocol was the information relating to field procedures which are the heart of the case study protocol and form the bulk of the document. These procedures establish a standard method to conduct all of the case studies and seek to generate consistent and comparable results among the case studies. The key pieces of the field procedures are the case study questionnaire and the case study questions. The questionnaire was one of the first documents to be sent participants. While each case study is unique and the interview process sought to capture that uniqueness, the purpose of the questionnaire was generate a standard set of readily comparable information. To that end, the questionnaire was primarily populated with yes/no questions and matrices of checklists and was specified to be filled for every case study in its entirety.

The section listing case study questions on the other hand was not expected to be answered in its entirety; instead, these questions were supplementary and to be used at the discretion of the researcher. Many of the questions represented in the questionnaire are open-ended questions crafted to generate in-depth discussion to help fill in the details the surveys cannot easily capture. The field procedures also include sample letters to send as well as a flowchart showing the order of key communications with participants.

4.3 Case Study Process

The case study protocol included a minimum of two pilot case studies to evaluate the efficacy of the process before modifying the case study procedures and completing the rest. Rather than conducting the minimum of two, three pilot case studies were conducted to allow each of the three principal research teams an opportunity to become familiar with the case study protocol for this project and provide comments on it or recommendations for changes. One of the key changes, which came out of this, was firmly establishing the order to gather information, as discussed below.

The case study protocol for this project included a particular order of communications and interactions with project participants that was to be followed on every project. First, direct contact was made with the project either over the telephone or in person. While initial inquiries occurred via email, personal contact was vital to every case study. The primary importance of personally contacting the key project participants lay in securing a champion for the research effort. Because participants received no compensation for their time by the research team, it was essential to make contact with participants who expressed enthusiasm about assisting with the research effort and was in a position to coordinate with the rest of the participants on the project.

After securing the support of a project champion, all of the key project participants (typically Owner/agency, designer, and builder quality or project managers) were sent a copy of the case study questionnaire and asked to complete and return it *before* the interview. This was the key change from the pilot case studies. Originally, the priority lay in simply completing the questionnaire before the end of the interview process. However, after the first round of case studies, it was discovered that the questionnaire was too time consuming to fill out in an interview setting and limited the amount of open-ended questions and discussion, which are vital to case studies, which could occur.

Subsequent case study participants were given explicit instructions to return the questionnaires before the interview. While freeing up time for more expansive questions in the interviews, having multiple participants fill out the questionnaire independently exposed differing opinions, which led to further discussion for clarification in the interviews.

After the questionnaires were completed, interviews were conducted with all of the key project staff. While these interviews typically took place with all the participants at once, in some instances, schedule conflicts were too great to overcome and individual interviews were used instead. While interviews were conducted in person as much as possible, due to limited budgets and geographic dispersion of project participants, in several cases interviews were conducted over the phone. When conducted in person, the authors recorded and showed the participants' answers using an electronic projector in real time so they could verify the accuracy of the recorded statements. By combining standard questionnaires with personal interviews, the case studies generated the consistent, comparable data and the unique features of each project that were sought.

The next step in the case study process was the collection of relevant project documents for later review. When possible, these documents were requested in electronic form for easier reproduction and use, though some materials were provided as hard copies. The documents requested included procurement and prequalification documents and project and quality management plans. The information in the documents was used to answer later questions that arose and to examine specific language used.

Finally, once the interview were complete, the information gathered was combined and used to craft the case study reports found in the appendices. When necessary, project participants were contacted after the interview for further clarification, but these contacts were kept to a minimum by the comprehensive nature of the list of case study questions in the field procedures.

4.4 Case Study Selection and Demographics

Given the limited number of case studies that were expected as part of this research, the selection of useful case studies was crucial. Guiding the selection process were a number of criteria that each narrowed the number of possible case studies. Table 4-1 contains a description of the selected case study projects.

Table 4-1 – List of Case Studies

#	Agency	State	Size	Delivery Method	Project	Mode
1	WSDOT	Washington	$18 million	DBB w/eci	George Sellar Bridge	Bridge
2	ODOT, P	Oregon	$135 million	CMGC	Willamette River Bridge	Bridge
3	TriMet	Oregon	$113 million	CMGC	Portland Transit Mall	Transit
4	USACE	Kansas	$175 million	CMGC	Tuttle Creek Dam	Dam
5	UDOT	Utah	$730 million	CMGC	Mountain View Corridor	Highway
6	CDOT, P	Colorado	$29.5 million	DB	US 160 4th Lane Addition	Highway
7	UDOT	Utah	$135 million	DB	I-15 Widening-Beck Street	Highway
8	MnDOT, P	Minnesota	$120 million	DB	Hastings River Bridge	Bridge
9	FDOT	Florida	$1.2 billion	PPP	I-595 Express Corridor	Highway
10	TxDOT	Texas	$1.5 billion	PPP	SH130 Turnpike Extension	Highway

P – Pilot case study

The primary criterion for case study selection was that the projects under consideration utilize some form of alternative quality management. While the range of possible alternative quality management procedures leads is long, this one requirement greatly limits the number of potential case studies as most projects still utilize the baseline delivery and quality management methods.

Next, case studies were selected such that all the major alternative delivery methods, design-build (DB), construction manager/general contractor (CM/GC), and public-private partnership (PPP), were well represented. A concerted effort was made to seek out projects from agencies that were mature in their experience with alternative delivery methods. Related to this effort was the requirement that the list of case studies include at least two projects from non-STAs and one project that utilized the ISO 9000 certification. Projects from the U.S. Army Corps of Engineers (USACE) and TriMet, a regional transit provider in Oregon, were located and used as case studies. In spite of a reasonable search, an ISO 9000 certified project was not identified. However, the USACE project utilized ISO 9000 certified organizations and QM documents, and the concessionaire for FDOT project used ISO 9000 documentation to train its subcontractors on the project's QM system.

The next goal in case study selection was achieving at least a moderate level of geographic dispersion. Although the project was not funded to include significant travel to project sites, a conscious effort was made to ensure that no more than two projects came from the same state and that projects were not clustered in a particular portion of the country. Figure 4-1 shows this dispersion. Lastly, while there was no set dollar value requirement for projects, only those projects of at least moderate size and scope were considered as these were more likely to have sophisticated quality management procedures in use.

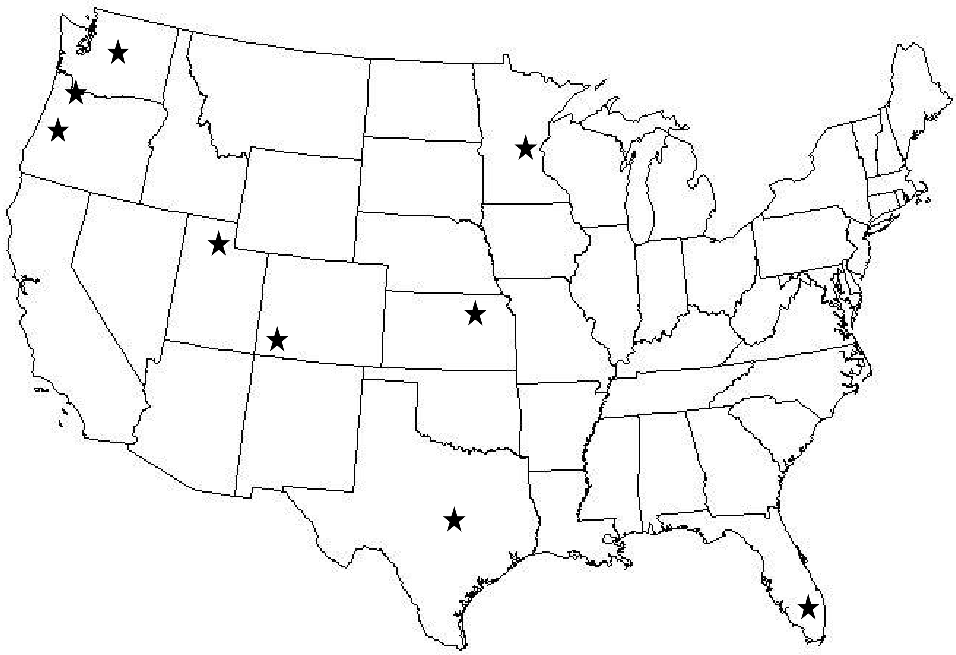

Figure 4-1 – Geographic Dispersion of Case Studies

After all the criteria were considered, 10 suitable projects were identified and used as case studies. As mentioned above, one of the most important aspects of all the projects was identification of a champion for the research effort. To that end, personal contacts of the primary investigators were leveraged to provide a more personal connection to each project when possible with the hope of increasing participant interest and involvement. Of the 10 projects identified there are/is:

- One DBB project utilizing early contractor involvement in the design process
- Two PPP projects
- Three DB projects
- Four CMGC projects (one of which uses the USACE ECI delivery method)
- One dam project
- One transit project
- Three bridge projects
- Five highway projects
- Eight states represented
- $3.8 billion represented

4.5 Case Study Summaries

The following subsections contain brief summaries of each of the ten case studies conducted for this project. Each summary begins with key project data including project name; the name of the agency or owner responsible for the project; the location of the project; the project delivery and procurement methods used; the contract payment type; and a brief description of the nature of the project. The project quality profile provides a quick snapshot of the basic premise of the quality management system used on the project and any notable features of that system. The graphic included with each summary is the QAO diagram for that project. The diagram is a visual representation of who controls which key aspects of design and construction quality management. Further explanation of these diagrams can be found in the full case study reports in the appendices.

The section devoted to QM plans describes whether these plans were required for design or construction and if so, what was required to be in them and when they were required to be submitted. The tables devoted to quality management roles list the primary quality management actions taken on most projects during design and construction and list (in greater detail than the QAO diagrams) who was responsible for what tasks. Following these tables is a list of notable and effective quality management procedures used on the project as determined by the authors.

4.5.1 George Sellar Bridge, Washington

Project Name: George Sellar Bridge Additional Eastbound Lane

Name of Agency: Washington State Department of Transportation (WSDOT)

Location: MP 0.16 to MP 0.39 over the Columbia River between the towns of Wenatchee and East Wenatchee in the state of Washington

Project Delivery Method/Procurement/Contract Type: DBB/A+B+C bidding/Lump sum

Project Description: The primary focus of this project was to add an additional eastbound lane to the George Sellar Bridge in order to substantially increase its capacity. To do so, sidewalks on either side of the roadway were removed and the bridge deck was expanded from 54’ to 61’ wide using the new space. The new configuration accommodates five 11’ wide lanes and a narrow median and shoulders. A 10’ wide cantilevered pedestrian and bike pathway was added to the south side of the bridge and a tunnel was constructed through the East side approach to accommodate a new recreational trail. In order to accommodate the new load and increased traffic area the bridge required significant strengthening of 100 truss members and modification of the parabolic portals at either end of the bridge.

Project Quality Profile: As a traditional design-bid-build project designed by WSDOT staff, the project quality profile exactly matches the baseline quality system. The constructor performed construction quality control and WSDOT performed all other quality functions. The notable feature of this project was its use of a joint WSDOT/AGC panel early in the design process to inform aspects of the design.

QAO: Figure 4-2 shows that the QAO for this project was Deterministic.

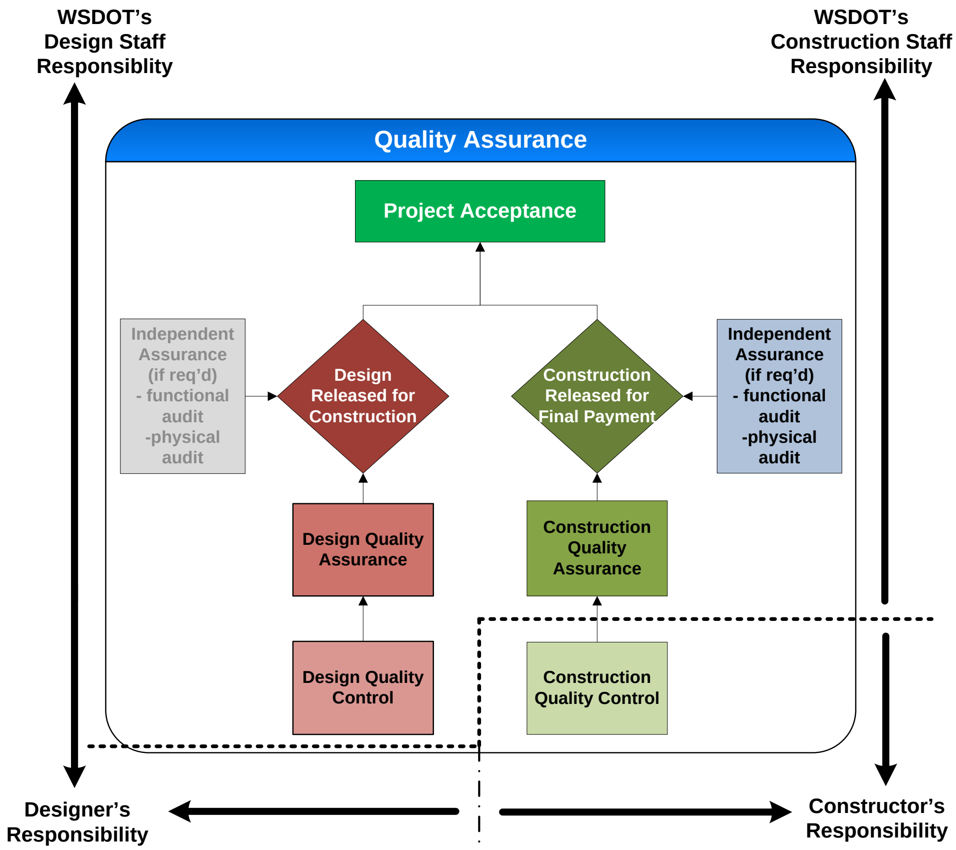

Figure 4-2 – George Sellar Bridge QAO

QA/QC Plans: While this project did use quality management plans on this project, they were more of a minor addition to the larger and more important project management plans (PMPs). WSDOT emphasizes the use of PMPs as the focus of the planning effort and references relevant documents related to quality as needed. For design, the PMP included references to WSDOT's standard design quality management plan included in its Bridge Design Manual. As with design, the focus of the construction planning effort was a PMP, not a unique quality management plan. Instead, the primary quality management requirement was that the contractor conforms to the standard specifications of WSDOT and the special provisions for the project. Included in these documents were specific material and testing requirements or references to WSDOT's materials manual, which lays out acceptable materials and certification tests. The contractor was never required to submit a formal quality control plan.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-2.

Table 4-2 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	✔	✔				
Checking of design calculations	✔					
Checking of quantities	✔					
Acceptance of design deliverables		✔				
Review of specifications	✔	✔				
Approval of final construction plans & other design documents		✔				
Approval of progress payments for design progress	N/A	N/A	N/A	N/A	N/A	N/A
Approval of post-award design QM/QA/QC plans	N/A	N/A	N/A	N/A	N/A	N/A
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of construction shop drawings	✔	✔		✔ cursory		
Technical review of construction material submittals	✔	✔		✔ cursory		
Checking of pay quantities		✔		✔		
Routine construction inspection		✔				
Quality control testing		✔		✔		
Verification testing		✔		✔		
Acceptance testing		✔				
Approval of progress payments for construction progress		✔		✔		
Approval of construction post-award QM/QA/QC plans		✔				
Report of nonconforming work or punchlist.		✔				

Effective QM Practices:

- Use of a joint AGC and WSDOT panel to inform the design process
- Use of pre-bid meetings for clarification

4.5.2 Willamette River Bridge, Oregon

Project Name: Willamette River Bridge

Name of Agency: Oregon Department of Transportation (ODOT)

Location: I-5 over the Willamette River in Lane County at the border of the cities of Eugene and Springfield, OR.

Project Delivery Method/Procurement/Contract Type: CM/GC/Best-Value/Lump sum w/ GMP

Project Description: The primary focus of the Willamette River Bridge project was the construction of two 1800'+ long arch bridges capable of carrying three lanes of traffic. Work included construction of the first bridge, demolition of an existing temporary bridge, and construction of the second bridge. In addition, the project included the repair or replacement of the nearby 100' long Canoe Canal Bridge, realignment and grading work along I-5 to match the new bridges, and construction of sound walls, associated pedestrian trails, and extensive public artwork. The project was conducted above an active railroad corridor, Franklin Blvd, and an exit ramp for Franklin Blvd.

Project Quality Profile: All four of the project parties collaborated on the design quality control function because of the contractor's early involvement in the design process and the presence of Oregon Bridge Delivery Partners (OBDP) a program manager. ODOT provided primary quality assurance functions on the project and was supplemented by OBDP in that role. ODOT's approach to construction quality control was rather restrictive limiting the contractor to only conduction quality control testing and nothing more. Acceptability, confidence, and verification testing were all performed by ODOT.

QAO: Figure 4-3 shows that the QAO for this project was Deterministic.

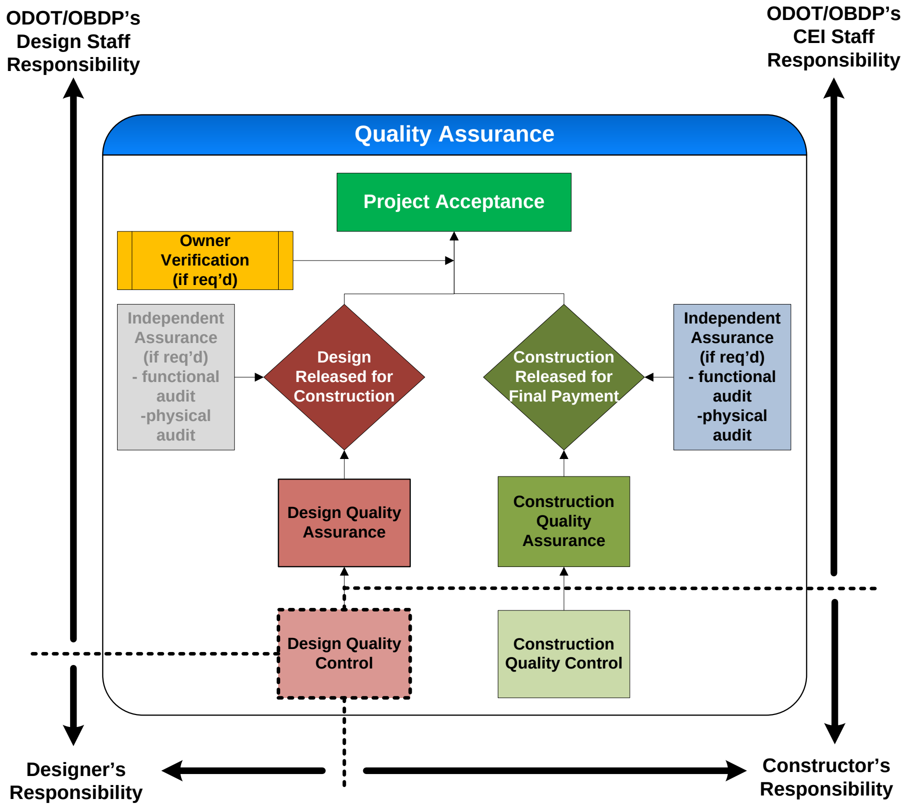

Figure 4-3 – Willamette River Bridge QAO

QA/QC Plans: ODOT required the design team to submit a standard quality control plan to be used by the design team and all of its consultants. The plan was submitted for approval as a part of the design team's proposal and was evaluated in determining which designer to award the contract to. Conversely, the construction quality control plan wasn't a required submittal until after the CMGC contract was awarded. In addition, the construction quality control plan was significantly less detailed than that required of the design team as the project made use of a construction quality management system identical to that used on ODOT design-bid-build projects. The project team went out of its way to ensure that the project looked and felt like a design-bid-build project on the construction side of things.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-3.

Table 4-3 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables		✔	✔			
Checking of design calculations			✔			
Checking of quantities		✔	✔	✔		
Acceptance of design deliverables		✔				
Review of specifications		✔	✔	✔		
Approval of final construction plans & other design documents	✔	✔	✔			
Approval of progress payments for design progress	✔					
Approval of post-award design QM/QA/QC plans	✔					
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of construction shop drawings		✔	✔			
Technical review of construction material submittals		✔	✔			
Checking of pay quantities		✔	✔			
Routine construction inspection		✔ OBDP+ ODOT	✔			
Quality control testing				✔		
Verification testing		✔				
Acceptance testing		✔				
Approval of progress payments for construction progress		✔				
Approval of construction post-award QM/QA/QC plans		✔				
Report of nonconforming work or punchlist.		✔ OBDP+ ODOT				

Effective QM Practices:

- Early contractor involvement in the design process
- Flexibility afforded by CMGC method
- Allowing contractor to use competitive bidding OR negotiated contracts for subcontractors

4.5.3 Portland Transit Mall Revitalization, Oregon

Project Name: Portland Transit Mall (Greenline) Revitalization

Name of Agency: Tri-County Metropolitan Transportation District or Oregon (TriMet)

Location: The Portland Transit Mall is located along SW 5th and 6th Avenues in downtown Portland, OR and stretches 1.4 miles south from Union Station to I-405

Project Delivery Method/Procurement/Contract Type: CM/GC/Best-Value/Cost plus fee w/ GMP

Project Description: The focus of this case study was the construction of a new light rail transit line along 5th and 6th Avenues, which was part of a larger revitalization of the whole Portland Transit Mall. The project included substantial utility relocation work both before and during construction of the rail bed, installation of 2.8 miles of light rail track, gantries, and supporting systems (signals, power substations, etc.), and the construction of a triple track turnout loop at the southern extent of the project. In addition, the contract included construction of 12 new light rail stations complete with shelters and signage.

Project Quality Profile: All three of the project parties collaborated on the design quality control function as a result of the CMGC delivery method and the contractor's early involvement in the design process. TriMet provided all primary quality assurance functions on the project and was supplemented with inspection staff from the city of Portland and local utilities. TriMet permitted the contractor to employ its own quality control inspectors and to perform its own materials testing if the staff were nationally certified for the work. Confidence testing was performed at the discretion of TriMet's resident engineer by 3rd party testing labs kept on-call by TriMet. The project was marked by close collaboration between the contractor's quality control manager and TriMet's resident engineer.

QAO: Figure 4-4 shows that the QAO for this project was Deterministic.

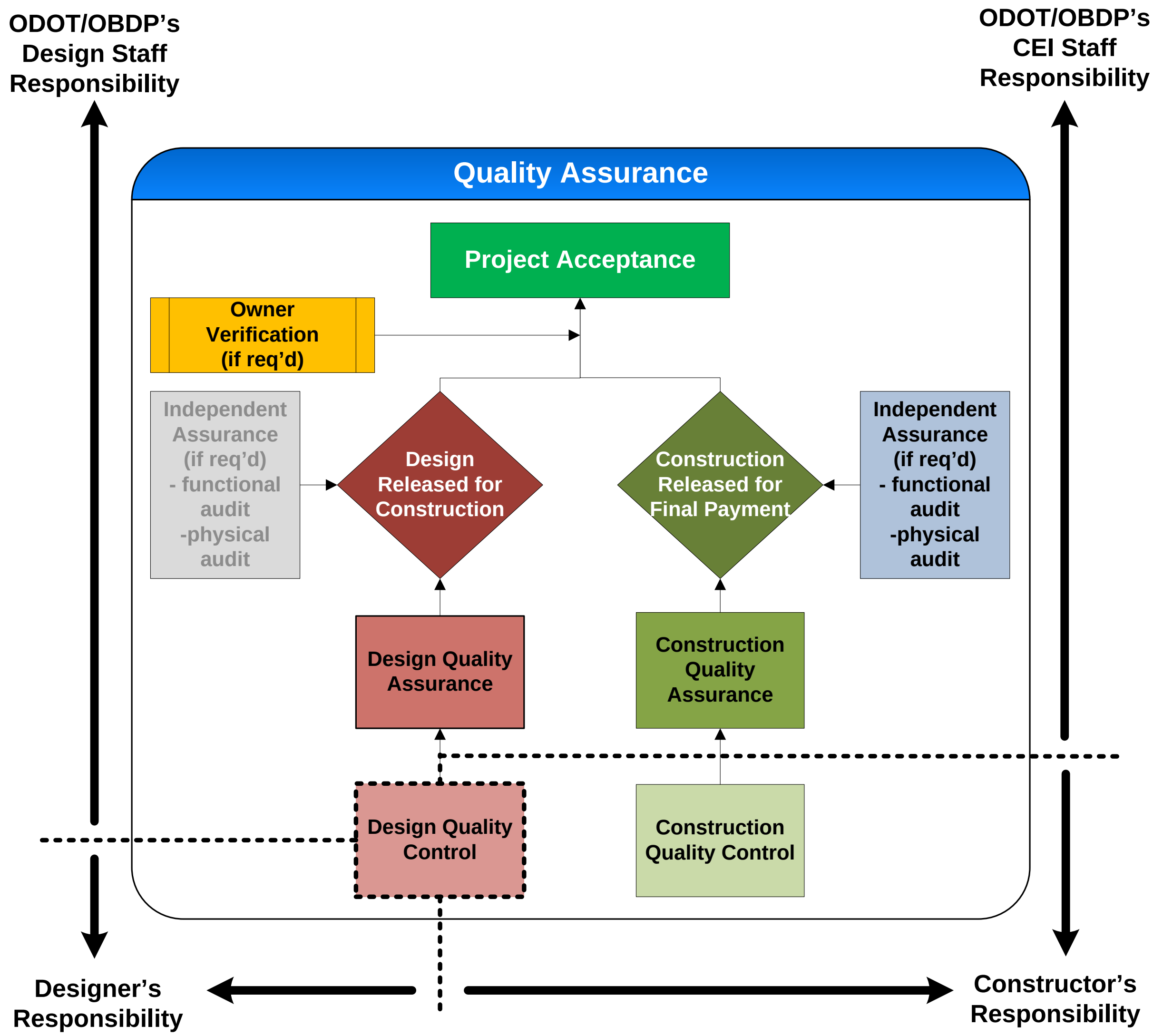

Figure 4-4 – Portland Transit Mall QAO

QA/QC Plans: The design QM plans used by TriMet are in some sense standardized across projects and delivery method types. TriMet has a formal quality assurance program approved by the Federal Transit Administration that design quality management plans (for both in-house staff and design consultants) must comply with. The contractor was required to develop a quality control plan and submit it for approval after it was awarded the project, it was not an evaluation criteria in the procurement process.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-4.

Table 4-4 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	N/A	✔	✔	✔		
Checking of design calculations	N/A	✔	✔			
Checking of quantities	N/A	✔	✔	✔		
Acceptance of design deliverables	N/A	✔	✔			
Review of specifications	N/A	✔	✔	✔		
Approval of final construction plans & other design documents	N/A	✔	✔			
Approval of progress payments for design progress	N/A	✔				
Approval of post-award design QM/QA/QC plans	N/A	✔				
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of construction shop drawings	N/A	**S**	**P**			
Technical review of construction material submittals	N/A	**P**	**S**			
Checking of pay quantities	N/A	**P**				
Routine construction inspection	N/A	**S**		**P**		
Quality control testing	N/A			**P**	**S**	
Verification testing – Note 1	N/A	**P**			**P**	
Acceptance testing	N/A			**P**		
Approval of progress payments for construction progress	N/A	**P**				
Approval of construction post-award QM/QA/QC plans	N/A	**P**				
Report of nonconforming work or punchlist.	N/A	**S**	**S**	**P**		

P – Primary responsibility; S – Secondary responsibility

Effective QM Practices:

- Contractor involvement early in the design process
- Electronic recording and submission of daily reports
- Allowing contractor utilize own inspectors for QC and materials testing
- Use of CMGC delivery method

4.5.4 Tuttle Creek Dam Safety Assurance Project, Kansas

Project Name: Tuttle Creek Dam Safety Assurance Project

Name of Agency: US Army Corps of Engineers (USACE)

Location: Tuttle Creek, north of the City of Manhattan in Kansas, along the Big Blue River

Project Delivery Method/Procurement/Contract Type: Corps Early Contractor Involvement (ECI)/Best-Value/Progressive GMP

> Note: ECI is the terminology used by USACE for a CMGC delivery method. It should not be confused with the ECI delivery method used in Europe and for the remainder of this report will be referred to as a CMGC delivery method.

Project Description: The Tuttle Creek Dam Safety Ground Modification Project is the largest Dam Safety, ground modification project on an active Dam that has ever been performed. This project consisted of multiple contracts to make various repairs to the dam. The Ground Modification base contract was awarded in 2005 to Treviicos South for $49M (this was the ECI/CMGC Contract). A contract to provide structural reinforcement and bearing rehabilitation on the 18 Spillway Tainter Gates was awarded in 2007 and completed in 2010 for $10M. The wire ropes for the Tainter Gates will be replaced in 2011 and 2012.

Project Quality Profile: The quality management system that was used on this project was not substantially different from that used by other agencies. USACE has documentation outlining the approach to quality assurance and quality procedures on projects. Also, an individual project specific quality management plan was written for the Tuttle Creek Dam project. The construction, design and project management organizations were all ISO certified.

QAO: Figure 4-5 shows that the QAO for this project was Deterministic.

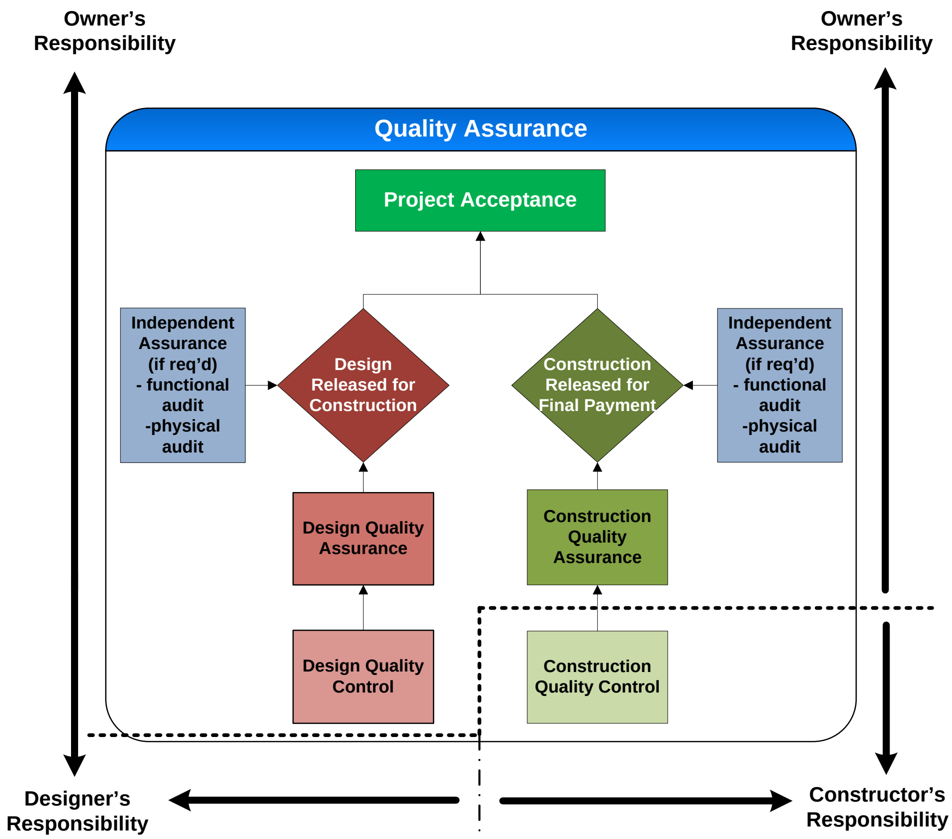

Figure 4-5 – Tuttle Creek Dam Safety Assurance Project QAO Model

QA/QC Plans: The design QM plans used on this project were different from design-bid-build (DBB) projects because this was a one of a kind design that involved both an advisory panel of experts as well as allowing for the construction contractor to participate in the design review process to help improve quality. The QM plan was not different as such, but it emphasized how heavily the government intended to rely on the construction contractors input. The construction QM plans used on this project were no different from the QM plans used on traditional DBB construction projects.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-5.

Table 4-5 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔		✔	✔
Checking of design calculations	✔			
Checking of quantities	✔		✔	
Acceptance of design deliverables	✔		✔	✔
Review of specifications	✔		✔	✔
Approval of final construction plans & other design documents	✔			✔
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔		✔	
Technical review of construction material submittals	✔		✔	
Checking of pay quantities			✔	
Routine construction inspection			✔	
Quality control testing			✔	
Verification testing			✔	
Acceptance testing			✔	
Approval of progress payments for construction progress				
Approval of construction post-award QM/QA/QC plans				
Report of nonconforming work or punch list.			✔	

Effective QM Practices: The following is a list of effective practices used on USACE projects.

- Advisory Panel
- Resident Management System (RMS) - An automated system for submittal and document control.
- Design check - The designer must have his work checked by highly experienced technical person before each design submittal. This checking procedure is essential to the production of a quality product.
- Quality control checklists - Checklists for designers and their checkers to ensure completeness.

- Interdisciplinary checks - Interdisciplinary coordination is a key element of the QCP. The checks are usually conducted by the design team members who check each other's work to assure compatibility.
- District Quality Control (DQC) Review - An internal peer review for quality control.
- Agency Technical Review (ATR) - An ATR is an independent technical review, which is a critical examination by a qualified person or technical team outside the submitting district.
- Independent External Peer Review (IEPR) - An IEPR is an independent review of the technical efficacy of a decision document by a review organization external to USACE.
- Quality management review - Quality management reviews to assure that USACE Regulations are met.

4.5.5 Mountain View Corridor Project, Utah

Project Name: Mountain View Corridor (MVC) Project

Name of Agency: Utah Department of Transportation (UDOT)

Location: The Mountain View Corridor encompasses Salt Lake County west of Bangerter Highway between I-80 and the Utah County border

Project Delivery Method/Procurement/Contract Type: CM/GC/Best-Value/GMP

Project Description: Initial construction includes building two outside lanes in each direction with signalized intersections where future interchanges will be located. This new roadway requires extensive grading and excavation, relocating utilities, acquiring property, constructing drainage systems, building bridges and structures, and laying new pavement. Trail sections will also be built. Future construction will build out the remainder of the corridor by adding interchanges and more lanes to achieve a fully functional freeway.

Project Quality Profile: UDOT will provide some quality control and all quality assurance for the Project. The contractor is responsible for assuring the quality of the work of the subcontractors at all levels. UDOT or its designee will perform limited inspection and testing to audit and verify that all work and materials comply with the drawings, specifications, and all reference standards. Audits will be performed on a systematic basis and will be coordinated with the Quality Control Plan or as warranted by general quality trends.

QAO: Figure 4-6 shows that the QAO for this project was Assurance.

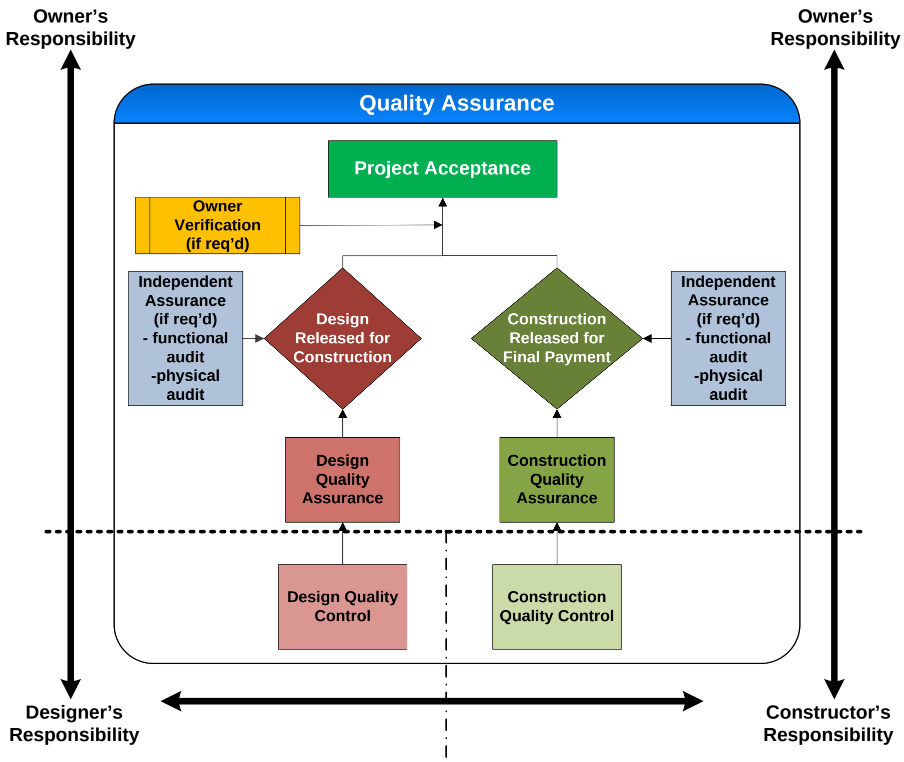

Figure 4-6 – Mountain View Corridor QAO

QA/QC Plans: The design QM plans are no different from the QM plans used on traditional design projects. For UDOT the delivery method does not affect the quality methods. The quality methods are driven by the size of the project. The contractor was required to develop, implement, and maintain a Quality Control Plan. The Quality Control Plan had to include, at a minimum, provisions for continued education and training, toolbox meetings, various meetings with subcontractors and suppliers, and other activities. In addition, the Quality Control Plan had to include the Contractor assuring the quality of the work of the subcontractors at all levels.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-6.

Table 4-6 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔	✔	
Checking of design calculations		✔		
Checking of quantities		✔	✔	
Acceptance of design deliverables	✔			
Review of specifications	✔	✔	✔	
Approval of final construction plans & other design documents		✔		
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans		✔		
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings		✔	✔	
Technical review of construction material submittals	✔		✔	
Checking of pay quantities	✔		✔	
Routine construction inspection	✔		✔	
Quality control testing			✔	
Verification testing	✔		✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔	✔		
Report of nonconforming work or punch list.	✔		✔	

Effective QM Practices: The following practices are used on the MVC project and lead to enhanced quality:

- Project Records File and Distribution System
- Regular Project Team Meetings
- Reviews - The contractor is required to participate in formal constructability and material availability reviews that are conducted at up to four milestones throughout the Project.
- Quality Personnel Education and Training - The extent of training is to correspond with the following:
    - Scope, complexity, and nature of the activity
    - Education, experience, and proficiency of the person
    - Specific requirements of the Contract Documents

- Goal-Setting Session - The Contractor was required to participate in an initial goal-setting session with UDOT

4.5.6 U.S. 160 4th Lane Addition, Colorado

Project Name: U.S. 160 4th Lane Expansion

Name of Agency: Colorado Department of Transportation (CDOT)

Location: U.S. 160 at Farmington Hill Interchange/Wilson Gulch in Grandview Colorado just east of Durango, CO

Project Delivery Method/Procurement/Contract Type: Modified Design-build (Low bid procurement)

> Note: Modified DB is a CDOT alteration on standard practice for DB. Modified DB contains a higher level of initial design and is awarded on a low-bid best value basis. For the remainder of this report, this case study will be listed simply as using a DB delivery method.

Project Description: The project included the design and construction of four bridges in mountainous terrain and crossing U.S. 160 and the environmentally-sensitive Wilson Gulch. Highly-curved ramp geometries, high settlement soils and a limited construction season created design challenges which were overcome to deliver a successful design.

Project Quality Profile: CDOT was responsible for all quality assurance and independent assurance on the project. The design builder was responsible for all quality control, both design and construction. Outside of the design builder having the responsibility for design QC, the project quality management was no different than a design-bid-build project. CDOT does use the same quality management system across all project, regardless of delivery method. CDOT performed testing on all materials; it appears that quality management system for the construction was heavily directed by the agency. The lack of a design builder created construction QC plan is further evidence that the construction quality management was directed by CDOT.

QAO: Figure 4-7 shows that the QAO for this project was Oversight.

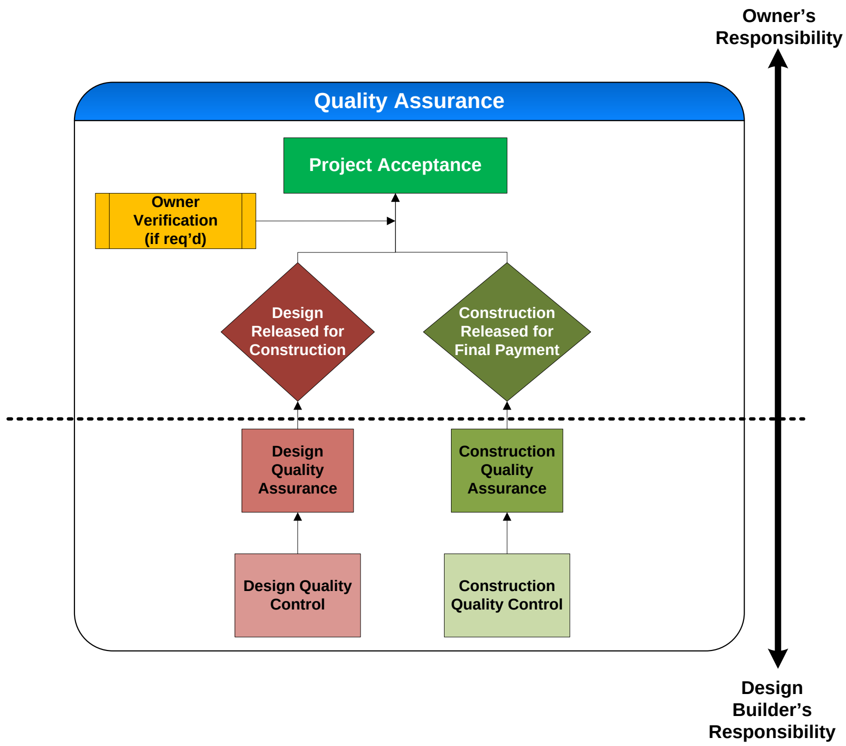

Figure 4-7 – U.S. 160 4th Lane Addition QAO

QA/QC Plans: The primary quality management plan in place for this project was the design quality control plan (DQCP) which was created by the designer on the design-build team. This plan had to be submitted and approved by CDOT before any work could begin. CDOT required a quality control plan to be created by the design builder, but it appears that the DQCP was the document that was what all parties referred to when asked about QA/QC plans for the project.

Quality Management Responsibility Allocation:

Table 4-7 shows a summary of design and construction QM roles.

Table 4-7 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔		
Checking of design calculations			✔	
Checking of quantities	✔	✔	✔	
Acceptance of design deliverables	✔			
Review of specifications		✔		
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔	✔		
Technical review of construction material submittals	✔	✔		
Checking of pay quantities	✔			
Routine construction inspection	✔			
Quality control testing	✔			
Verification testing	✔		✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔			

Effective QM Practices: Design quality control forms that were included as parts of the appendix of the DQCP were very effective in tracking and organizing the various Design QC processes.

4.5.7 I-15 Widening, Beck Street Project, Utah

Project Name: I-15; Widening, 500 North to I-215

Name of Agency: Utah Department of Transportation (UDOT)

Location: I-15, 500 North to I-215, Utah

Project Delivery Method/Procurement/Contract Type: DB/Best-Value/Lump Sum

Project Description: The project consists of the reconstruction of Interstate 15 from 500 North in Salt Lake City to the I-215 overpass in Davis County. The project includes the design, reconstruction, and widening of the mainline highway to include an Express Lane and three general purpose lanes in each direction. The work includes the total reconstruction of Mainline I-15 between 500 North and the I-215 overpass. UDOT requires removal and replacement of the existing Beck Street Bridge with twin 600-feet, four-span bridges. Additionally, the 1100 North and U.S. 89 bridges will be replaced with two-span rapid bridges. The 800 North Bridge will be removed permanently.

Project Quality Profile: The Quality Management plans used on this project were the same as those used on traditional UDOT projects, except the tracking and administration was handled differently. This was because the goals were the same with regards to testing requirements etc. except payment was not by quantity. Lump Sum payment was used; therefore quantities were recorded separately for verification testing.

QAO: Figure 4-8 shows that the QAO for this project was Oversight.

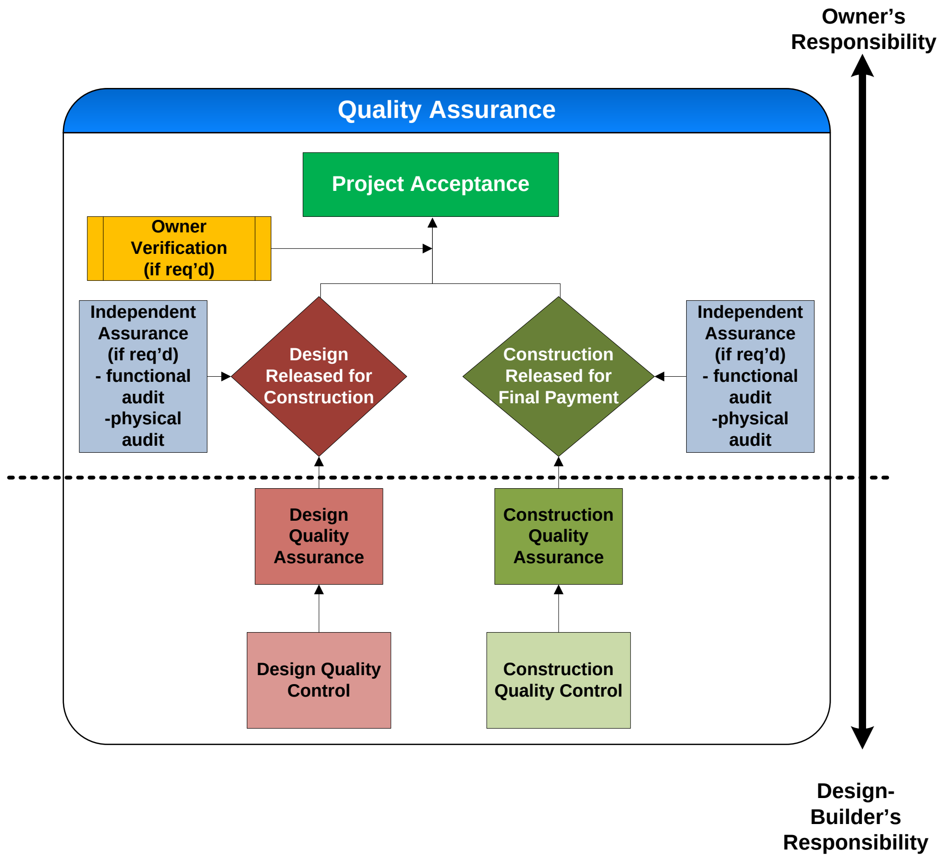

Figure 4-8 – I-15 Widening QAO Model

QA/QC Plans: UDOT specified that the Quality Management Plan (QMP) had to include procedures for design-builder construction quality control, design quality control and assurance, and Agency inspection and testing. The Design-Builder had the primary responsibility for the overall quality of the work including the quality of work produced by subcontractors, fabricators, suppliers, and vendors. An IQF was not required for this project. UDOT was to conduct oversight and inspection for the project.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-8.

Table 4-8 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔	✔	
Checking of design calculations		✔		
Checking of quantities		✔		
Acceptance of design deliverables	✔			
Review of specifications	✔	✔	✔	
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔			
Technical review of construction material submittals	✔			
Checking of pay quantities	✔			
Routine construction inspection	✔			
Quality control testing			✔	
Verification testing			✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔			

Effective QM Practices: The following procurement and project n practices helped the project achieve enhanced quality:

- One-on-One Meetings - The Agency conducted one-on-one meetings with each Proposer to discuss issues and clarifications regarding the RFP and Proposer's ATCs.
- Alternative Technical Concept (ATCs) Process -_A process for pre-Proposal review of ATCs that conflict with the requirements for design and construction of the Project, or otherwise require a modification of the technical requirements of the Project.
- Competitive Range - The term "Competitive Range" means a list of the most highly rated Proposals, based on initial Technical Proposal ratings and evaluations of Price Proposals, which were judged by the Agency to have a reasonable chance of being selected for award.

- Summary of Innovation and Enhanced Quality - The Proposers were to prepare a summary of no more than three pages that outlined the specific areas in which the Proposer had introduced innovation and provided enhanced quality in long-term performance, durability, or maintainability.
- Document Control - The QMP had to specify procedures for meeting documentation requirements, for document control and for the specific responsibilities of personnel to satisfy these requirements.
- Over-the-Shoulder Design Reviews - The DQM was to conduct design reviews.
- Milestone (30% and 60%) Reviews - The DQM was to conduct formal milestone reviews.
- Incentive/Disincentive Program

4.5.8 Hastings Bridge Project, Minnesota

Project Name: TH61 Hastings Bridge Design-Build Project

Name of Agency: Minnesota Department of Transportation (MnDOT)

Location: T.H. 61 over the Mississippi River along the border of Washington and Dakota County, Minnesota within and near the City of Hastings.

Project Delivery Method/Procurement/Contract Type: Design-Build/Best-Value/Lump Sum

Project Description: The Project scope is to design and construct a new four-lane bridge over the Mississippi River, remove the existing 2-lane bridge, and construct the approaches on the north and south sides of the bridge.

Project Quality Profile: The overall quality approach required the Contractor to develop, implement, and maintain a quality management system that encompassed the design and construction quality aspects, and documentation requirements for the Project. In addition, ATCs were used to permit the design-builder to literally negotiate the design quality criteria and the process for submitting and evaluating them was set forth in the Instructions to Proposers (ITP).

QAO: Figure 4-9 shows that the QAO for this project was Oversight.

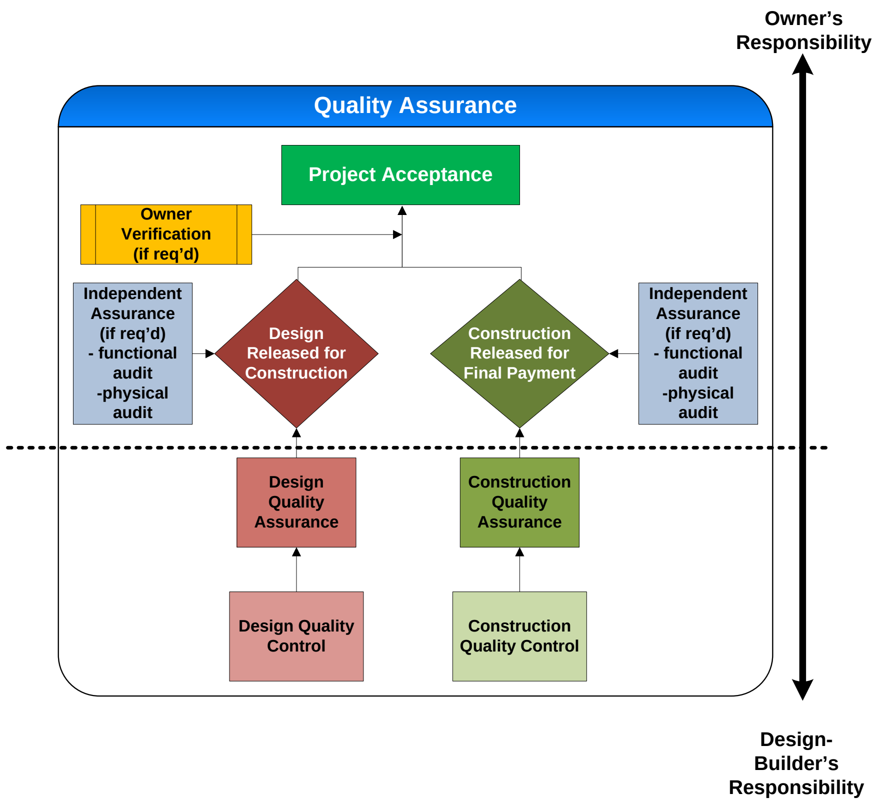

Figure 4-9 – Hastings Bridge QAO Model

QA/QC Plans: The quality management process used on this project was a formal one that was project specific. The Contractor's quality management system had to contain a Quality Manual (QM) that encompassed all Contract requirements with regard to design, construction, and documentation for all quality processes. The Quality Manual also included an Inspection and Testing Plan describing all of the proposed inspections and tests to be performed throughout the construction process. MnDOT had provided a Construction Quality Inspection and Testing Plan in the Quality Manual Template. The Contractor was to tailor the Inspection and Testing Plan to meet the Project requirements.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-9.

Table 4-9 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔		
Checking of design calculations		✔		
Checking of quantities		✔		
Acceptance of design deliverables	✔			
Review of specifications		✔		
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔	✔		
Technical review of construction material submittals	✔			
Checking of pay quantities				
Routine construction inspection	✔		✔	
Quality control testing			✔	
Verification testing	✔			
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔		✔	

Effective QM Practices: The following practices were implemented for the project and contributed to managing the quality of the project:

- ATC/PAE Process -_Approved ATCs were known as Pre-Approved Elements (PAEs). MnDOT then conducted one-on-one meetings with proposers to discuss ATCs and the Proposers were able to incorporate one or more acceptable ATCs in to their proposal.
- Disciplinary Task Forces - Each task force will focus on a specific discipline of work.
- Over-the-shoulder design reviews - Informal examinations by MnDOT of design documents during the project design process.
- In-Progress Design Workshops -_Throughout the design process, the Contractor or MnDOT could request in-progress design workshops to discuss and verify design progress and to assist the Contractor and/or its designer(s) in resolving design questions and issues.

- Quality Oversight Visits - During the design process, MnDOT could make oversight visits to discuss and verify design progress and ascertain the overall progress of the Project with respect to the Contractor's Quality Manual.
- Disincentive - Subject to MnDOT's determination, MnDOT could assess the Contractor a $100-per-hour monetary deduction for failure to facilitate satisfactory progress or completion of the Work.

4.5.9 I-595 Express Corridor Improvements Project, Florida

Project Name: I-595 Express Corridor Improvements Project

Name of Agency: Florida Department of Transportation (FDOT)

Location: Broward County, FL

Project Delivery Method/Procurement/Contract Type: Public-Private-Partnership (P3), 2 step process for procurement, lump sum for design, construction, operate, and maintenance

Project Description: The I-595 Express Corridor Improvements Project consists of the reconstruction of the I-595 mainline and all associated improvements to frontage roads and ramps from the I-75/Sawgrass Expressway interchange to the I-595/I-95 interchange, for a total length along I-595 of approximately 10.5 miles, and approximately 2.5 miles on Florida Turnpike from Peters Road to Griffin Road. The design and construction cost of the project is approximately $1.2 billion.

Project Quality Profile: Because the project is PPP, and the concessionaire will be operating the project for 30 years, the concessionaire held the majority of the responsibility of the quality responsibilities, which equates to the acceptance quality assurance organizations, as shown in Figure 4-10. FDOT did hire several engineering consultants such as the design manager and the Oversight Construction Engineer Inspector (OCEI). Overall, the design manager's responsibility was to make sure that the produced design met the requirements of the contract. FDOT and the design manager did have more involvement in the design when it came to elements of the project that were related to safety, such as bridges, and traffic control. The OCEI was responsible for conducting statistical sampling verification testing regarding the Concessionaire's Construction Engineering Inspection.

QAO: Figure 4-10 shows that the QAO for this project was Acceptance.

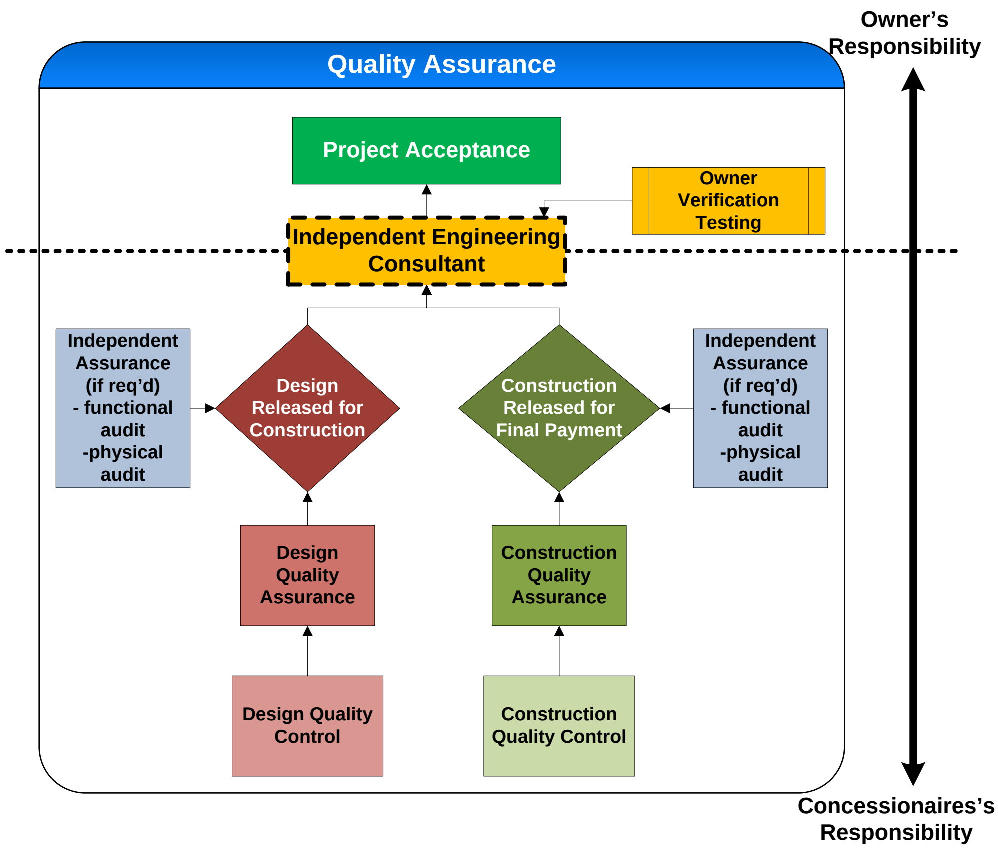

Figure 4-10 – I-595 Express Corridor Improvements Project QAO

QA/QC Plans: The concessionaire holds most of the risk associated with gaining a quality product, in that they are responsible for operation and maintenance of the corridor for 30 years after construction. To ensure that quality was a priority, part of the contract required submission and approval of a QA and QC plan for both design and construction before work began. The concessionaire created an overall QM plan, while the designer created the design QM, QA, and QC plans and the design builder created the construction QM, QA, and QC plans.

Quality Management Responsibility Allocation Summary

For this case study independent questionnaires were received from the design builder (D), the concessionaire (C), the agency (A) and the engineer (E). Not all four responded the same way to the questionnaire, thus table 4-10 shows how each party responded.

Table 4-10 – Summary of design and construction QM roles

Responsible Party (select all that apply)						
Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	☐	☐	☒	☐	☐	☒1
Checking of design calculations	☐	☐	☐	☐	☒	☒2
Checking of quantities	☐	☐	☐	☐	☐	☒2
Acceptance of design deliverables	☐	☒	☐	☐	☐	☐
Review of specifications	☐	☒	☒	☐	☒	☒2
Approval of final construction plans & other design documents	☐	☒	☐	☐	☐	☐
Approval of progress payments for design progress	☐	☐	☐	☐	☐	☒2
Approval of post-award design QM/QA/QC plans	☐	☒	☐	☐	☐	☒2
Other: 1 – Is FDOT design construction; 2 – Is the Concessionaire						
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of construction shop drawings	☐	☐	☒	☒	☒	☐
Technical review of construction material submittals	☐	☐	☒	☒	☒	☐
Checking of pay quantities	☐	☐	☐	☐	☐	☒
Routine construction inspection	☐	☐	☐	☒	☐	☐
Quality control testing	☐	☐	☐	☒	☐	☐
Verification testing	☐	☐	☐	☐	☐	☒
Acceptance testing	☐	☐	☐	☐	☒	☐
Approval of progress payments for construction progress	☐	☐	☐	☐	☐	☒
Approval of construction post-award QM/QA/QC plans	☐	☐	☐	☐	☐	☒
Report of nonconforming work or punchlist.	☐	☐	☐	☒	☒	☐
Other: Concessionaire and Concessionaire CEI						

D – Design Builder; A – Agency; C – Concessionaire; E – Engineer

Effective QM Practices:

- The dual Construction Engineer Inspection process where there is an oversight CEI (OCEI) hired by the agency and a CEI hired by the concessionaire (CCEI). The CCEI is responsible for the construction inspections on the project, while the oversight CEI audits the CCEI based on a statistical sampling process. This has been very successful, however because this was a new concept it took about a year to establish an understanding as to how the two CEI's can best work together for the betterment of the project.
- During the construction phase unique electronic inspection and testing request were implemented as part quality management system for all subcontractors to follow. This process included converting emails to text messages to be received by people in the field without email.
- Two major procedures of the quality system, which affect all project work, are the witness and hold procedure and the testing and sampling (TSR) procedure, initiated by subcontractors, inspected by the design builder QC and verified by the CCEI. All work and materials used to advance the project are recorded and regulated by multiple parties (contractor's QC staff, CCEI, OCEI).
- This project had many subcontractors that had never worked on a FDOT project, much less one that was a P3 project and had requirements for both FDOT and the concessionaire. Every subcontractor had to be trained on FDOT requirements and the Concessionaire team requirements, which included the submittal of quality management plans by the subs and material suppliers. The training also included concepts of different quality management processes/philosophies such as ISO 90001 etc. ISO was also included as reference materials to the training and development of the subs quality management plans.

4.5.10 SH 130 Turnpike Project, Texas

Project Name: SH 130 Turnpike Project Exclusive Development Agreement

Name of Agency: Texas Department of Transportation (TxDOT) **–** Texas Turnpike Authority

Location: SH 130 through Travis and Williamson Counties, Texas

Project Delivery Method/Procurement/Contract Type: PPP/Best-Value/Guaranteed Lump Sum (Exclusive Development Agreement).

Project Description: State Highway (SH) 130 is an approximately 49-mile new toll-way extending from IH-35 near SH 195, north of Georgetown, Texas Southward to US Highway 183 southeast of Austin. SH 130 is a four-lane controlled-access toll-way with discontinuous frontage roads and directional interchanges where warranted. Work for this project included the design, right-of-way acquisition, utility adjustment, construction, and fifteen years of capital maintenance (if elected by TxDOT).

Project Quality Profile: The SH 130 project QC/QA program consisted of four inter-dependent components: the Quality Control (QC) Program, the Owner Oversight Program, the Independent Assurance (IA) Program, and the independent Construction Quality Assurance (CQA) Program. TxDOT developed a project-specific quality assurance program (QAP) for the SH130 project. In addition to safeguards in the QAP, the EDA had several measures to ensure the quality of workmanship and materials in the project. The measures were broken into three basic categories including quality control, acceptance testing and inspection, and owner verification.

QAO: Figure 4-11 shows that the QAO for this project was Acceptance.

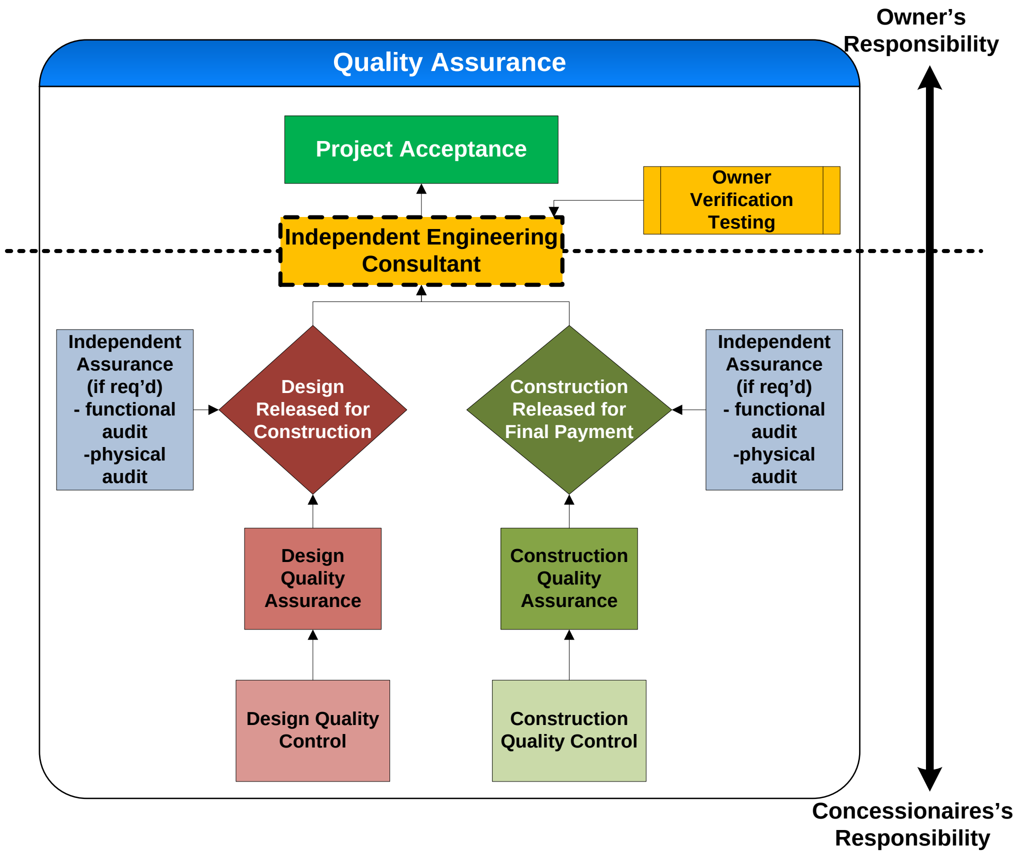

Figure 4-11 – SH 130 Turnpike QAO

QA/QC Plans: The SH 130 was the first design-build highway infrastructure project in Texas where contractor QC testing was used in the acceptance decision for all project-produced materials. An enhancement to the previous owner verification process was the new three-tiered approach. In this approach Level 1 is applied to the tests which are strong indicators of performance and provides the highest level of confidence in the contractor's QC testing. Level 2 is applied to tests that are secondary indicators of performance. Level 3 is applied to tests with extremely low test frequencies.

Quality Management Responsibility Allocation: A summary of design and construction QM roles is shown in table 4-11.

Table 4-11 – Summary of design and construction QM roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables		✓		✓
Checking of design calculations		✓		✓
Checking of quantities		✓		✓
Acceptance of design deliverables	✓			✓
Review of specifications		✓		
Approval of final construction plans & other design documents	✓			✓
Approval of progress payments for design progress		✓		
Approval of post-award design QM/QA/QC plans	✓			
Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings		✓		
Technical review of construction material submittals			✓	
Checking of pay quantities			✓	
Routine construction inspection			✓	✓
Quality control testing				✓
Verification testing			✓	✓
Acceptance testing			✓	
Approval of progress payments for construction progress	✓			
Approval of construction post-award QM/QA/QC plans	✓			✓
Report of nonconforming work or punchlist.				✓

Effective QM Practices: Effective QM Practices that contributed to the success of the SH 130 Project are described below:

- Co-location: Due to the magnitude of the project, it was critical for all parties to be co-located on the project.
- Escalation Matrix: An escalation matrix was developed to provide a clear chain of command for escalating issues that could not be agreed upon, while promoting the resolution of issues at the lowest possible levels.
- Clarification Requests and Reports: Field clarification requests were used to clarify plans that had disconnects or discrepancies. Construction Deficiency Reports and Non-Conformance Reports were used to track non-conforming materials and workmanship.
- The Web-Based EDMS: The Electronic Laboratory Verification Information System (ELVIS) is a set of web-based data management and engineering analysis tools originally

developed to process material testing data and to transmit them electronically to TxDOT for statistical validation. To meet the project needs, ELVIS was further expanded to support CQAF construction inspection reporting and manage pavement surface ride quality.

- Industry Review Process: The industry review process included the development of a risk allocation table as a trade-off with the proposers and includes a reiterative cycle of subtasks.

4.6 Case Study Synthesis

This section includes a series of tables summarizing the key details of all the case studies. The purpose of these tables is to provide a visual manner in which to compare the various case studies and recognize key trends. While these tables certainly do not tell the full story of any of the case studies and cannot capture all of the unique features of and methods used on each project, they are nonetheless useful for distilling each project into its key quality constituents.

4.6.1 Relationship between Delivery Method and QAO

Table 4-12 lists the case studies along with their delivery, procurement, and payment methods and their identified QAO type as well. While it is theoretically possible to use a number of different QAO models for a given project delivery method, the case studies analyzed suggest that certain QAOs may be well suited for particular delivery methods. For example, while a project using the PPP delivery method could theoretically structure its QAO to include the owner in design or construction quality management roles, such a system was not found in the case studies. Instead, of the two PPP projects studied, both utilized the Acceptance QAO in which the owner only performs project acceptance and delegates the remaining QM roles and responsibilities.

Table 4-12 – Delivery, Procurement, and Payment Methods and QAO

#	Agency	Name	QAO	Delivery Method	Procurement Method	Payment Provisions
1	WSDOT	George Sellar Bridge	Deterministic	DBB w/eci	Best value	Lump sum
2	ODOT	Willamette River Bridge	Deterministic	CMGC	Best value	GMP
3	TriMet	Portland Transit Mall	Deterministic	CMGC	Best value	GMP
4	USACE	Tuttle Creek Dam	Deterministic	CMGC	QBS	Prog. GMP
5	UDOT	Mountain View Corridor	Assurance	CMGC	Best value	GMP
6	CDOT	US 160 4th Lane Addition	Oversight	Mod. DB	Low bid	Lump sum
7	UDOT	I-15 Widening-Beck Street	Oversight	DB	Best value	Lump sum
8	MnDOT	Hastings River Bridge	Oversight	DB	Best value	Lump sum
9	FDOT	I-595 Express Corridor	Acceptance	PPP	Best value	Lump sum
10	TxDOT	SH130 Turnpike Extension	Acceptance	PPP	Best value	Lump sum

GMP – Guaranteed Maximum Price; QBS – Quality Based Selection;
Prog. GMP – Progressive GMP, multiple bid packages with separate GMPs for each package

All three of the case studies using the DB delivery method used the Oversight QAO model. The Oversight QAO leaves all design and construction QA and QC functions in the hands of the designer, contractor, or design-builder. While an owner could retain a QA function if desired as found in the Assurance QAO, this was not found in the case studies examined.

Similarly, while a project using DBB delivery could potentially allow the contractor to assume a quality assurance role as found in an Assurance QAO, the baseline QAO and the one used on the WSDOT project studied was the Deterministic QAO. The Deterministic arrangement of quality roles accurately reflects the baseline QM system and it would be expected to be found on most DBB projects.

In contrast, the case studies, which used the CMGC delivery method, showed slightly more variation in their QAOs. While three of the case studies utilized a Deterministic QAO, the fourth, Mountain View Corridor, made use of an Assurance QAO. The Assurance QAO allows the designer to perform its own design QC without interference from the owner and its use on the Mountain View Corridor project may reflect UDOT’s long period of experience and comfort with the CMGC delivery method.

Table 4-13 provides a succinct summary of the QM roles and responsibilities, which must be assigned under each QAO model. Only four of the five QAO models were found in the case studies as none of them made use of the Variable QAO. The QAOs show very little variation for the most part. However, case studies 2 and 3, which both used the CMGC delivery method, as shown in table 4-13 show some deviation from the other case studies using Deterministic QAOs. The primary difference is the sharing of the design QC function between the owner, designer, and builder. In fact, were it not for the sharing of this role, these case studies would have been listed as using an Assurance QAO. On each of these projects however, the owner wanted to maintain an active role in design QC despite outsourcing most of the projects’ design.

Table 4-13 – Summary of Varying Quality Roles

Quality Management Roles and Responsibilities																						
#	QAO	Project Acceptance			Design QC			Design QA			Const. QC			Const. QA			Indep. Assurance			OVT		
		O	D	B	O	D	B	O	D	B	O	D	B	O	D	B	O	D	B	D	B	B
1	Deterministic	✔			✔			✔					✔	✔			✔					
2	Deterministic	✔			✔	✔	✔	✔					✔	✔			✔			✔		
3	Deterministic	✔			✔	✔	✔	✔					✔	✔			✔			✔		
4	Deterministic	✔			✔			✔					✔	✔			✔					
5	Assurance	✔				✔		✔					✔	✔			✔			✔		
6	Oversight	✔				✔			✔			✔			✔					✔		
7	Oversight	✔				✔			✔			✔			✔		✔			✔		
8	Oversight	✔				✔			✔			✔			✔		✔			✔		
9	Acceptance	✔			Conc			Conc			Conc			Conc			Conc			✔		
10	Acceptance	✔			Conc			Conc			Conc			Conc			Conc			✔		

O – Owner; D – Designer; B – Builder; Conc – Concessionaire

4.6.2 Documents Required Before Contract Award

Quality management is not a static process but rather is affected by decisions made at all points along a project's timeline from conception to ribbon cutting. One milestone where decisions must be made that will affect the overall quality of the project is just before the release of procurement documents like RFQs and RFPs. Table 4-14 lists the documents that were required to be submitted by interested designers, builders, or design-builders before the award of any contracts for design or construction. Those documents marked with a plus sign were specifically listed as being evaluated as part of the award decision.

Table 4-14 – Summary of Required pre-Award Submittals

Required Proposal/Bid Package Submittals	**Case Study Number**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Qualifications of Design Quality Manager		✔+			✔+		✔+	✔+	✔+	✔+
Qualifications of Construction Quality Manager			✔		✔+		✔+	✔+	✔+	
Qualifications of other QM personnel		✔+		✔+	✔+		✔+	✔+	✔+	
Design quality management plan		✔+			✔+		✔+		✔+	✔+
Design criteria checklists		✔+			✔+				✔+	✔+
Construction quality management/control plan					✔+		✔+		✔+	
Construction testing matrix					✔+			✔		
Quality-based incentive/disincentive features					✔+			✔		
Warranties								✔	✔	✔+

+: Evaluated to make award decision(s)

Four case studies required submission of one of these documents or less before making award decisions. Of these four, three, with the exception of the sole DBB project, required several of these documents were after the award. For the remaining six case studies, the most common documents required were the qualifications of design quality managers (6 case studies), of other QM personnel (6), of the construction quality manager (5), and the design QMP (5). From this information, the owners of these six projects valued incorporating quality into their projects from the start.

4.6.3 Inventory of Emerging Tools

Each of the case studies furnished a number of QM tools considered non-traditional that project participants indicated as beneficial to their project. Table 4-15 lists the primary tools identified and divides them into two groups: those used before the award of design or construction contracts and those used after. Use of the pre-award tools can help to ensure clarity in the procurement process, to modify project requirements, and to adjust quality requirements when it is prudent to do so.

Owner, design-builders and concessionaires can use the post-award tools to improve aspects of QM along all the phases of a project after selecting a designer and contractor. One of the reasons for dividing the tools in this manner was to draw attention to the importance of *when* to incorporate quality in to a project. Traditional QM methods are reactive and emphasize QC testing to evaluate quality after completion of portions of a project. Most of the emerging tools discovered in the case studies are used not to measure if quality standards were met, as in QC testing, but rather to plan for and build quality into the project long before any designs are complete or any construction is started. Later research efforts will explore under what circumstances these tools might be used and with which QAOs they are compatible.

Table 4-15 – List of Emerging Alternative QM Tools

Pre-award Tools	**Post-award Tools**
▪ Owner led o Pre-bid meeting with focus on quality o Industry review of draft RFP with focus on quality o ISO 9000 certification for organization, project, or team member o Alternative QM approaches in procurement o Quality based selection of contractors/subcontractors (project-specific prequalification) o Use of warranties (performance or materials) ▪ Contractor led o One-on-one meetings during procurement with a focus on alternative quality o Contractor proposed alt. quality standards/specification deviations o “Red Flag” review of standard specs o Alternative Technical Concepts (ATCs)	Design process ▪ Design review: o External contractor panel input o Independent party review (agency, staff extension) o Over-the-shoulder agency reviews o In-progress design workshops o Discipline task force (parallel entire project) Construction process ▪ Teaming: o Formal partnering with regulatory agencies o Formal team partnering/goal-setting process o Co-location of QM personnel o Discipline task force (parallel entire project) o No low bid requirement for subcontractors o Use of dual CEI/OCEI roles ▪ Process control: o Innovation in witness and hold points o Continuous internal process audit o Real time electronic QM information management o Financial incentive/disincentives for quality o Contractor “controlled” QC testing o Innovation in clarification reports ▪ Training: o ISO 9000 training of sub-contractors o Project-specific QM team training
OCEI – Oversight CEI	

4.7 Summary

As seen in this chapter, great time and consideration was given to the identification and selection of the case studies used for this report and to ensuring that they were conducted using a rigorous and thorough methodology. After conducting the case studies, the information gathered was distilled into the full case studies found in the appendices and synthesized in the tables at the end of this chapter. Case studies were examined for their successes related to alternative QM as well as a breakdown of the primary design and construction QM roles and responsibilities. This information was then used to craft a QAO diagram for each case study which was then matched to one of the five primary QAOs identified in Chapter 3. Each of the ten case studies conducted for this project provided a wealth of information regarding the implementation of alternative QMSs and a number of innovative alternative QM tools.

CHAPTER 5: QAO SELECTION AND TOOLS

5.1 Introduction

The selection of a QAO should occur as early in the project development process as possible. At a minimum, it should be completed before any procurement of design and/or construction begins. Inclusion of the QAO in the procurement process allows for the RFQ, RFP and/or IFB to define the project QAO so that the responding party can appropriately account for costs, risks or staffing requirement.

In implementing any QMS, project and quality managers need tools and procedures to implement a quality management plan. This chapter presents a set of tools of various types, which are potentially valuable aids in a quality management plan. These include items for inclusion with procurement documents, a contract agreement, or quality management plans. This chapter provides a brief description of these tools and how to select a tool based on individual project characteristics.

This chapter describes the background and development of the QAO and tool selection procedures that are described in the accompanying guidebook. This chapter summarizes the methodologies, data collection and validation that were performed in the research to arrive at the selection procedures in the guidebook.

5.2 QAO Selection Process Development

Appropriate project QAO selection requires an analysis of the factors that influence the selection and their relationship factors to each QAO. Identifying the factors involved interviews with agency project staff from 23 projects in 13 states. The interview process had two goals, first to identify the factors and second, to confirm that there is not a process currently in place for an agency to select a project QAO when the default QAO is not appropriate for projects. This was confirmed, and the interviewees reported that most often when an alternative QAO is needed (i.e., the Deterministic QAO is not appropriate) for a project, the selection is left up to the project team without guidance or a standardized, transparent decision process.

5.2.1 Identifying QAO Selection Factors

Ten factors that influence the selection of a project QAO were identified through interviews. The ten factors fell into three categories: project, agency, and industry. Any factors that were a condition of circumstances occurring after the RFP process, such as the experience of the contractor's project management staff, were excluded because this information is unknown at the time QAO selection for a project takes place.

5.2.2 Project Factor Categories

Project factors are characteristics of specific projects. The four factors that influence the selection of a QAO are: project size, project complexity, project schedule sensitivity, and project delivery method. *Project size* is determined by the budget of the project including both design and construction. *Project complexity* is related to how similar the project is to a typical project.

Complexity can result from characteristics including project scope, design requirements and constraints, construction methods, site conditions, budget and funding constraints, quality requirements, project delivery method, and specialty materials.

Project schedule sensitivity refers to the vulnerability of the project schedule to changes due to delays, conflicts, and/or events outside of the designer and/or contractor's control, such as coordination of observations, inspections and/or testing performed by the agency. *Project delivery methods* is "the process by which a construction project is comprehensively designed and constructed for an owner including project scope definition, organization of designers, constructors and various consultants, sequencing of design and construction operations, execution of design and construction, and closeout and start-up" (Touran et al. 2011).

5.2.2.1 Agency Factors

Agency factors are characteristics and abilities of SHAs that are responsible for projects. The four agency factors are culture, staffing availability, staffing experience and the amount of quality responsibility the agency wants to shift to another project participant. *The culture of the agency* is the agency's attitude toward the implementation of change in project management techniques. *Agency staffing availability* stems from the SHAs across the nation being downsized, and is determined by the quantity of agency staff available to commit to projects as compared to the traditional levels of agency staffing for comparable projects. *Agency staffing experience* is the average number of years of experience of the agency staff committed to the project.
The amount of quality shift away from the agency has to do with shifting responsibility for quality to another project participant. These shifts refer to the amount of liability for the management of the project's quality that an agency wants to shift to another project partner (e.g., contractor, designer, engineer, design builder, CMGC, concessionaire).

5.2.2.2 Industry Factors

Industry factors are characteristics or abilities of local design, engineering, contracting and consulting communities. The two industry factors are the industry's ability to manage their own quality and the level of trust established between the industry and the agency. *The industry's ability to manage their own quality* refers to the local communities' levels of competence in managing their own quality. This competence may result from either education, training, experience, industry culture or a combination of these. *The level of trust between the industry and agency* is important because as agency control over a project is reduced, increased levels of trust are required because the project becomes more collaborative. Effective collaboration depends on an agency's level of confidence that project decisions made by industry partners will be based on achieving the best results for the project, rather than on the partners' interests.
The next step involved is establishing relationships between each of the selection factors and each fundamental QAO to understand how the selection factors influence project QAO selection.

5.2.3 Establishing Relationships Between Selection Factors and QAOs

A Delphi study was conducted to establish the relationships between the ten selection factors, and the five fundamental QAOs. A panel of 12 experts rated the appropriateness of each QAO to each category of selection factor. Each expert was required to have a minimum of 15 years of industry experience.

Four appropriateness ratings were used for the Delphi study, fatal flaw (denoted with X), least appropriate (–), appropriate (+), and most appropriate (++). After three rounds of the Delphi study 93% of the ratings had reached consensus in the Delphi study; the remaining 7% either had an outlier or were torn between two ratings that included appropriate and a rating on either side of appropriate. The selection factors that did not reach consensus require consideration in conjunction with the other factors; these factors are marked with * in the summary table 5-1.

Table 5-1 – Selection factor appropriateness rating sheet

Selection factor category	Determin.	Assure.	Var.	Over.	Accept.
Project delivery method					
Design bid build	++	+	+	+*	-
Design build	-	-	+	++	-
CMGC/CMAR	-	+	+	++	+
P3/DBOM	X	-	-	+	++
Project size					
<$10M	++	++	+	+*	-
$10M - $50M	++	++	+	+	+
$50M-$500M	-	+	+	++	++ *
$500M - $2B	X	-	+	++*	++
>$2B	X	-	+	++*	++
Availability of agency project staff					
fully staffed	++	+	+	+	X
moderately staffed	-	+	+	+	-
minimally staffed	X	-	+	++	++
Industry ability to manage their own quality					
Low	++	+	+	-	X
Medium	+	+	+	+	+
High	-*	+	+	++	++
Trust between agency and industry					
Low	++	+	+	-	X
Moderate	+	+	+	+	+
High	+	++	++	++	++
Shift the quality risk away from the agency					
All	X	X	X	++	++
Some QA and some QC	-	-	++	++	+
Some QA	- *	-	+	++	+*
Some QC	+ *	+	+	++	X
None	++	-	-	X	X
Project complexity					

Selection factor category	Determin.	Assure.	Var.	Over.	Accept.
Low	++	+	+	+	+
Medium	+	+	+	+*	+
High	-	+	++	++	++
Schedule sensitivity					
Low	+	+	+	+	+
Medium	-	+	+	+	+
High	-	+	+	++	++
Agency project staff experience					
<5 years	+	+	+	-	- *
5 years - 10years	+	+	+	+	+
10 years - 20 years	++*	++	++	++	++
>20 years	+	+	++	++	++
Agency culture					
Traditional	++	+	-	-	-
Moderate	+	+	+	+	+
Progressive	-	+	+	++	++

*needs to be considered in conjunction with the other factors.

The selection factors and the appropriateness ratings presented in this section form the basis for the development of the project QAO selection process tool with the intent of providing guidance, transparency, and understanding to the process.

5.2.4 The QAO Selection Process Tool

The goal of the QAO selection process is to help SHAs identify the most appropriate QAO for projects by rating the appropriateness of the five fundamental QAOs according to the categories of selection factors that apply to the projects. This research suggests that project QAOs be selected before the RFQ, RFP or IFB process for design or construction begins so project quality roles and responsibilities can be accurately accounted for the procurement.

The QAO selection process tool uses a three-step process for selecting the most appropriate QAOs for a particular project (Figure 5-1). The three steps are identifying barriers to QAO adoption, using the selection process profile form to prepare a selection factor profile, and using the QAO factor analysis form to select the most appropriate QAO.

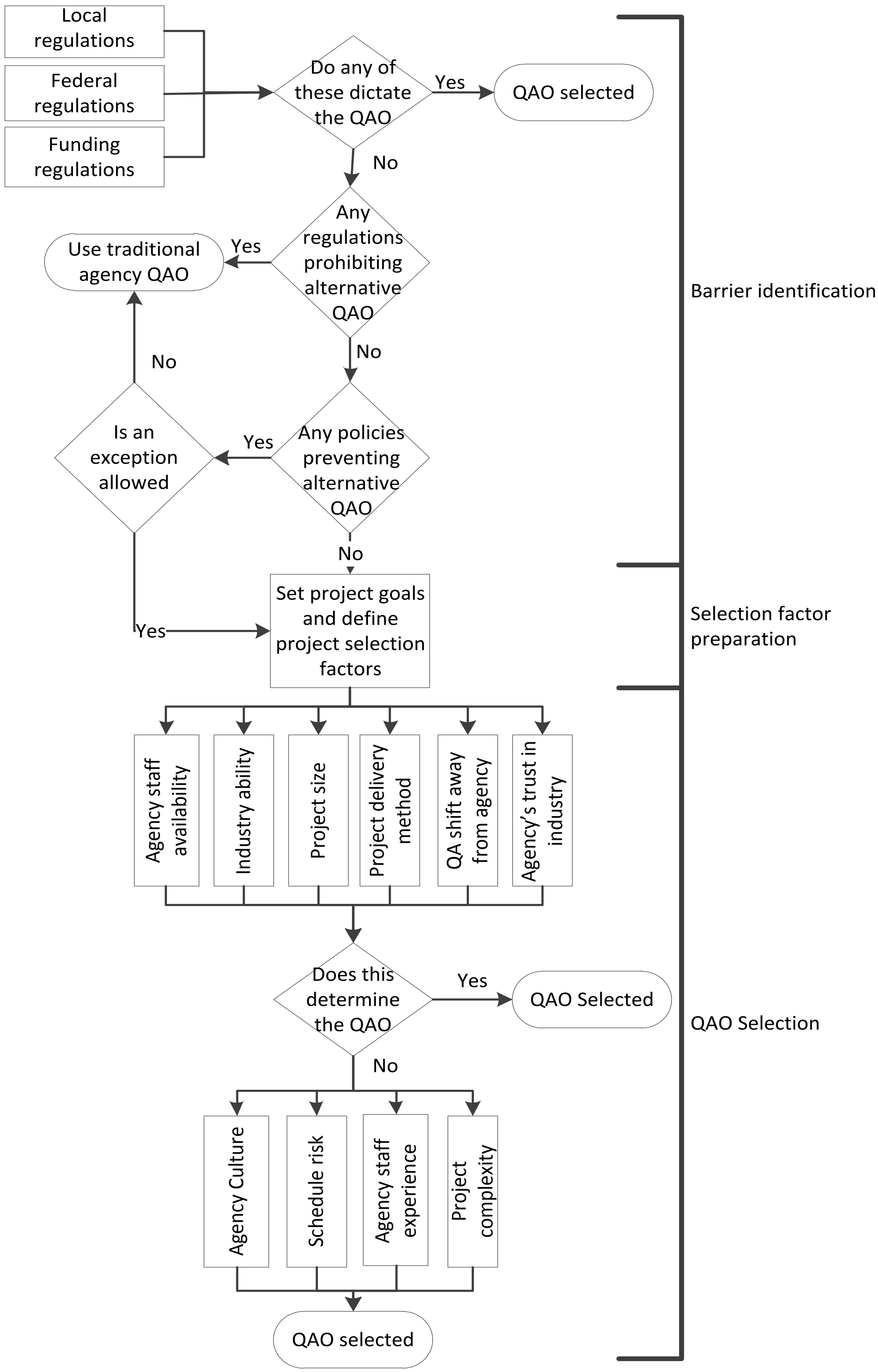

Figure 5-1 - Project QAO selection process

The QAO selection steps are discussed in detail in Chapter 4 of the accompanying guidebook. The guidebook provides an example project application for illustration. Additionally, the guidebook contains an appendix with forms for applying the process. The forms include instructions which have been tested and validated for use.

5.2 Tools for Alternative QMS

An extensive literature review and the case study evaluations assisted with discovering the tools for alternative QMSs. These tools encourage effective quality management across a variety of QMSs, including both the baseline and the alternative systems. The purpose is to provide a matrix of each tool and each tool provides information on what it is, why use it, what it does, suggestions on when to use it, how to use it, examples case studies that used the tool, and helpful references. Appendix B of the guidebook provides a more in-depth discussion of each tool.

This guidebook subdivides the tools into two major categories, pre-award and post-award. Additional tool subcategories under these primary categories aid in their selection and ultimate application to the various phases and parties that make up a project.

5.2.1 Pre-Award tools

Incorporating pre-award quality management tools occurs before selecting the design or construction team. These tools help owners better define requirements for the project, inform interested designers or contractors of warranties designed to encourage a quality-focused approach, allow contractors to suggest changes to project documents or concepts before having to bid on them, and other quality management opportunities. Pre-award quality management tools set the tone and expectations early on for the project in terms of quality.

The pre-award tools contain two subcategories of tools, owner-led and contractor-led. Owner-led tools are those that a STA initiates. These types of tools may include specific procedures to select designers and contractors based on the quality of their work, project warranties to ensure project members guarantee a quality product, or broad project goals regarding quality and its implementation. Then, it may seem counterintuitive to have contractor-led quality management tools available for use before a awarding the construction contract. However, several of the tools focus primarily on receiving contractor feedback regarding RFP details, project specifications and/or project designs during the procurement phase. Through experience, state transportation agencies found that contractors who compete to build their projects have valuable insights to share with project planners that can lead to a higher quality product. Also, contractors, in the right settings, are willing to share insights before an agency awards the contract.

5.2.2 Post-Award tools

Post-award tools are those procedures and tools implemented after the completion of procurement and through the end of the project. These include quality management tools for both the design and construction processes. The basis for the subcategories of the post-award tools is the specific project phase for which they apply – design or construction – as well as the nature of the tools. The subcategories are design review tools, teaming tools, process control tools, and training tools. Design review tools provide assistance to ensure the production of quality designs. Teaming tools focus on increasing the levels of communication and cooperation on a project during the construction phase. Process control tools can increase quality or the efficiency of the quality management process as work progresses. These tools assist project managers by providing streamlined access to quality management reports and information, incentivizing or de-incentivizing contractors specifically for quality, and by offering innovations to some well-used existing processes. Finally, training tools assist the project-team to focus on quality issues specific to the project and to extend a broad-level quality focus from the upper management down to individual subcontractors.

5.3 Selection of Tools

The QMS tools are not necessarily compatible with every project delivery method or QAO. When project managers develop a QMS, they must consider the goals of the project and the justification for selecting to use a particular set of tools and procedures. For example, if a project has no administrative or legal authority to alter its quality standards or overall design, then inviting contractor input into the design or quality procedures would not be worthwhile and could in fact be counter-productive.

Table 5-1 presents a matrix that agencies can use to identify a set of tools compatible with both the project QAO and the specific project requirements. Using their knowledge of the project, project managers should approach the matrix by first identifying categories of tools they are interested in adding to their QMS. Then project managers will need to determine which tools are compatible with the selected QAO. The project manager then adds the selected tools to the set of procedures compatible with the agency building the project. From this final set, project managers can select a combination of quality management tools that best meet the needs and goals of their project. Not every tool is useful for every project and agencies should not expect to incorporate all or even most of the tools listed here on a particular project.

Table 5-2 – List of Alternative Pre-Award QMS Tools

	Tools	QAOs Applicable With				
		D	A	V	O	S
Pre-award Tools						
Owner Led	B.1. Pre-bid meeting with specific focus on quality	+	+	+		
	B.2. Industry review of draft RFP w/focus on quality			+	+	+
	B.3. Alternative quality management approaches in procurement	+	+	+	+	+
	B.4. Quality based selection of contractors/ subcontractors (project specific prequalification)	+	+	+	+	+
	B.5 Use of warranties (performance or materials)	+	+	+	+	+
	B.6 Requirements Management - Verification	+	+	+	+	+
Contractor Led	B.7. One-on-one procurement meetings with a focus on quality			+	+	+
	B.8 Contractor involvement in establishing and streamlining quality control standards	+				+
	B.9. Alternative Technical Concepts (ATCs)		+	+	+	
	B.10. External contractor panel input	+	+	+		

Table 5-3 – List of Alternative Post-Award QMS Tools

Tools		QAOs Applicable With				
		D	A	V	O	S
Post-award Tools						
Design Review	B.11. Independent party design review	+	+	+	+	
	B.12. Over-the-shoulder agency reviews			+	+	+
	B.13. In-progress design workshops			+	+	
	B.14. Discipline task force (parallel entire project)	+	+	+	+	+
Construction – Teaming	B.15. Formal partnering with regulatory agencies	+	+	+	+	
	B.16. Formal team partnering/goal-setting process	+	+	+	+	+
	B.17. Co-location of quality management personnel	+	+	+	+	+
	B.18. No low bid requirement for subcontractors	+	+	+	+	+
	B.19. Use of dual CEI/OCEI roles					+
Construction – Process Control	B.20. Innovation in witness and hold points			+	+	+
	B.21. Continuous internal process audit					+
	B.22. Real-time electronic quality management information	+	+	+	+	+
	B.23. Financial incentive/disincentives for quality	+	+	+	+	
	B.24. Contractor “controlled” QC testing	+	+	+	+	+
Construction – Training	B.25. ISO 9000 training					+
	B.26. Project-specific quality management team training	+	+	+	+	+

Key:
D = Deterministic QAO
A = Assurance QAO
V = Variable QAO
O = Oversight QAO
S = Acceptance QAO

5.4 Summary Guidance for Assembling a QMS

The guidebook accompanying this research report provides a process for designing a QMS that meets the agency and project needs. The guidebook provides suggestions for designing a QMS that meets the user's needs. The framework of a full QMS is introduced in Chapter 1. QAOs and their selection are discussed in Chapters 3 and 4. Alternative tools to use and their selection are introduced in Chapter 5 of the Guidebook. The guidebook suggests a process for assembling a QMS – to combine the QAO/tool combinations selected into a broader QMS applicable to every aspect of their project.

Development of a QMS begins with an understanding of the project conditions, especially considering the project delivery system, and whether the design and construction organizations vary from the "baseline" systems noted in this guidebook. The next step is to determine potential QAOs. Once the options are clear for QAOs, then it is appropriate to establish the "business case" for each QAO, carefully considering the pros and cons for each QAO, especially in relation to administrative and regulatory requirements and industry custom. Once the business cases are established, any QAO that varies from the baseline QAO for the organization should be presented to appropriate decision-makers in the agency. Selection of the QAO for the project should be made as a collaborative effort between project personnel and administrative decision-makers.

The chosen QAO can then be matched with tools described in Chapter 5 to assemble a complete QMS that will become the guiding quality principle for the project. Clear documentation of the holistic QMS will provide the basis for contractor and consultant proposal and contract documents, aligning team efforts toward the same quality goal and establishing each party's role in the process.

As the project participants are brought on board, it is important to disseminate the principles and procedures outlined in the project QMS. It is also important to recognize that some QMSs differ from the traditional QMS, and without specific communication, any new party to the project could just "default" to the traditional system, causing misunderstandings and conflicts.

CHAPTER 6: CONCLUSIONS, LIMITATIONS and FUTURE RESEARCH

6.1 Conclusions

Quality management systems in the United States transportation industry are evolving. Innovations in QAOs and other features of quality programs are being used by STAs across the country on projects with both traditional DBB delivery and alternative delivery methods. However, these alternative quality management systems are being applied on a project-by-project basis due to the lack of national guidance to promote standard approaches. For highway agencies, this lack of guidance is resulting in significant investment to develop individual programs and minimizing the ability to capture and utilize knowledge across agencies. For consulting engineers and contractors, this lack of guidance is resulting in significant investment in response to project solicitations which require unique QMSs for different agencies.

The objective of this research was to address the needs for QMS guidance for evolving alternative project delivery methods. This research has provided guidance through the following accomplishments:

- Documentation of practices as found in quality management literature, surveys and case studies;
- Analysis of the benefits and challenges of the alternative QMS through rigorous and scientific case study means;
- Identification and definition of five fundamental QAOs for highway design and construction projects;
- Identification and definition of ten factors influencing the selection of a QAO for highway design and construction projects;
- Development of a selection model for matching these systems to alternative project delivery methods;
- Increasing industry understanding of the impacts that alternative QAOs have on highway design and construction projects; and
- Providing agencies with a roadmap of changes to the baseline QMS to accommodate alternative delivery methods.

The research defines the roles and responsibilities of all project stakeholders (agency, contractor, designer and consultants) in a clear and understandable manner. The research also describes each of the fundamental QAOs through a description of the stakeholder's roles and responsibilities, and the applicable project delivery methods. The results provide a better understanding of the impact that a particular QAO has on a project. With this information, an agency can better anticipate the consequences of using a particular QAO on the management of a highway project.

6.2 Challenges to Implementation

The research team believes that the guidance in this research will increase the efficiency and effectiveness of overall project delivery and the end product. Continued advancement will take a willingness of STAs to implement alternative QMSs and measure their effectiveness. It has taken decades to establish the baseline QMS. It will take highly motivated individuals and champions of change before the industry can truly realize the impacts of these advances.

The challenges of implementing alternative QMS processes are similar any process changes in large public or private organizations. State highway agencies must consider several challenges when deploying this research. Challenging the status quo and creating a cultural change requires leadership and mentoring to ensure that alternative QMSs are thoughtfully applied. The dedication of sufficient time to changing agency attitudes toward incorporating alternative QAOs and incremental changes to the baseline systems will be required. It will be necessary to assign champions within the organization to implement the models, methods and tools in this guidebook. These champions will need to educate their peers and serve as resources for implementation.

6.3 Limitations of the Research

Due to the nature of the research questions and the limited use of alternative QMSs in the United States, this research was based on largely qualitative research methods. The survey conducted in this research did not, for the most part, yield statistically significant results. Rather, the survey led the team to a sample of diverse case studies from which to draw conclusions. While the case studies were rigorously conducted and validated, the results are limited by the case study sample size. As a result, the fundamental QAOs identified by the research are based on QAOs that currently exist in the industry. It is possible that additional QAOs not identified in this research may develop in the future as the industry becomes more comfortable with alternative project delivery methods and more comfortable with the contractor taking on more responsibility for quality. The development of additional fundamental QAOs implies that the industry is embracing not only alternative project delivery, project management and quality methods, but also developing relationships with contractors that are built up trust, the contractor's expertise, and a willingness to shift more quality responsibility to the contractor.

While there is historical data pertaining to material specifications and material quality in every SHA, there is a lack of data and consistent measures of quality assurance organizations within the industry. It can be speculated that the reason for this is the industry focus on "how to implement alternative quality systems" at this point, rather than evaluating the effectiveness of quality assurance organizations. The development of measures to assess the performance of QAOs is a topic for future research.

The complexity of the topic was evident by a variety of conditions within the industry. This complexity created barriers for the research. For example, there is widespread inconsistent use of quality terminology throughout the industry. The complexity of the topic has resulted in SHAs have differing opinions about the transfer of quality responsibility to the contracting community. Furthermore, during the structured interviews SHAs expressed a need for further guidance regarding quality on a highway project with shifting project roles and responsibilities.

6.4 Future Research

The limitations of this research point towards topics to be addressed in the future. Quality management systems in the United States will continue to evolve. Quality management research should strive to lead this change. The following are a few areas for future research.

- What levels of quality performance result from each QAO variation?
- What additional tools are available to assist with incremental changes to the baseline systems?
- Do the need and/or amount of agency staff reduce as the amount of quality responsibility shifts to the industry?
- How can QAOs be assigned on a programmatic basis rather than a project-by-project basis?

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APPENDIX A: GLOSSARY

A-1 Standard Definitions – Quality Terminology

For the purposes of this report, the Transportation Research Circular E-C137: Glossary of Highway Quality Assurance Terms (Leahy 2009) will be used to define the quality related terminology in this report.

Acceptance. The process of deciding, through inspection, whether to accept or reject a product, including what pay factor to apply. [Where contractor test results are used in the agency's acceptance decision, the acceptance process includes contractor testing, agency verification, and possible dispute resolution.]

Acceptance plan. An agreed–upon method of taking samples and making measurements or observations on these samples for the purpose of evaluating the acceptability of a lot of material or construction.

Composite pay factor. Also called **combined pay factor** or **overall pay factor**. A factor obtained from two or more quality characteristics and often expressed as a percentage, to be multiplied by the bid price to determine the contractor's final payment for a unit of work. [Methods typically employed to arrive at this factor are (1) calculate either a standard or a weighted average of individual pay factors, (2) multiply individual pay factors, or (3) use the lowest individual pay factor. Composite pay can also be calculated by adding the sum of individual pay adjustments to the bid price, as would likely be the case when pay adjustments are expressed in direct dollar amounts.]

Contract payment provision. The contract language that defines how design and construction professionals will be paid for their services. The four primary contract payment provisions are fixed price lump sum, guaranteed maximum price (GMP), cost plus fee, and cost reimbursable.

Construction deliverable. A product produced by the design-builder's construction team that is submitted for review to the agency. (shop drawings, product submittals, etc.)

Construction Manager/General Contractor (CMGC). A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.

Design-bid-build (DBB). A project delivery method where the design is completed either by in-house professional engineering staff or a design consultant before the construction contract is advertised. Also called the "traditional method."

Design-build (DB). A project delivery method where both the design and the construction of the project are simultaneously awarded to a single entity.

Design deliverable. A product produced by the design-builder's design team that is submitted for review to the agency. (i.e. design packages, construction documents, etc.)

End result specifications. Specifications that require the contractor to take the entire responsibility for supplying a product or an item of construction. The highway agency's responsibility is to either accept or reject the final product or to apply a pay adjustment commensurate with the degree of compliance with the specifications. [End result specifications have the advantage of affording the contractor flexibility in exercising options for new materials, techniques, and procedures to improve the quality or economy, or both, of the end product.]

Incentive–disincentive provision (for quality). A pay adjustment schedule that functions to motivate the contractor to provide a high level of quality. [A pay adjustment schedule, even one that provides for pay increases, is not necessarily an incentive–disincentive provision, as individual pay increases–decreases may not be of sufficient magnitude to motivate the contractor toward high quality.]

Independent assurance (IA). A management tool that requires a third party, not directly responsible for process control or acceptance, to provide an independent assessment of the product and/or the reliability of test results obtained from process control and acceptance testing. (The results of independent assurance tests are not to be used as a basis of product acceptance).

Inspection. The act of examining, measuring, or testing to determine the degree of compliance with requirements.

Liquidated damages provision (for quality). A pay adjustment schedule whose primary function is to recover costs associated with the contractor's failure to provide the desired level of quality. [This same concept also can be used to justify pay increases for superior quality above the level specified.]

Manufacturing-based quality. Conformance to specifications. (ASQ 2013)

Materials and methods specifications. Also called **method specifications**, **recipe specifications**, or **prescriptive specifications**. Specifications that require the contractor to use specified materials in definite proportions and specific types of equipment and methods to place the material. Each step is directed by a representative of the highway agency. [Experience has shown this tends to obligate the agency to accept the completed work regardless of quality.]

Materials and workmanship warranties. Specifications that hold the contractor responsible for correcting defects in work elements within the contractor's control during the warranty period. [Under materials and workmanship warranties, the highway agency is responsible for the pavement structural design. The contractor assumes no responsibility for pavement design or those distresses that result from the design. Some responsibility is shifted from the agency to the contractor for materials selection and workmanship.]

Pay adjustment. The actual amount (either in dollars or in dollars per area, weight, or volume) that is to be added or subtracted to the contractor's payment for a unit of work.

Pay adjustment schedule (for quality). Also called **price adjustment schedule** or **adjusted pay schedule**. A pre-established schedule, in either tabular or equation form, for assigning pay factors associated with estimated quality levels of a given quality characteristic. The pay factors are usually expressed as percentages of the contractor's bid price per unit of work, but may also be given as direct dollar amounts.

Pay adjustment system (for quality). Also called **price adjustment system** or **adjusted pay system**. All pay adjustment schedules along with the equation or algorithm that is used to determine the overall pay factor for a submitted lot of material or construction. [A pay adjustment system, and each pay adjustment schedule, should yield sufficiently large pay increases/decreases to provide the contractor sufficient incentive–disincentive for high/low quality.]

Pay factor. A multiplication factor, often expressed as a percentage, used to determine the contractor's payment for a unit of work, based on the estimated quality of work. [Typically, the term "pay factor" applies to only one quality characteristic.]

Performance specifications. Specifications that describe how the finished product should perform over time. [For highways, performance is typically described in terms of changes in physical condition of the surface and its response to load, or in terms of the cumulative traffic required to bring the pavement to a condition defined as "failure." Specifications containing warranty/guarantee clauses are a form of performance specifications. Other than the warranty/guarantee type, performance specifications have not been used for major highway pavement components (subgrades, bases, riding surfaces) because there have not been suitable nondestructive tests to measure long-term performance immediately after construction. They have been used for some products (e.g., highway lighting, electrical components, and joint sealant materials) for which there are suitable tests of performance.]

Performance-based specifications. QA specifications that describe the desired levels of fundamental engineering properties (e.g., resilient modulus, creep properties, and fatigue properties) that are predictors of performance and appear in primary prediction relationships (i.e., models that can be used to predict pavement stress, distress, or performance from combinations of predictors that represent traffic, environmental, roadbed, and structural conditions). [Because most fundamental engineering properties associated with pavements are currently not amenable to timely acceptance testing, performance-based specifications have not found application in highway construction.]

Performance-related specifications. QA specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance. These characteristics (for example, air voids in AC and compressive strength of PCC) are amenable to acceptance testing at the time of construction. [True performance-related specifications not only describe the desired levels of these quality characteristics but also employ the quantified relationships containing the characteristics to predict as-constructed pavement performance. They thus provide the basis for rational acceptance/pay adjustment decisions.]

Performance warranties. Specifications that hold the contractor fully responsible for product performance during the warranty period. [Under performance warranties, the contractor guarantees that the pavement will perform at a desirable quality level. The contractor assumes some level of responsibility, depending on the specific project, for the structural pavement or mix decisions. Pavement performance warranties can be classified as either short-term (typically 5–10 years) or long-term (typically 10–20 years). Pavement materials and workmanship warranties are typically 2–4 years.]

Product-based quality. Quality is a precise and measurable variable and differences in quality reflect differences in quantity of some product attribute.

Project delivery method. The comprehensive process by which designers, constructors, and various consultants provide services for design and construction to deliver a complete project to the owner. While names can vary in the industry and owners often create hybrid delivery methods, there are essentially three primary project delivery methods: design-bid-build (DBB), construction manager-at-risk (CMR), and design-build (DB).

Project Quality Assurance (PQA). All those actions necessary for the owner to ensure that design-builder performed QA activities give a true representation of the quality of the completed project. This may include owner verification and acceptance testing or independent assurance as owner oversight actions when the design-builder is assigned the responsibility for design and/or construction QA activities. Additionally, these also include owner oversight, verification, validation, acceptance, and other activities necessary to satisfy FHWA Technical Advisory 6120.3 (2004) for projects with federal funds and the employment of independent quality consultants that may be necessary in DB projects with post-construction operations and/or maintenance options.

Quality. (1) The degree of excellence of a product or service; (2) the degree to which a product or service satisfies the needs of a specific customer; or (3) the degree to which a product or service conforms with a given requirement.

Quality assurance (QA). All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. (QA addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities).

Quality assurance specifications. A combination of end result specifications and materials and methods specifications. The contractor is responsible for QC (process control), and the highway agency is responsible for acceptance of the product. [QA specifications typically are statistically based specifications that use methods such as random sampling and lot-by-lot testing, which let the contractor know if the operations are producing an acceptable product.]

Quality assurance organization (QAO). The assignment of the roles and responsibilities associated with the quality management of a project from concept through completion.

Quality control (QC). Also called process control. Those QA actions and considerations necessary to assess and adjust production and construction processes so as to control the level of quality being produced in the end product.

Quality Management (QM). The totality of the system used to manage the ultimate quality of the design as well as the construction encompassing the quality functions described above as acceptance, QC, independent assurance and verification.

Relative Quality. Loose comparison of product features and characteristics.

Statistically based specifications. Also called **statistical specifications** or **statistically oriented specifications**. Specifications based on random sampling, and in which properties of the desired product or construction are described by appropriate statistical parameters.

User-based quality. Fitness for intended use.

Validation. The process of confirming the soundness or effectiveness of a product (such as a model, a program, or specifications) thereby indicating official sanction. [The *validation* of a product often includes the *verification* of test results.]

Verification. The process of testing the truth, or of determining the accuracy of test results, by examining the data or providing objective evidence, or both. [Verification sampling and testing may be part of an independent assurance program (to verify contractor QC testing or agency acceptance) or part of an acceptance program (to verify contractor testing used in the agency's acceptance decision).]

Value-based quality. Conformance at an acceptable cost.

A-2 Standard Definitions – Procurement Terminology

For the purposes of this report, the Federal Highway Administration report entitled: *Design-Build Effectiveness Study – As Required by TEA-21 Section 1307(f): Final Report* (2006) will be used to define the procurement and alternative project delivery terminology in this report.

Administrative prequalification: A set of procedures and accompanying forms/ documentation that must be followed by a construction contractor to qualify to submit bids construction projects using traditional project delivery.

Alternative or Innovative Contracting: Various methods of contracting authorized by state statute that departs to some degree from the traditional design-bid-build low-bid process. These methods include but are not limited to Time-Plus-Money (A + B), Design/Build, Warranty, and Incentive/Disincentive.

Best Value: The overall maximum value of the proposal to a sponsor after considering all of the evaluation factors described in the specifications for the project including but not limited to the time needed for performance of the contract, innovative design approaches, the scope and quality of the work, work management, aesthetics, project control, and total project cost of the formulas or other criteria for establishing the parameters for the Best Value are generally clearly defined with the goal of being objective.

Bid Proposal: A technical proposal and a separately sealed price proposal submitted by each Design-Build Firm.

Bonus: A monetary incentive placed on a specific milestone within a contract for the expressed purpose of completing that element within the prescribed time.

Construction Manager-General Contractor (CMGC): A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.

Construction Manager-at-Risk (CMR): A project delivery method similar to CMGC, but where the CM does not self-perform any of the construction work.

Contract payment provision: the contract language that defines how design and construction professionals will be paid for their services. The four primary contract payment provisions are fixed price lump sum, guaranteed maximum price (GMP), cost plus fee, and cost reimbursable.

Construction deliverable: A product produced by the design-builder's construction team that is submitted for review to the agency. (shop drawings, product submittals, etc.)

Design-Bid-Build (DBB): The traditional method for building highways and making highway improvements where the state transportation department (STA) or a consulting engineer working for the STA designs the project, solicits bids, and awards the construction contract to the lowest responsive bidder (construction contractor) to build the project.

Design-Build (DB): The process of entering into a single contract with a contractor in which the contractor agrees to design and build a highway, structure or facility, or any other items required in an RFP.

Design-Builder (or Design-Build Contractor or Firm): An individual, company, firm, partnership, corporation, association, joint venture or other legal entity that is permitted by law to provide the necessary design and construction services, including engineering, architecture, construction contracting, and contract administration. The entity may include a construction contractor as the primary party with a design professional as the secondary party or vice versa. The contractor or design professional cannot team with other partners to submit more than one bid per project. Likewise, the secondary part of the design-build team, either designer or contractor, cannot change after award. Design-Build Contractor means the same as Design-Builder.

Design-Build Package (also Design and Construction Criteria Package): Document published by the STA that contains the Public Advertisement (Notice to Bidders), the Request for Proposals, General Requirements, Design Scope of Work, Technical Specifications, Price Proposal Documents including the Bid Schedule, and any forms, drawings and other supporting documents necessary to guide the proposers in preparation and submittal of a proposal for a design-build project.

Design deliverable: A product produced by the design-builder's design team that is submitted for review to the agency. (i.e. design packages, construction documents, etc.)

Incentive: Monies paid to the contractor for early completion of a project as provided for in the contract. Incentives may be paid for on A + B, Bonus, Incentive/Disincentive, Liquidated Savings, and Escalating Incentive/Disincentive contracts.

Incentive/Disincentive: Various methods of contracting authorized by state statutes which apply an incentive for early completion or a disincentive for late completion by the contractor. These methods include but are not limited to Incentive/Disincentive and Escalating Incentive/Disincentive arrangements.

Performance based prequalification: A set of procedures and back-up documents that must be followed by a construction contractor to qualify to submit a bid on a construction project based on quality, past performance, safety, specialized technical capability, project-specific work experience, key personnel, and other factors.

Price Proposal: Contains the proposer's price for performing the work contained in the technical proposal and specified in the design-build package. In general, the price proposal is sealed and completed only on forms included in the design-build package. The proposer for an A + B type of price proposal also quotes a specified project time.

Project: The project to be designed and constructed as described in the public announcement.

Project delivery method: the comprehensive process by which designers, constructors, and various consultants provide services for design and construction to deliver a complete project to the owner. While names can vary in the industry and owners often create hybrid delivery methods, there are essentially three primary project delivery methods: design-bid-build (DBB), construction manager-at-risk (CMR), and design-build (DB).

Procurement procedure: the process of buying and obtaining the necessary property, design, contracts, labor, materials, and equipment to build a project. The four primary procurement procedures are low-bid, best-value, qualifications-based, and sole-source procurement.

Project Manager: The STA's designee responsible for administering the design-build project.

Proposer: A design, construction management, design-build firm or joint venture submitting a technical proposal for a design-build project.

Request for Proposal (RFP): The package to be provided to the firms qualified to bid on a project. It may contain, but is not limited to a detailed scope of work, including design concepts, technical requirements and specifications, time allowed for design and construction, STA's estimated cost of the project, deadline for submitting a proposal, selection criteria and a copy of the contracts. FHWA approval of the RFP is required on FHWA oversight projects prior to authorization and the release of the RFP to short-listed Firms. The RFP must clearly define all functions and responsibilities required by the firm.

Request for Qualifications (RFQ): A frequent part of the design-build selection process that contains the desired minimum qualifications of the firm, a scope of work statement, project requirements, amount of stipend or reimbursement (if any) that the STA has determined will be paid to prospective firms who qualify for the short list, but are not awarded a contract, selection criteria that STA will use in compiling the short list of prospective Firms to consider, and a copy of the contract.

Responsive: A proposal that substantially complies with the criteria identified in the short-listing process or a proposal that contains all the information and level of detail requested in the RFP and complies with the design and construction criteria defined in the RFP or design-build package.

Scope of Work: Information provided or furnishes in the design-build package and RFP that describes the project work and provides the firm with the essential requirements.

Standard Bid: The traditional cost associated with the materials and labor to construct the project.

STA: State transportation agency.

Statement of Qualifications (SOQ): Refers to the process that establishes criteria for evaluating interested Firms. Criteria required for the SOQ is stated in the advertisement. Often, firms desiring to submit bid proposals on design-build projects must submit an SOQ setting forth the qualifications of members of the firm and providing any other information required by the announcement of the project.

Stipend: The fee paid to unsuccessful firms for development of a responsive proposal.

Technical Proposal: The design-builder's response to the Request for Proposals. This document contains detailed descriptions and methodology of the design-builder's approach to designing, constructing, and managing the project in accordance with the design-build package. The design-builder's conceptual design is included as well as a proposed construction sequence and schedule. Technical proposals are expected to be in-depth, and could contain tables, charts, drawings, plots, and sketches.

Time-Plus-Money: Various methods of contracting including but not limited to Lane Rental, A + B Bidding, and Liquidated Savings. These methods consider both the construction costs and time of project. Reduction of contract time is a critical consideration for these methods.

Total Bid: The standard bid cost and the time bid cost added together for determining the low bidder.

Warranties: An insurance policy to warranty a specific element or elements within the contract from premature failure.

Weighted Criteria: The technical proposal and the price proposal are evaluated individually. A weight is assigned to the price and each of the technical evaluation factors. The sum of these values becomes the total score. The offeror with the highest total score is selected.

APPENDIX B: ONLINE SURVEY

NCHRP 10-83 Alternative Quality Management Systems for Highway Construction

INTRODUCTION/BACKGROUND:

The purpose of this questionnaire is to identify how state highway agencies (SHA) have implemented alternative QA programs and from that baseline, identify commonly used practices for dissemination and use by SHAs that intend to implement alternative procurement on future projects or alternative QA methods in their current program.

DEFINITIONS: The research will use TRB Circular E-C074, *Glossary of Highway Quality Assurance Terms* to standardize its terminology. The following are terms that must be carefully understood to properly complete this survey.

Quality Assurance (QA). All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service

[QA addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities.] TRB E-C074.

Quality control (QC). Also called process control. Those QA actions and considerations necessary to assess and adjust production and construction processes so as to control the level of quality being produced in the end product. TRB E-C074.

Quality Management (QM): The overarching system of policies and procedures that govern the performance of QA and QC activities. The totality of the effort to ensure quality in design and/or construction.

Design-bid-build (DBB): A project delivery method where the design is completed either by in-house professional engineering staff or a design consultant before the construction contract is advertised. Also called the “traditional method.”

Design-build (DB): A project delivery method where both the design and the construction of the project are simultaneously awarded to a single entity.

Construction Manager-General Contractor (CMGC): A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.

Construction Manager-at-Risk (CMR): A project delivery method similar to CMGC, but where the CM does not self-perform any of the construction work.

Design deliverable: A product produced by the design-builder’s design team that is submitted for review to the agency. (i.e. design packages, construction documents, etc.)

Construction deliverable: A product produced by the design-builder’s construction team that is submitted for review to the agency. (shop drawings, product submittals, etc.)

General Information:

1. US state in which the respondent is employed:

2. You are employed by what type of organization?

☐ State Department of Transportation
☐ Other public transportation agency; Name of Agency:
☐ Federal Agency; Name of Agency:
☐ Other; Please describe:

3. What group/section do you work in?

☐ Design group/section	☐ Alternative project delivery group/section
☐ Construction group/section	☐ Materials group/section
☐ Operations group/section	☐ Contracts/procurement group/section
☐ Maintenance group/section	☐ Other, please specify:

4. Please check the appropriate boxes for your agency's project delivery program.

Project Delivery Method	Legislative/Legal Authority	PDM Experience
DBB		☐ NA; ☐ 1-5; ☐ 5-10; ☐ > 10
CMGC	☐ NA; ☐ Pilot projects only; ☐ General authorization	☐ NA; ☐ 1-5; ☐ 5-10; ☐ > 10
DB	☐ NA; ☐ Pilot projects only; ☐ General authorization	☐ NA; ☐ 1-5; ☐ 5-10; ☐ > 10
P3	☐ NA; ☐ Pilot projects only; ☐ General authorization	☐ NA; ☐ 1-5; ☐ 5-10; ☐ > 10
Other	☐ NA; ☐ Pilot projects only; ☐ General authorization	☐ NA; ☐ 1-5; ☐ 5-10; ☐ > 10

5. Are Quality Management systems different between Project Delivery Methods? ☐Yes ☐No

6. What is the approximate proportion of in-house design versus outsourced design services? In-house design services % Outsourced design services %

Agency Quality Management Policy/Procedures Information:

The following questions will break up the quality management process into the following three phases:

- Procurement phase: Actions taken regarding the quality management process that are reflected in the agency's contractor prequalification requirements and/or solicitation documentation such as in the Invitation to Bid (IFB), Request for Qualifications (RFQ) and the Request for Proposals (RFP).

- Design Phase (in-house): Actions taken after approval to start design work regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements. ***OR***

- Design Phase (out-source): Actions taken after design contract award regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements.
- Construction Phase: Actions taken after contract award regarding the quality of the final constructed product to ensure that it complies with both the completed design and other contractual requirements.

The research team understands that term "Approval" has a variety of slightly different meanings from state to state. It is used here to indicate the process by which the agency indicates that it is satisfied with the quality of the design or construction deliverable and is willing to make payment for satisfactory completion of that task if asked.

Procurement phase:

Administrative prequalification: A set of procedures and accompanying forms/ documentation that must be followed by a construction contractor to qualify to submit bids construction projects using traditional project delivery.

Performance based prequalification: A set of procedures and back-up documents that must be followed by a construction contractor to qualify to submit a bid on a construction project based on quality, past performance, safety, specialized technical capability, project-specific work experience, key personnel, and other factors.

1. Does your agency use a prequalification program for design firms? ☐Yes ☐No

If the answer to the previous question is YES, please answer for your agency's program to prequalify design firms.

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐
Other: please specify:		

2. Does your agency use a prequalification program for construction contractors?

   ☐Yes ☐No

   If the answer to the previous question is YES, please answer for your agency's construction contractor prequalification program.

Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐
Other: please specify:		

3. Please answer for your agency's typical procurement process. If your process can be conducted in more than one way, please answer for the most prevalent set of procedures

Do the IFB, RFQ or the RFP require the following to be submitted as part of the process to reach a design, construction, and/or design-build contract award?	Required proposal/ bid package submittal?		If YES: Is it evaluated to make the award decision?		If NO: Is it a required submittal after contract award?	
	Yes	No	Yes	No	Yes	No
Qualifications of the Design Quality Manager	☐	☐	☐	☐	☐	☐
Qualifications of the Construction Quality Manager	☐	☐	☐	☐	☐	☐
Qualifications of other Quality Management Personnel (inspectors, technicians, etc.)	☐	☐	☐	☐	☐	☐
Design quality management plan	☐	☐	☐	☐	☐	☐
Design quality assurance plan	☐	☐	☐	☐	☐	☐
Design quality control plan	☐	☐	☐	☐	☐	☐
Construction quality management plan	☐	☐	☐	☐	☐	☐
Construction quality assurance plan	☐	☐	☐	☐	☐	☐
Construction quality control plan	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐
Do your IFB, RFQ or your RFP contain the following?						
Quality management roles and responsibilities	☐	☐	☐	☐	☐	☐
Design criteria checklists	☐	☐	☐	☐	☐	☐
Construction testing matrix	☐	☐	☐	☐	☐	☐
Quality-based incentive/disincentive features	☐	☐	☐	☐	☐	☐
Warranties	☐	☐	☐	☐	☐	☐
Optional warranties	☐	☐	☐	☐	☐	☐

Design Phase:

1. Does your agency have a formal design quality assurance program for design performed in-house? ☐ Yes ☐ No
2. Does your agency have a formal design quality assurance program for design performed by design consultants? ☐ Yes ☐ No
3. Does your agency combine in-house design services with projects delivered by alternative methods (CMGC, DB, P3)? ☐ Yes ☐ No

Who performs the following design quality management tasks? (Check all that apply)	Does not apply	Agency design staff	Agency project manage-ment staff	Project design consult-ant	Project con-struction staff in CMGC, DB, P3	Indepen-dent quality consultant	Other Please specify below
Technical review of design deliverables	☐	☐	☐	☐	☐	☐	☐
Checking of design calculations	☐	☐	☐	☐	☐	☐	☐
Checking of quantities	☐	☐	☐	☐	☐	☐	☐
Acceptance of design deliverables	☐	☐	☐	☐	☐	☐	☐
Review of specifications	☐	☐	☐	☐	☐	☐	☐
Approval of final construction plans & other design documents	☐	☐	☐	☐	☐	☐	☐
Approval of progress payments for design progress	☐	☐	☐	☐	☐	☐	☐
Approval of post-award design QM/QA/QC plans	☐	☐	☐	☐	☐	☐	☐

Other:

Construction Phase:

Who performs the following construction quality management tasks? (Check all that apply)	Does not apply	Agency design staff	Agency project manage-ment staff	Project design consult-ant	Project con-struction staff in CMGC, DB, P3	Indepen-dent quality consultant	Other Please specify below
Technical review of construction shop drawings	☐	☐	☐	☐	☐	☐	☐
Technical review of construction material submittals	☐	☐	☐	☐	☐	☐	☐
Checking of pay quantities	☐	☐	☐	☐	☐	☐	☐
Routine construction inspection	☐	☐	☐	☐	☐	☐	☐
Quality control testing	☐	☐	☐	☐	☐	☐	☐
Verification testing	☐	☐	☐	☐	☐	☐	☐
Acceptance testing	☐	☐	☐	☐	☐	☐	☐
Approval of progress payments for construction progress	☐	☐	☐	☐	☐	☐	☐
Approval of construction post-award QM/QA/QC plans	☐	☐	☐	☐	☐	☐	☐
Report of nonconforming work or punchlist.	☐	☐	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐	☐	☐

Other:

Quality Management Planning: Please answer the following questions from a general perspective based on your experience.

1. Are the construction QA plans used on CMGC/DB/P3 projects significantly different from the QA plan used on traditional DBB construction projects?

   ☐ Never ☐ Sometimes ☐ Always

   If yes, what is the major difference?

2. Are the design QA plans used on CMGC/DB/P3 projects significantly different from the QA plan used on traditional design projects?

   ☐ Never ☐ Sometimes ☐ Always

   If yes, what is the major difference?

3. Does the agency specify what must be included in the design-builder's QA plans?

   ☐ Never ☐ Sometimes ☐ Always

4. Does the agency mandate the use of its own standard QA plans?

☐ Never ☐ Sometimes ☐ Always

5. Does the agency mandate the use of standard agency specifications?

   ☐ Never ☐ Sometimes ☐ Always

6. Does the agency mandate the use of standard agency design details?

   ☐ Never ☐ Sometimes ☐ Always

7. Does the agency mandate the use of standard agency construction means and/or methods? ☐ Never ☐ Sometimes ☐ Always

8. Does the agency mandate a specific set of qualifications for the quality management staff of design consultants and construction contractors in DBB projects?

   ☐ Never ☐ Sometimes ☐ Always

   If yes, what are those qualifications?

9. Does the agency mandate a specific set of qualifications for the quality management staff of design consultants and construction contractors in CMGC projects? ☐ Never ☐ Sometimes ☐ Always

   If yes, what are those qualifications?

10. Does the agency mandate a specific set of qualifications for the design-builder/P3 concessionaire's design quality assurance staff?

    ☐ Never ☐ Sometimes ☐ Always

    If yes, what are those qualifications?

11. Does the agency mandate a specific set of qualifications for the design-builder/P3 concessionaire's construction quality assurance staff?

    ☐ Never ☐ Sometimes ☐ Always

    If yes, what are those qualifications?

12. Does your agency utilize contractor quality assurance acceptance testing on any of its projects?

☐ Yes. Do you use a performance based prequalification process in conjunction with the contractor acceptance testing program? ☐ Yes ☐ No

☐ No. Would you use it if you could prequalify contractors and/or their quality assurance personnel on a performance basis? ☐ Yes ☐ No

General Quality Management Procedures:

1. Is the quality management system used on federal-aid projects different from that used on projects funded using other resources?

   ☐ Never ☐ Sometimes ☐ Always

   If yes, what is the major difference?

1. Do you think that the agency holds the outsourced design consultant's staff to a higher standard of care than it sets for its internal design staff? ☐ Yes☐ No

   ☐ No opinion Comments?

2. Do you think that the agency holds the CMGC/design-builder/P3 concessionaire's construction quality management staff to a higher standard of care than it sets for its internal construction inspection staff? ☐ Yes ☐ No ☐ No opinion

   Comments?

3. Does your organization have a document that outlines its approach to quality assurance on projects delivered using alternative methods like CMGC, DB, and or P3?

   ☐ Yes ☐ No If yes and would you be willing to share it with this research project, please contact Dr. Doug Gransberg at dgran@iastate.edu

4. Does your agency use an approach to quality management that is substantially different than that used by other agencies and might be considered an "alternative QA system"? An example might be a statistical analysis of material test reports that eliminates the need for agency acceptance testing.

   ☐ Yes ☐ No If yes and would you be willing to share it with this research project, please contact Dr. Doug Gransberg at dgran@iastate.edu

5. Which of the below best describes your agency's approach to QA for each delivery method?

DBB	CMGC	DB	P3
☐ Design consultant primarily responsible for QA/Agency audits consultant program ☐ Contractor primarily responsible for QA/Agency audits contractor program ☐ Agency retains traditional QA roles ☐ Agency retains an independent party to perform QA roles ☐ Agency uses two or more of the above depending on the project ☐ None of the above	☐ Design consultant primarily responsible for QA/Agency audits consultant program ☐ Contractor primarily responsible for QA/Agency audits design-builder's program ☐ Agency retains traditional QA roles ☐ Agency retains an independent party to perform QA roles ☐ Agency uses two or more of the above depending on the project ☐ None of the above	☐ Design-builder primarily responsible for QA/Agency audits design-builder's program ☐ Agency retains traditional QA roles ☐ Agency retains an independent party to perform QA roles ☐ Agency uses two or more of the above depending on the project ☐ None of the above	☐ Concessionaire primarily responsible for QA/Agency audits concessionaire's program ☐ Agency retains traditional QA roles ☐ Agency retains an independent party to perform QA roles ☐ Agency uses two or more of the above depending on the project ☐ None of the above

6. What are the three biggest challenges to implementing QA on projects delivered using alternative project delivery methods?

   1.
   2.
   3.

7. Please rate the following factors for their impact on the quality of the project.

Factor	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact
Qualifications of agency design staff	☐	☐	☐	☐	☐
Qualifications of agency project management staff	☐	☐	☐	☐	☐
Qualifications of agency construction staff	☐	☐	☐	☐	☐
Qualifications of the design consultant's staff	☐	☐	☐	☐	☐
Design consultant past project experience	☐	☐	☐	☐	☐
Qualifications of the construction contractor's staff	☐	☐	☐	☐	☐
Construction contractor's past project experience	☐	☐	☐	☐	☐
Quality management plans submitted/reviewed	☐	☐	☐	☐	☐
Level of agency involvement in the QA process	☐	☐	☐	☐	☐
Use of agency specifications and/or design details	☐	☐	☐	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☐	☐	☐	☐	☐
Use of performance criteria/specifications	☐	☐	☐	☐	☐
Detailed design criteria	☐	☐	☐	☐	☐
Warranty provisions	☐	☐	☐	☐	☐
Incentive/disincentive provisions	☐	☐	☐	☐	☐
Follow-on maintenance provisions	☐	☐	☐	☐	☐
Innovative financing (PPP/concession)	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐
	☐	☐	☐	☐	☐

8. Do you have any other information that you would be willing to share with the researchers that might add value to this research? If so, please submit it in the following text block.

Thank you very much for participating in this research. The results of the research will be published by NCHRP and should be available on the TRB website within the next 18 months. If you have questions or would like to contribute a case study project or other informational material, please contact Dr. Doug Gransberg at 405-325-6092 or send him an email at dgransberg@ou.edu.

APPENDIX C: CASE STUDY PROTOCOL

C.1 Overview of Case Study

Background Information

Delivering highway projects using alternative project delivery methods demands a shift in the traditional agency quality assurance (QA) and quality control (QC) programs to accommodate the faster pace of design and construction as well as the redistribution of responsibilities among project stakeholders. Thus, the objectives of this research are to:

- Identify and understand alternative quality management systems
- Develop guidelines for their use in highway construction projects

Alternative project delivery in highway construction often requires the application of alternative quality management systems that emphasize contractor quality control and quality assurance. These new systems allow owners to have confidence through a verification of contractor quality system processes. They also permit state transportation agencies (STAs) to satisfy due diligence requirements for federal-aid highway projects. For example, the International Organization for Standardization (ISO) 9001 quality management system regulates quality management at all levels from material suppliers through the contractors to owners. It requires a formal project performance evaluation after completion and uses that information to publish contractor performance ratings, which can then be used for future contractor prequalification. The U. S. Army Corps of Engineers' quality management system relies on detailed guide specifications and rigorous on-site testing by contractors. The Corps has used alternative project delivery on a routine basis for over thirty years on a wide variety of heavy civil projects that include roads and bridges, and as a result, furnishes an excellent analog from which to draw lessons learned and best practices that apply to highway design and construction.

Research is needed to provide guidance on the use of alternative quality management systems for highway construction projects using alternative delivery methods. This research needs to address the major quality issues associated with these methods including accelerated project timelines and the change of the designer-of-record's (DOR) contractual relationships with the owner to permit the required level of integration with the construction contractor. Issues of quality are further complicated by the addition of private funding of public projects in public-private partnerships (PPP). On these projects, an argument can be made that since the concessionaire is at risk for project performance the public agency has few if any reasons to involve itself in the quality management process.

From current and past projects, there exists a limited but rapidly expanding body of experience associated with alternate methods of assuring quality. The purpose of this research is to bring together this relatively new body of experience and summarize it in one easily accessible reference treating the subject of QA in alternative projects. The case studies for this research will be used to learn how existing projects have managed quality in light of non-traditional delivery methods. After analyzing and comparing the various case studies, the information gathered will be condensed into working theories and used to modify what the authors of this research are calling the Integrated Quality Management Model (IQ2M) shown in Figure C1. The model was developed to be generic to all forms of project delivery and furnish a foundation for assigning quality management responsibilities between the owner, the designer, and the constructor. As such, it acts as a framework to structure the analysis of other alternative project delivery quality systems that are common in highway construction and will be used in that manner in this research.

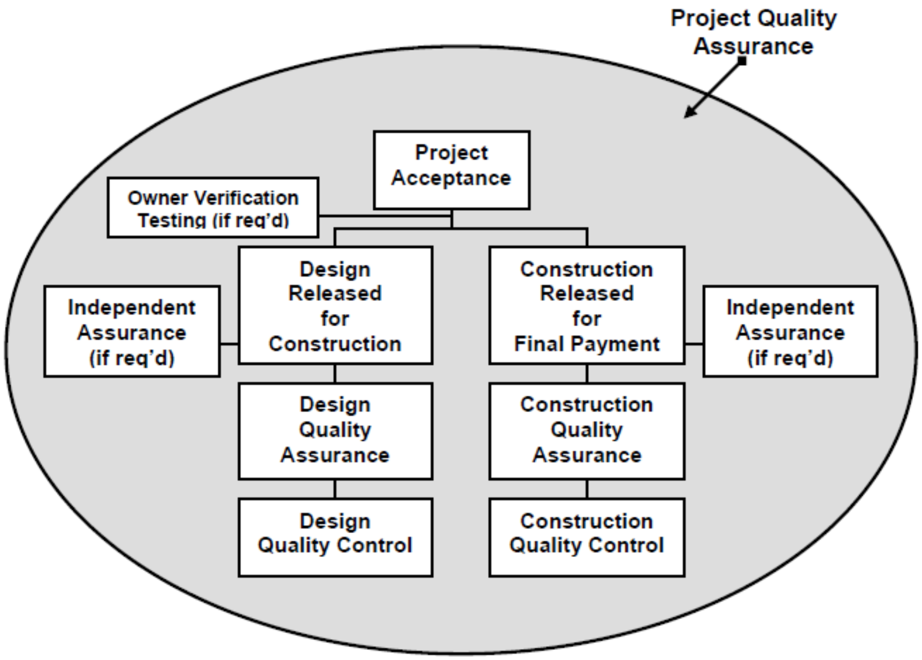

Figure C1 – Integrated Quality Management Model (IQ2M)

(adapted from Synthesis 376 (Gransberg and Molenaar 2008))

Relevant Definitions

Across the highway construction and engineering industry, terms relating to quality often have multiple meanings that in some cases overlap with one another and in others supersede each other. To prevent confusion among several vital terms important to this study, the following definitions have been provided. These definitions are in accordance with the most recent issuance of the TRB Circular Glossary of Highway Quality Assurance Terms E-C137 and the NCHRP Synthesis 376.

- **Quality:** (1) The degree of excellence of a product or service. (2) The degree to which a product or service satisfies the needs of a specific customer. (3) The degree to which a product or service conforms to a given requirement.
- **Quality Assurance (QA):** All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. [QA addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities.] TRB E-C074.

- **Quality Control (QC):** Also called process control. Those QA actions and considerations necessary to assess and adjust production and construction processes, so as to control the level of quality being produced in the end product. TRB E-C074.
- **Quality Management (QM):** The overarching system of policies and procedures that govern the performance of QA and QC activities. The totality of the effort to ensure quality in design and/or construction.
- **Design-Bid-Build (DBB):** A project delivery method where the design is completed either by in-house professional engineering staff or a design consultant before the construction contract is advertised. Also called the "traditional method."
- **Design-Build (DB):** A project delivery method where both the design and the construction of the project are simultaneously awarded to a single entity.
- **Construction Manager-General Contractor (CMGC):** A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.
- **Construction Manager-at-Risk (CMR):** A project delivery method similar to CMGC, but where the CM does not self-perform any of the construction work.
- **Public Private Partnership (P3):** A project delivery method where the agency contracts with a concessionaire organization to design, build, finance and operate an infrastructure facility for a defined extended period of time.
- **Design deliverable:** A product produced by the design-builder's design team that is submitted for review to the agency (i.e. design packages, construction documents, etc.).
- **Construction deliverable:** A product produced by the design-builder's construction team that is submitted for review to the agency (shop drawings, product submittals, etc.).

Statement of Purpose

The primary research objectives and research questions for this project are as follows:

Objectives

- *Document and categorize* **current practices** and applications of Quality Management Systems (both traditional and alternative) in highway construction for all project delivery methods
- *Explore* **how** highway construction projects of all project delivery methods are effectively applying alternate quality management systems. (developing and **implementing** quality management systems)
- *Identify* **benefits** and **limitations** of the approaches

- *Explore* **how** to **implement and apply** quality management system for all methods of project delivery
- *Produce* a guidebook that will match appropriate quality management systems to selected alternative delivery methods
    - o Describes the quality systems in the I2QM model
    - o Discusses the barriers to each system
    - o Gives guidance for individual roles in development and adoption of alt. quality management models in their agency
- *Produce* a research report that addresses the implications of adopting the guidelines and the barriers to implementation

Research Questions

1. What is the fundamental definition of quality and what is the underlying purpose of a "quality program?"
2. How are projects using alternative delivery methods currently applying quality management systems?
3. What are the advantages and disadvantages to the contractor and the owner of alternative quality management systems relating to various project delivery alternatives?
4. What changes must be made to the baseline quality management system to adapt to evolving project delivery methods?

Relevant Readings

The protocol is based largely on the following documents and research reports.

- NCHRP Project 10-83 Proposal
- Coding Structure for NCHRP Project 10-83
- TRB Circular E-C137 Glossary of Highway Quality Assurance Terms
- NCHRP Synthesis 376
- NCHRP Synthesis 40-02

C.2 Field Procedures

Project Researchers

The following is a list of the project investigators and their contact information.

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Case Study delegation

Note: The information in this section will not be available until after potential case studies have been identified and selected for study. When this information is available, this section will list who will be contacting each case study, what the scope of their questions/role will be, and who will be following up to garner additional information or thank participants for their time and effort.

Case Study Identification and Schedule

Case study project selection criteria

In the original research proposal, it was stated that "a concerted effort will be made to select case study projects from transportation agencies that have mature experience with at least two different project delivery methods." A total of 6 – 12 case studies will be performed with at least two of the case studies coming from a non-STA (USACE or the FTA). Additionally 2 pilot studies will be conducted and reviewed prior to the remaining studies to validate the case study protocol and data coding and to ensure that the research objectives will be met by the data collected.

Potential case studies will be identified in Task 1 of the research as a part of the initial survey that aims to identify alternative quality management systems currently in use. The results of this survey will be used to populate an initial list of potential case studies. Case study project selection protocol will involve three tiers of project information that must be present to move a potential case study project into the final list of candidates. The case study candidates will be forwarded to the NCHRP Panel for approval. The tiers are as follows:

1. *Project Factor Information:* This tier seeks to create a uniform set of data points for every case study project to ensure that trends or disconnects found during analysis can be uniformly mapped across the entire case study population (Yin 2008). Examples of this information are project location, size, major type of construction, initial and final budget amounts, initial and final delivery periods, delivery method, and other factors as required.
2. *Project Quality Factor Information:* This tier seeks to explicitly define the precise details of the system used to manage quality across the case study project's life cycle. Examples of this information are quality plans, quality organization composition, use of consultants for independent technical review or independent assurance/oversight, quality audits, division of quality management responsibility between the various stakeholder in the project and other factors as required.
3. *Project Performance Information:* This tier seeks to measure, if possible, the success of the quality management system employed in each project. It will use to the extent possible the stipulated performance metrics for scope, schedule, cost, quality and risk that were created for each case study project and will attempt to back-calculate performance metrics for common areas in all the projects to furnish a means of comparison and to identify and quantify the magnitude of the trends and disconnects in the case study project population.

In addition to the above, a concerted effort will be made to select case study projects from transportation agencies that have mature experience with at least two different project delivery methods. The FHWA Report to Congress on Design-Build Effectiveness (2006) identified more than 30 state STAs that had been authorized to delivery design-build projects under SEP-14 authority. However, of that sample 12 had not completed a single design-build project, another eight had only completed one design-build project, and only six had finished more than five design-build projects. Thus, at that point in time, for this project delivery method the quality management systems of only six STAs could have been impacted by multiple project experiences. Since that time additional experience has been gained and NCHRP Synthesis 376 (2008) reported that four STAs had completed five to 10 design-build projects and nine had completed greater than 10. Thus, depending on the final criterion for design-build experience, as many as 13 STAs will have potential case study design-build projects that had quality management systems that were tailored for DB project delivery. That is not the case in construction management at risk. NCHRP Synthesis 40-02 (2010) reported that only Florida and Utah have completed more than a single construction management at risk project. Thus, case study projects with construction management at risk tailored quality management systems will have to come from those two STAs or from another mode of transportation such as transit.

To summarize, the primary criterion for case study project selection will be the requirement to have come from an agency that has sufficient experience with a given project delivery method that the potential exists that the project was designed and built using a quality management system that was modified from the baseline design-bid-build system based on actual experience, using the USACE cyclical quality management system where quality management experience is fed back into the quality planning process to continuously improve the performance of the system itself.

This list of potential case studies created from the previously mentioned protocol will be supplemented by the Industry Advisory Board and the investigators' industry contacts. The following three pieces of information will have been collected for each case study as a part of the survey in Task 1: (1) name and location of the project; (2) description of the project delivery, procurement, and contracting method in use; and (3) description of the quality management system. The goal for selecting the case studies will be to generate a cross section of cases that allow for analysis of the advantages and disadvantages of the quality management systems across the various project delivery method characteristics. To ensure that this goal is met, the following criteria will be placed on the case study selection will include:

- Quality management systems for design and construction;
- Quality assurance by all parties and independent auditors;
- Project quality assurance including independent verification and independent acceptance;
- Project delivery methods including design-build, construction manager-at-risk, and PPP;
- Procurement methods including best value, A+B, and qualifications-based selection; and
- Payment methods including incentives, lump sum, and guaranteed maximum price.

Case study informant selection

Once a case study project has been selected, several members of the team directly associated with creating and implementing the quality management plan will need to be interviewed. While many people are responsible for ensuring quality on a project during its lifecycle from conception through construction, we will seek to speak with – at a minimum – enough project team members to fully satisfy the research objectives and goals. This may include speaking with representatives from the owner's, designer's, and contractor's project team to develop a full picture of the quality management systems utilized on a project and their relation to each other. Potential interviewees include the following:

- Agency project manager, contracting manager, quality manager, etc.
- Project design manager, construction manager, design quality manager, construction quality manager, etc.
- Designer quality manager, project manager
- Contractor preconstruction manager, quality manager, project manager
- Third party quality assurance/quality control inspectors

Case Study Basic Data and Research Delegation Tables

#	Case Study Name	Location	Organization	Contact (Information)
1				
2				
3				
4				
5				
6				
7				
8				

#	Case Study Name	Contacted ?	Lead Investigato r	Interview Type	Intervie w Date	Follow-up Date
1						
2						
3						
4						
5						
6						
7						
8						

#	Case Study Name	Materials/Documents Received
1		
2		
3		
4		
5		
6		
7		
8		

C.3 Requested Documents

The following is a list of documents that will be requested. However, successful completion of the research study does not require that each of the documents is collected. A subset of these documents will likely be collected depending upon the unique attributes of the project being studied.

- Project RFP/RFQ
- Project RFP/RFQ Response
- Project Quality Management Plan
- Project Design Quality Plan
- Project Construction Quality Plan
- Agency/Company Quality Plan
- Project Quality Organizational Chart
- Copy of the contract with the engineer/contractor/consultant
- Organizational document that outlines its approach to quality assurance on project

Case Study Questions

This section seeks to formalize the interview questions asked of each case study to allow for easier comparison and analysis between case studies later on. Each interview will be unique and largely guided by the case study participants. To draw out the pertinent information, specific questions may be needed while some of the questions listed here may not be relevant. In modifying the protocol questions, generality should still be maintained so that the results can still be readily compared and categorized according to the coding structure.

Questionnaire

The purpose of the questionnaire is to identify how state highway agencies (SHA) have implemented alternative QA programs and from that baseline, identify commonly used practices for dissemination and use by SHAs that intend to implement alternative procurement on future projects or alternative QA methods in their current program. The questionnaire consists of closed ended questions which will allow the researchers to perform a quantitative analysis. The data gathered by the questionnaire will be used to validate the case study findings. Ideally this questionnaire will be completed by the respondent prior to the interview. If it is not completed prior to the interview then it will be requested that the respondent complete it during the interview. The questionnaire is included in **APPENDIX B**.

Background and Overall Quality Questions

Background

- Background information to keep track of who we spoke with on each project
- Relevant prior experience used to potentially weight their opinions in later comparison

1. Name, occupation, employer
2. What are you current duties, especially related to QM, QA, QC?
3. Have you held any positions prior to your current position related to QM, QA, or QC? If so, please briefly list that information.
4. How long have you held your current position?
5. Have you worked on projects of different project delivery methods? If so specifically what project delivery methods do you have experience with?
6. How many years of experience do you with projects using baseline/DBB quality systems?
7. Name and location of the project for which you are answering project-specific questions

Overall Understanding of Quality

- Examines the overall understanding of quality and the informants attitudes towards quality
- Establishes a baseline of traditional/DBB quality for comparison

8. How do you define project quality?
9. What is your understanding of the differences between quality management, quality assurance, and quality control?
10. In your experience, how has quality management been approached on a traditional/DBB project?
    - Project by project basis?
    - During the RFP process?
    - Dictated by owner agency? If so, how is it dictated?? Specifications, performance…
11. What are the critical elements/milestones of a quality management plan on a traditional/DBB project?
12. How are the quality roles and responsibilities divided on a traditional/DBB project?
13. In your experience, what quality systems/procedures have been successful on traditional/DBB projects?

14. What are some characteristics of a successful quality management plan, regardless of the project delivery method, contracting method, or procurement method?

Organizational Questions

- Provides the needed categories and statistics (from the coding structure) to later sort and group the enterprise level QM information we receive. As not everyone selected for an interview will have answered the survey, these questions are not redundant

Please answer the following questions related to quality management at different phases of a project for the organization you work for as a whole. Please be as thorough as possible when discussing what quality management systems may exist and be utilized within your organization.

15. Of the projects your organization *designs/builds/owns* what percent of the projects are managed using the following delivery methods:
    - Design-bid-build (DBB): ______
    - Design-build (DB): _______
    - Construction Manager/General Contractor (CM/GC): _______
    - Public-Private-Partnership (PPP): _______
    - Other (please list): _______

16. Of the projects your organization *designs/builds/owns* what percent of the projects are procured using the following procurement methods:
    - Cost: ______
    - Best-value: _______
    - Qualifications: _______
    - Design: _________

17. Of the projects your organization *designs/builds/owns* what percent of the projects utilize the following contract payment methods:
    - Payment type: ________
    - Incentive type: ________

18. If you work for a STA, what due diligence requirements must your organization meet in your state for quality assurance purposes on public projects?
    - Please list applicable laws, reporting requirements, or processes required in your state
    - Can you utilize new or alternative quality management practices that produce equal or superior quality projects to meet these requirements? If not, what legal barriers prevent you from doing so?
    - If so, what steps are required to do this? Has this been done before? Please describe if it has.

19. Does your organization perform any in-house design work?
    - On what percent of your projects do you perform in-house design?
    - Do you have formal quality assurance systems in place for this process?
    - If so, please describe this process.

20. Does your organization self-perform any construction work?
    - On what percent of your projects do you self-perform some amount of construction?
    - Do you have formal quality assurance systems in place for this process?
    - If so, what are they?

Design Phase QM

- Examines design QM and is broken up into components according to the coding structure to allow for easier comparison between case studies later on
- How is design quality management managed on all project delivery types whether design is kept in-house or out of house

21. Does your organization have any *design quality assurance* systems in place?
    - If so*, please describe* the systems, policies, procedures, techniques, or standards used to ensure the quality of the designs you produce or receive. Can you provide us with an electronic or hard copy of these systems, policies, procedures, techniques, or standards?
    - Have you found these systems to be effective at producing quality designs? If yes, what makes them superior to other systems you are familiar with or function well? If no, what changes would you suggest to increase their efficacy?
    - Are there any additional procedures that would further improve the quality of designs you produce or receive? If so, please describe them.
22. Does your organization have any *design quality control* systems in place?
    - If so*, please describe* the systems, policies, procedures, techniques, or standards used for quality control of the designs you produce or receive. Can you provide us with an electronic or hard copy of these systems, policies, procedures, techniques, or standards?
23. Does your organization utilize any form *of peer review* or *3rd party/independent* design quality assurance?
    - If so, *please describe* how this is conducted and how the results are utilized to improve the quality of the original design.
    - If this process is formalized, can you provide us with any documents detailing it?

Construction Phase QM

- Examines construction QM from a STA's point of view and is broken up into components according to the coding structure to allow for easier comparison between case studies later on
- The primary focus of many QM plans and where the bulk of the information gathered at an enterprise level may be found

24. How does your organization perform *construction quality assurance*? Who has primary responsibility?
    - Does the process change based on the project type, contract style, or delivery method? If so, how is the process tailored? Who decides which method will be used?
    - Has your organization experimented with new quality assurance methods? Are you actively implementing any now? If so, what are they and how have you evaluated their efficacy?
    - Has your organization modified traditional quality assurance processes to make them applicable to projects with alternative delivery methods? If so, how have you modified them?

25. Who is responsible for *construction quality control* on projects your organization is a part of?
    - What is the process used for quality control? If this process changes due to project type, contract style, or delivery method, how does it change?
    - Do you still utilize traditional quality control methods such as control charts?
    - Has your organization modified traditional quality control processes to make them applicable to projects with alternative delivery methods? If so, how have you modified them?

- Has your organization experimented with new quality control methods? Are you actively implementing any now? If so, what are they and how have you evaluated their efficacy?

26. What role does *independent assurance* (IA) play in your projects?
    - Which parties – owner, designer, or builder – utilize IA to ensure a quality product?

27. How is *owner verification testing* used in your traditional projects?
    - What role does it have in your projects?
    - What statistical tests are used to verify the contractor's results?
    - Who conducts the testing the owner or a third party?
    - Is it used on your non-traditional projects as well? If so, what function does it serve on those projects?

28. How is *owner acceptance testing* utilized on this project?
    - Is this seen as sufficient justification of quality construction to ensure final payment? How are the results used?
    - Who conducts the testing, the owner or a third party?
    - If it is used on non-traditional projects, what function does it serve?

29. Does your organization make use of or offer any form of post-construction quality assurance? Please describe this if you can.
    - Is this part of a warranty or of an operate-and-maintain contract? If not, what is it?
    - If you are engaged in contracts with warranties or operate-and-maintain clauses, how does this impact your quality management model before and during construction?

Project Specific Questions

Please answer the following questions for the specific project you were contacted about. While not every question may apply to your project, please be as thorough as possible. If you have additional information regarding the quality management process on you project that you would like to provide, please feel free to add that below or contact us directly.

Procurement and delivery method

- Used to categorize the case studies for later comparison, these identifying questions will help focus future analysis
- Seeks to explore the relationship (if one exists) between the delivery method selected and the QM techniques used

30. What delivery method is being/was used for this project (DBB, DB, CM/GC, PPP, etc.)?

31. What procurement method (cost, best-value, qualifications based, design based, A + B, multiparameter bidding, etc.) was used to select the designer/builder/concessionaire on this project?

32. Was a prequalification process used? If so, please describe that process.
    - If a prequalification process was used, were interested parties required to submit a quality management plan (QMP)? Were they required to identify a dedicated quality manager? If you still have the QMPs from the initial solicitations, can you provide us with copies?

33. What requirements related to Quality were included in the RFP?

- Submittal of a QMP prior to award, qualifications of the quality staff on the project, submittal of a QMP after award, etc.

34. Were either the procurement or delivery methods selected partially or in whole because of their effect on quality management? If so, why were the particular methods selected?
35. What contract payment approach was selected for the project, payment or incentive?
    - What effect did this have/is this having on quality management on the project?

Quality Management Plan

- Determine roles and responsibilities for creating the overall quality management plan
- Determine the purpose/requirements of the quality management plan
- Determine how the Quality Management plan was developed and approved

36. How was the Quality Management Plan (QMP) created?
    - Was it a stock plan modified for the project? Was it created from scratch?
37. Who was responsible for creating the Quality Management Plan?
38. How was the overall quality management hierarchy created for this project?
    - What is the overall quality management hierarchy? Can you provide us with a copy of the org chart?
39. What were the Agency's quality objectives/requirements for this project and how were these communicated?
40. Describe the QMP approval process.
41. How did the QMP differ from a traditional DBB project QMP?
    - Why did this project's QMP need to be different from a traditional DBB?
42. How was the QMP development process different from a traditional DBB project?
    - Why was this projects QMP development process different from a traditional DBB QMP development?
43. How was this QMP and its development process successful?
    - What about the QMP and its development process could be improved for the next project?
44. What other management plans were required for this project and what were the quality roles and responsibilities associated?
    - Design, construction, environmental, traffic, etc…
45. Describe how the quality management on this project is different from a traditional DBB project
    - What procedures/processes/systems were different?
    - What project factors required the design quality management plan to be different from the traditional (project delivery, project complexity, funding),

Design phase QM

- Details the specific design QM techniques used on this project as broken down by the coding structure and gathers any additional information related to this process

- Seeks to understand the relationship between the techniques used on the project and those recommended at the agency-wide level
- Seeks to understand how the design QM was developed and approved and requests the needed documents

46. How was the design Quality Management Plan (QMP) created and by whom?
    - What requirements was it based on?
47. What was your organization's role/responsibilities in developing and implementing the design QMP on this project?
48. What was the project hierarchy (org chart) for this phase of the project? Who was responsible for design QA/QC on this project?
    - Can we get a copy of that chart?
49. What was the approval process for the Design QM?
50. How were the Agency's design quality requirements communicated to the Designer?
    - By RFP, design guidelines, performance specifications, etc.
51. Describe how the design quality management on this project is different from a traditional DBB project
    - What procedures/processes/systems were different?
    - What project factors required the design quality management plan to be different from the traditional (project delivery, project complexity, funding),
52. What was the basic premise of the design QMP for this project?
    - Over the shoulder reviews, spot checks, design checks at certain milestones, etc.
53. Was *quality assurance* incorporated in the design phase of this project? If so, how was it implemented on this project?
    - Who was responsible for QA, the owner or designer?
    - Was a formal plan drafted detailing how design QA would be considered? If so, can you provide us with a copy of that report?
54. Were design *quality control* processes utilized on this project? If so, how?
    - Are there documents outlining these processes? If so, can you provide us with a copy?
55. Was a dedicated design quality manager assigned by the owner, designer, CM, or concessionaire? What were their responsibilities? What authority did they have to make changes to the design or QA processes?
56. Was a *peer review* or *independent assurance* component included in design phase quality management?
    - If so, what was its role and how did it impact the final design?
57. What problems were discovered and corrected through the design phase quality management process?
    - What problems were not discovered until the construction phase of the project? Could these have been avoided with a more robust design quality management process? If so, what changes would need to be made to your process to catch these problems in the future?

58. Was the design phase QMP used on this project a standardized system used on most or all of your organization's projects? If not, was it tailored to meet the needs of this project from an existing process or created from scratch for this project?
    - How much time/what resources did creating the design QMP for this project require?
    - If an existing design QMP was modified for this project, can you provide copies of both for comparison?

59. How effective was the design QMP on this project?
    - How could it have been improved?

Construction Phase QM

- Details the specific construction QM techniques used on this project as broken down by the coding structure and gathers any additional information related to this process
- Seeks to understand the relationship between the techniques used on the project and those recommended at the agency-wide level
- Seeks to understand how the design QM was developed and approved and requests the needed documents

60. How was the Construction Quality Management Plan (QMP) created and by whom?

61. How much of the quality systems were developed during the RFP/contracting phase?
    - Was a quality plan required at RFP submittal? after award?
    - Was the quality plan developed collaboratively?

62. What was the approval process for the construction QMP?

63. How were the Agency's design quality requirements communicated to those crafting the construction QMP?
    - By RFP, design guidelines, performance specifications, etc.

64. How were this project's QM, QA, and QC systems different from a project using traditional DBB?
    - Roles/responsibilities, liabilities, etc.
    - What project factors required the design quality management plan to be different from the traditional (project delivery, project complexity, funding),

65. Was there a dedicated quality manager for this project? Who employed the manager, the owner, builder, designer, concessionaire, etc.?
    - What responsibility and authority to make changes did this manager have?

66. How was construction *quality assurance* put into place on this project?

67. What role did construction *quality control* play on this project? If a problem was discovered in the QC process, were changes made quickly enough to prevent future problems?
    - What facilitated or hindered this rapid communication?
    - How was QC implemented on this project?

68. Was *owner verification testing* used on this project to check the contractor's QC process?
    - Who performed the testing, the owner or a 3rd party?
    - Were significant discrepancies discovered on this project? If so, did the QMP provide an effective way to deal with these? How?

69. Was *owner acceptance testing* included on this project before final payment?

- Who performed this testing?
- Were significant issues discovered?
- How were they handled? Were all parties satisfied with the outcome?

70. Was *independent assurance* included as part of the construction QMP on this project?
    - If so, what role did it play in quality management on the project?

71. What other features/systems were parts of the QMP during the construction phase of this project?
    - What additional features could have prevented quality issues from arising on this project?

72. How was QM in the construction phase affected by the contract delivery method?
    - By the procurement method?

73. Can you provide a copy of the construction QMP for this project?
    - Did you modify an existing QMP for the construction phase of this project or develop one from scratch? If you modified an existing plan, can you provide copies of both for comparison?

74. What challenges did the QMP on this project face and how were they overcome?

75. Overall, were you satisfied with the quality management of the construction phase of this project?
    - Which particular aspects of the QMP were you especially pleased with?
    - If not, what would you change regarding quality management for your next project?

76. Based on your experience, would any of the quality techniques/systems used on this project be beneficial if applied to a traditional/DBB project?

Post-Construction QM

- Explores whether a formal policy for QM relating to the post-construction period exists and if such a policy exists, seeks to understand its relationship to the QMP implemented during design and construction of the project

77. Did/does this project include any warranty or operate-and-maintain provisions in the contract? If no, skip the rest of this section. If yes, please answer the following questions.
    - How did the inclusion of these provisions affect the QMP *during* construction?
    - When compared with other projects NOT having these provisions, how did these provisions affect the overall quality of the project?

Additional Questions

- This section is designed to allow for further refinement of the interview (in the pilot study phase)
- Offers the participant the opportunity to add any additional information he/she believes is relevant to our study that we may have overlooked or not asked about for lack of project specific knowledge

78. As a case study participant, how easy to understand did you find the interview questions? Were they straight forward? Did you struggle to understand the intent of some questions? In *addition* to any answers to these questions, please provide a rating from 1 to 10 (10=easy to understand, 1=so hard to understand it was difficult to finish).

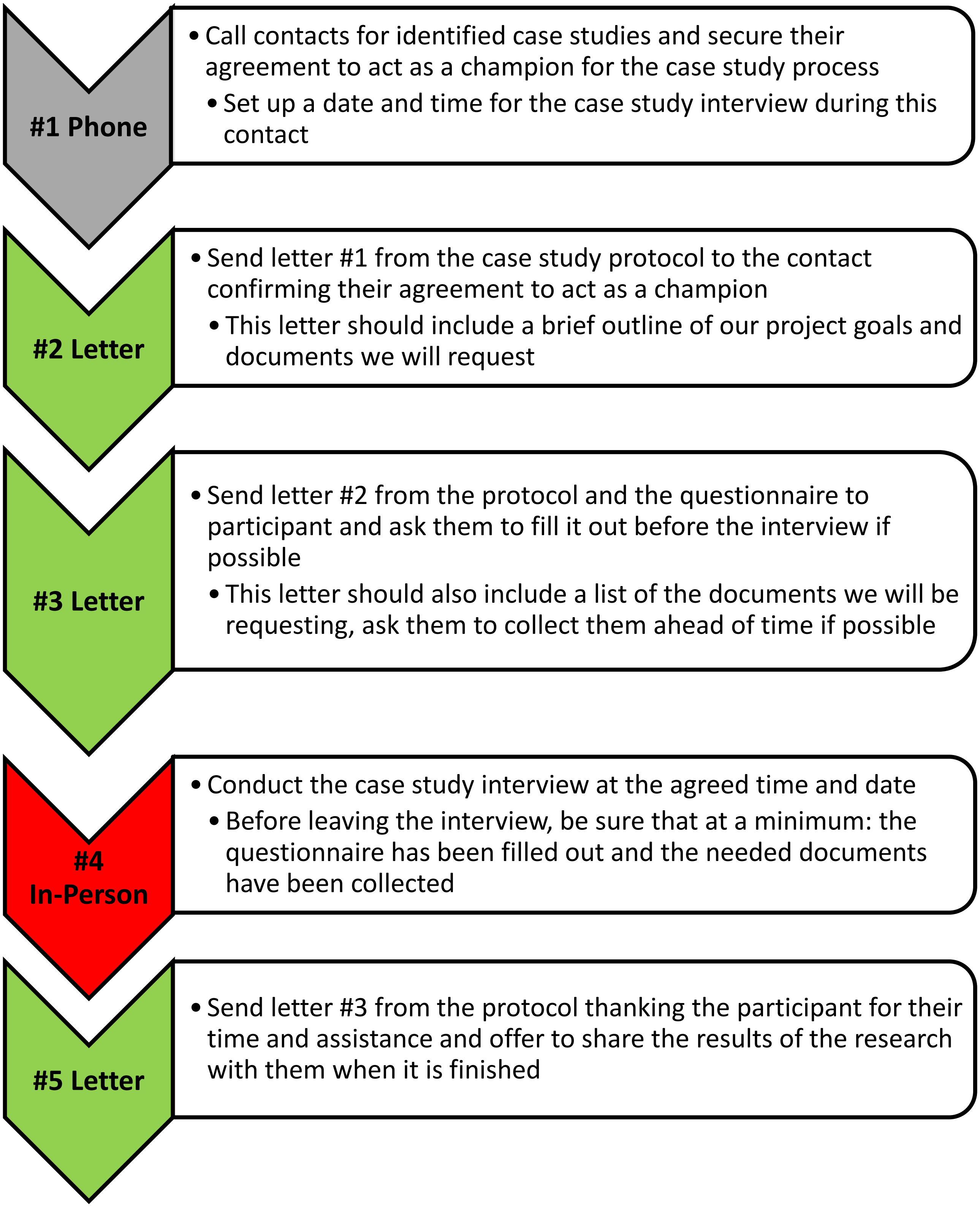
- Which questions did you find especially difficult to understand or answer?

79. Did the interview seem repetitive to you? If so, what sections/questions seemed to contain overlapping material?
80. Was the interview burdensome to complete? Were you able to answer each question to the extent of your knowledge without fatigue?
81. Given our project objectives, what additional information can you provide that would help us to better understand alternative quality management? What other QM processes, procedures, or ideas are you aware of (for any phase of a project) that you have not shared with us thus far or have been unable to utilize first-hand?
82. Given our project objectives, are there additional questions that you feel we should be asking? If so, what questions would you suggest?
83. Do you know of any other co-workers or industry peers with a position related to quality management that would be interested in speaking with us? If so, can you provide their contact information?
84. Are you aware of any projects that have utilized or are utilizing excellent quality management procedures on a project with a non-traditional delivery method (DB, CM/GC, PPP, etc.)? If so, can you provide us with the name, location, and any other pertinent information for the project?

C.4 Data Analysis

- The complete data analysis plan is described in the project Work Plan. The main points of the analysis include:
- Advantages and disadvantages to each system from the agency’s and the designer’s/constructor’s point of view;
- Identification of trends and common finding between the lit review, survey and case studies;
- Triangulate the common findings from these three sources of data to arrive at valid conclusions;
- Case studies will be summarized individually in the lens of the IQ2M model;
- Using literature review and survey information, compare key attributes of the baseline approach to key attributes in the IQ2M models. (design quality is a gap, but rigorous comparison of construction quality control, construction quality assurance and independent audit procedures will be made);
- Individual findings will analyzed across the cases using pattern matching techniques; and
- Comparison to baseline quality management system approaches.

C.5 Case Study Contact Flowchart



C.6 Sample Letters

Letter #1

MEMORANDUM

DATE

TO: Survey Participant

FROM: Keith Molenaar

Principal Investigator

SUBJECT: NCHRP 10-83 Case Study

Thank you for agreeing to participate in the NCHRP 10-83 Research Project case study concerning alternative quality management procedures for highway construction projects utilizing non-traditional contracts. We have enclosed some brief background information about the research project, its objectives, goals, and methods. We are currently scheduled to (meet with/call) you on (*insert day/month*) at (*insert time*) to conduct our interview. If for some reason this no longer works for you, please contact me as soon as possible to reschedule. Before our interview, we will send you a questionnaire related to the topics we would like to cover in the interview. Please review the questionnaire prior to the interview to become acquainted with the nature of the questions that we will be discussing. I've attached a brief outline of our research interests along with a list of documents related to the project that we would like to collect.

If you have any questions, please feel free to contact me by telephone at 303-735-4276 or by email at Keith.Molenaar@Colorado.edu.

Regards,

Keith Molenaar

Requested Documents

Below is a list of documents we would like to collect regarding the project this case study is focusing on. While your project may not have all of the listed documents, we need to obtain a copy of any of the documents included on your project as well as any additional documents not listed that you believe are relevant to our research objectives as outlined below. While we would prefer (hard/electronic) copies, either will suffice. Additionally, are there any online resources we can examine (FTP sites, project websites, etc.) before the interview to familiarize ourselves with the project?

- Copy of the contract with the engineer/ contractor/ consultant
- Project RFP/RFQ
- Project RFP/RFQ response
- Project Quality Management Plan
- Project design quality Plan
- Organizational document that outlines its approach to quality assurance on project
- Project Quality Organizational Chart
- Project Construction quality plan
- Agency/Company quality plan
-

Project Background

The NCHRP 10-83 research project has four primary research objectives. They are to:

- *Document and categorize* **current practices** and applications of Quality Management Systems (both traditional and alternative) in highway construction for all project delivery methods
- *Explore* **how** highway construction projects of all project delivery methods are effectively applying alternate quality management systems. (developing and **implementing** quality management systems)
- *Identify* **benefits** and **limitations** of the approaches
- *Explore* **how** to **implement and apply** quality management system for all methods of project delivery

In the course of meeting those objectives, we will seek to answer these four questions:

1. What is the fundamental definition of quality and what is the underlying purpose of a "quality program?"
2. How are projects using alternative delivery methods currently applying quality management systems?
3. What are the advantages and disadvantages to the contractor and the owner of alternative quality management systems relating to various project delivery alternatives?
4. What changes must be made to the baseline quality management system to adapt to evolving project delivery methods?

To answer these questions, we are performing several in-depth project case studies, covering both traditional and alternative delivery methods. The case studies will be used to learn how existing projects have managed quality in light of non-traditional delivery methods. After analyzing and comparing the various case studies, the information gathered will be condensed into working theories, used to modify what we are calling the Integrated Quality Management Model (IQ2M), and ultimately used to prepare a final research report for the NCHRP and a set of guidelines for when implementing certain AQM systems may be useful in light of other project characteristics.

Letter #2

MEMORANDUM

April 17, 2015

TO: Survey Participant

FROM: Keith Molenaar

Principal Investigator

SUBJECT: NCHRP 10-83 Case Study Questionnaire

Thank you again for your assistance with this research effort investigating alternative quality management procedures for highway construction projects utilizing non-traditional contracts. Enclosed is a questionnaire that touches on many of the topics we would like to cover in our in-depth interview. The questionnaire will be used as a baseline to generate easily comparable data across all of the different case studies we will be performing. It will be a starting point for our discussion and we would greatly appreciate it if you would take the time to look it over and fill it out to the best of your ability before our scheduled interview on (*insert day/month*) at (*insert time*). Also enclosed is a list of the documentation we are seeking for this case-study. While we would prefer (hard/electronic) copies, either will suffice. If this information is available on a website for FTP site, please let us know so that we may familiarize ourselves with the information ahead of time.

If you have any questions, please feel free to contact me by telephone at 303-735-4276 or by email at Keith.Molenaar@Colorado.edu.

Regards,

Keith Molenaar

Letter #3

MEMORANDUM

April 17, 2015

TO: Survey Participant

FROM: Keith Molenaar
Principal Investigator

SUBJECT: NCHRP 10-83 Case Study Follow-Up

Thank you for your participation in the NCHRP 10-83 interview process. We recognize that this process is time consuming and very much appreciate your assistance in helping us better understand alternative quality systems in this industry. Your insight and experience with this project will be invaluable as we compare it with projects from across the country and try to develop a better understanding of which systems work well and which do not. The research report and guidelines will not be finished until the summer of 2012, but we would be happy to share the research results with you then if you would like. Again, thank you for your time!

If you have any questions, please feel free to contact me by telephone at 303-735-4276 or by email at Keith.Molenaar@Colorado.edu.

Regards,

Keith Molenaar

C.7 Questionnaire

INTRODUCTION/BACKGROUND:

The purpose of this questionnaire is to identify how state highway agencies (SHA) have implemented alternative QA programs and from that baseline, identify commonly used practices for dissemination and use by SHAs that intend to implement alternative procurement on future projects or alternative QA methods in their current program.

DEFINITIONS: The research will use TRB Circular E-C074, *Glossary of Highway Quality Assurance Terms* to standardize its terminology. The following are terms that must be carefully understood to properly complete this survey.

Quality: (1) The degree of excellence of a product or service. (2) The degree to which a product or service satisfies the needs of a specific customer. (3) The degree to which a product or service conforms with a given requirement.

Quality Assurance (QA): All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. [QA addresses the overall problem of obtaining the quality of a service, product, or facility in the most efficient, economical, and satisfactory manner possible. Within this broad context, QA involves continued evaluation of the activities of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, and maintenance, and the interactions of these activities.] TRB E-C074.

Quality Control (QC): Also called process control. Those QA actions and considerations necessary to assess and adjust production and construction processes, so as to control the level of quality being produced in the end product. TRB E-C074.

Quality Management (QM): The overarching system of policies and procedures that govern the performance of QA and QC activities. The totality of the effort to ensure quality in design and/or construction.

Design-Bid-Build (DBB): A project delivery method where the design is completed either by in-house professional engineering staff or a design consultant before the construction contract is advertised. Also called the "traditional method."

Design-Build (DB): A project delivery method where both the design and the construction of the project are simultaneously awarded to a single entity.

Construction Manager-General Contractor (CMGC): A project delivery method where the contractor is selected during the design process and makes input to the design via constructability, cost engineering, and value analysis reviews. Once the design is complete, the same entity builds the projects as the general contractor. CMGC assumes that the contractor will self-perform a significant amount of the construction work.

Construction Manager-at-Risk (CMR): A project delivery method similar to CMGC, but where the CM does not self-perform any of the construction work.

Public Private Partnership (P3): A project delivery method where the agency contracts with a concessionaire organization to design, build, finance and operate an infrastructure facility for a defined extended period of time.

Design deliverable: A product produced by the design-builder's design team that is submitted for review to the agency (i.e. design packages, construction documents, etc.).

Construction deliverable: A product produced by the design-builder's construction team that is submitted for review to the agency (shop drawings, product submittals, etc.).

Requested Documents

Below is a list of documents we would like to collect regarding the project this case study is focusing on. While your project may not have all of the listed documents, we need to obtain a copy of any of the documents included on your project as well as any additional documents not listed that you believe are relevant to our research objectives as outlined below. While we would prefer electronic copies if available, but either will suffice.

- Copy of the contract with the engineer/ contractor/ consultant
- Project RFP/RFQ
- Project RFP/RFQ response
- Project Quality Management Plan
- Project design quality Plan
- Organizational document that outlines its approach to quality assurance on project
- Project Quality Organizational Chart
- Project Construction quality plan
- Agency/Company quality plan
-

Additionally, are there any online resources we can examine (FTP sites, project websites, etc.) before the interview to familiarize ourselves with the project?

General Information -STA:

7. US state in which the respondent is employed:

8. Name of Agency:

9. Names and groups/sections of interviewees:

10. Please check the appropriate boxes for your agency's project delivery program (PDM).

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
CMGC	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
P3	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10

11. Are your Quality Management systems different between Project Delivery Methods?

☐Yes ☐No

12. What is the approximate proportion of in-house design versus outsourced design services?

    In-house design services - Click here to enter text.%

    Outsourced design services - Click here to enter text. %

Administrative prequalification: A set of procedures and accompanying forms/documentation that must be followed by a designer or construction contractor to qualify to submit bids on construction projects using traditional project delivery.

Performance based prequalification: A set of procedures and back-up documents that must be followed by a designer or construction contractor to qualify to submit a bid on a construction project based on quality, past performance, safety, specialized technical capability, project-specific work experience, key personnel, and other factors.

3. Does your agency use a prequalification program for design firms? ☐Yes ☐No

If the answer to the previous question is YES, please answer for your agency's program to prequalify design firms.

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐

4. Does your agency use a prequalification program for construction contractors? ☐Yes ☐No

If the answer to the previous question is YES, please answer for your agency's construction contractor prequalification program.

Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐

Case Study Project Information and Data

1. Project Name and location:

2. Project scope of work:

3. Original Total Awarded Value of project: $ Final Total Value of project: $

4. Date preliminary design contract awarded: Date project advertised:

5. Date final design contract awarded: Date construction contract awarded: [Note: same if DB]

6. Original Project Delivery Period (including design) Final Project Delivery Period (including design)

   Explanatory notes:

7. Project delivery method used on this project:

Design-Bid-Build	CM-at-Risk	Design-Build	P3
☐	☐	☐	☐

   Please explain what effect this choice had on the overall quality of the project:

8. Which of the following were reasons why your agency selected the delivery method used for this project? Check all that apply.

   - ☐ Reduce/compress/accelerate project delivery period
   - ☐ Establish project budget at an early stage of design development
   - ☐ Get early construction contractor involvement
   - ☐ Encourage innovation
   - ☐ Facilitate Value Engineering
   - ☐ Encourage price competition (bidding process)
   - ☐ Compete different design solutions through the proposal process
   - ☐ Redistribute risk
   - ☐ Complex project requirements
   - ☐ Flexibility needs during construction phase
   - ☐ Reduce life cycle costs
   - ☐ Provide mechanism for follow-on operations and/or maintenance

☐ Innovative financing

☐ Other: Explain

9. Which of the above was the single most significant reason for the delivery method decision on this project?

10. Please explain the process that led you to the choice of the project delivery system for this project .

Case Study Project Quality Management Policy/Procedures Information:

The following questions will break up the quality management process into the following four phases:

- Procurement phase: Actions taken regarding the quality management process that are reflected in the agency's contractor prequalification requirements and/or solicitation documentation such as in the Invitation for Bids (IFB), Request for Qualifications (RFQ) and the Request for Proposals (RFP).
- Design Phase (in-house): Actions taken after approval to start design work regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements. ***OR***
- Design Phase (out-source): Actions taken after design contract award regarding ensuring the quality of the design deliverables as well as that the final design complies with contractual requirements.
- Construction Phase: Actions taken after contract award regarding the quality of the final constructed product to ensure that it complies with both the completed design and other contractual requirements.

The research team understands that the term "Approval" has a variety of slightly different meanings from state to state. It is used here to indicate the process by which the agency indicates that it is satisfied with the quality of the design or construction deliverable and is willing to make payment for satisfactory completion of that task if asked.

Procurement phase:

1. What procurement method was used to select the designer, builder, or concessionaire? (low bid, best-value, qualifications based selection, etc.)

2. Please answer for the case study project. If your process was conducted in more than one way, please answer for the most prevalent set of procedures.

Do your project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.) contain the following?	**Required proposal/ bid package submittal?**		**If YES: Is it evaluated to make the award decision?**		**If NO: Is it a required submittal after contract award?**	
	Yes	No	Yes	No	Yes	No
Qualifications of the Design Quality Manager	☐	☐	☐	☐	☐	☐
Qualifications of the Construction Quality Manager	☐	☐	☐	☐	☐	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	☐	☐	☐	☐	☐
Design quality management plan	☐	☐	☐	☐	☐	☐
Design quality assurance plan	☐	☐	☐	☐	☐	☐
Design quality control plan	☐	☐	☐	☐	☐	☐
Construction quality management plan	☐	☐	☐	☐	☐	☐
Construction quality assurance plan	☐	☐	☐	☐	☐	☐
Construction quality control plan	☐	☐	☐	☐	☐	☐
Quality management roles and responsibilities	☐	☐	☐	☐	☐	☐
Design criteria checklists	☐	☐	☐	☐	☐	☐
Construction testing matrix	☐	☐	☐	☐	☐	☐
Quality-based incentive/disincentive features	☐	☐	☐	☐	☐	☐
Warranties	☐	☐	☐	☐	☐	☐
Optional warranties	☐	☐	☐	☐	☐	☐

3. Was your procurement method selected in part because of its effect on quality management? If so, what effect did the method you chose have on overall project quality?

Design Phase:

4. Did this project have a formal design quality assurance program for any design performed in-house? ☐Yes ☐No

5. Did this project have a formal design quality assurance program for design performed by design consultants? ☐Yes ☐No

6. Did this project combine in-house design services with projects delivered by alternative methods (CMGC, DB, P3)? ☐Yes ☐No

For this project who performed the following design quality management tasks? (Check all that apply)	**Does not apply**	**Agency design staff**	**Agency project manage-ment staff**	**Project design consult-ant**	**Project con-struction staff in CMGC, DB, P3**	**Indepen-dent quality consultan t**	**Other Please specify below**
Technical review of design deliverables	☐	☐	☐	☐	☐	☐	☐
Checking of design calculations	☐	☐	☐	☐	☐	☐	☐
Checking of quantities	☐	☐	☐	☐	☐	☐	☐
Acceptance of design deliverables	☐	☐	☐	☐	☐	☐	☐
Review of specifications	☐	☐	☐	☐	☐	☐	☐
Approval of final construction plans & other design documents	☐	☐	☐	☐	☐	☐	☐
Approval of progress payments for design progress	☐	☐	☐	☐	☐	☐	☐
Approval of post-award design QM/QA/QC plans	☐	☐	☐	☐	☐	☐	☐

Construction Phase:

For this project who performed the following construction quality management tasks? (Check all that apply)	**Does not apply**	**Agency design staff**	**Agency project manage-ment staff**	**Project design consult-ant**	**Project con-struction staff in CMGC, DB, P3**	**Indepen-dent quality consultan t**	**Other Please specify below**
Technical review of construction shop drawings	☐	☐	☐	☐	☐	☐	☐
Technical review of construction material submittals	☐	☐	☐	☐	☐	☐	☐
Checking of pay quantities	☐	☐	☐	☐	☐	☐	☐
Routine construction inspection	☐	☐	☐	☐	☐	☐	☐
Quality control testing	☐	☐	☐	☐	☐	☐	☐
Verification testing	☐	☐	☐	☐	☐	☐	☐
Acceptance testing	☐	☐	☐	☐	☐	☐	☐
Approval of progress payments for construction progress	☐	☐	☐	☐	☐	☐	☐
Approval of construction post-award QM/QA/QC plans	☐	☐	☐	☐	☐	☐	☐
Report of nonconforming work or punchlist.	☐	☐	☐	☐	☐	☐	☐

Quality Management Planning: Please answer the following questions about the project based on your experience.

12. Are the design QM plans used on this project different from the QM plans used on traditional design projects?

☐No ☐ Yes

If yes, what is the major difference? Click here to enter text.

13. Are the construction QM plans used on this project different from the QM plans used on traditional DBB construction projects?

☐No ☐ Yes

If yes, what is the major difference? Click here to enter text.

14. Did the agency mandate the use of standard agency specifications?

☐No ☐ Yes

15. Did the agency mandate the use of standard agency design details?

☐No ☐ Yes

16. Did the agency mandate the use of standard agency construction means and/or methods?

☐No ☐ Yes

If no, what was required in their place?

17. Did the agency mandate a specific set of qualifications for the quality management staff of design consultants and construction contractors on this project?

☐No ☐ Yes

If yes, what are those qualifications? Click here to enter text.

18. Did your agency utilize contractor quality assurance test results for acceptance on this project?

☐Yes. ☐No.

Quality Management Procedures:

2. Do you think that the agency held the CMGC/design-builder/P3 concessionaire's design/construction quality management staff to a higher standard of care than it sets for its internal staff?

☐Yes ☐No

Comments? Click here to enter text.

3. Does your organization have a document that outlines its approach to quality assurance on project? ☐Yes ☐No

   If yes, was it used on this project? If no, what was used in its place?

4. Does your agency use an approach to quality management that is substantially different than that used by other agencies and might be considered an "alternative QM system"? (i.e. statistical analysis of material test reports that eliminates the need for agency acceptance testing)

   ☐Yes ☐No

   Describe:

5. Which of the below best describes your agency's approach to QA on this project?

   Interviewer: select appropriate delivery method

DBB	CMGC	DB	P3
☐Design consultant primarily responsible for QA/Agency audits consultant program ☐Contractor primarily responsible for QA/Agency audits contractor program ☐Agency retains traditional QA roles ☐Agency retains an independent party to perform QA roles ☐Agency uses two or more of the above depending on the project ☐None of the above	☐Design consultant primarily responsible for QA/Agency audits consultant program ☐Contractor primarily responsible for QA/Agency audits designers and CMGC's program ☐Agency retains traditional QA roles ☐Agency retains an independent party to perform QA roles ☐Agency uses two or more of the above depending on the project ☐None of the above	☐Design-builder primarily responsible for QA/Agency audits design-builder's program ☐Agency retains traditional QA roles ☐Agency retains an independent party to perform QA roles ☐Agency uses two or more of the above depending on the project ☐None of the above	☐Concessionaire primarily responsible for QA/Agency audits concessionaire's program ☐Agency retains traditional QA roles ☐Agency retains an independent party to perform QA roles ☐Agency uses two or more of the above depending on the project ☐None of the above

If "None of the above" was selected, please describe the approach that was used instead:

6. What was the biggest quality challenge in the procurement phase?

7. What was the biggest quality challenge in the design phase?

8. What was the biggest quality challenge in the construction phase?

9. Please rate the following factors for their impact on the quality of this project:

Factor	**Very High Impact**	**High Impact**	**Some Impact**	**Slight Impact**	**No Impact**
Qualifications of agency design staff	☐	☐	☐	☐	☐
Qualifications of agency project management staff	☐	☐	☐	☐	☐
Qualifications of agency construction staff	☐	☐	☐	☐	☐
Qualifications of the design consultant's staff	☐	☐	☐	☐	☐
Design consultant's past project experience	☐	☐	☐	☐	☐
Qualifications of the construction contractor's staff	☐	☐	☐	☐	☐
Construction contractor's past project experience	☐	☐	☐	☐	☐
Submittal of Quality management plans prior to work start	☐	☐	☐	☐	☐
Level of agency involvement in the QM process	☐	☐	☐	☐	☐
Use of agency specifications and/or design details	☐	☐	☐	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☐	☐	☐	☐	☐
Use of manuals, standards and specifications developed for DBB type projects	☐	☐	☐	☐	☐
Allowing flexibility in choice of design standards and construction specifications	☐	☐	☐	☐	☐
Use of performance criteria/specifications	☐	☐	☐	☐	☐
Detailed design criteria	☐	☐	☐	☐	☐
Warranty provisions	☐	☐	☐	☐	☐
Incentive/disincentive provisions	☐	☐	☐	☐	☐
Follow-on maintenance provisions	☐	☐	☐	☐	☐
Innovative financing (PPP/concession)	☐	☐	☐	☐	☐

C.8 Case Study Selection Matrix

Case Study Selection Matrix					Delivery Method				Procurement Method		
#	Case Study Name	State	Est. Value (millions)	Pilot	Design-Bid-Build	Design-Build	CM/GC	PPP	No Prequalifications	Designer Prequalification	Contractor Prequalification
1	Hastings River Bridge	MN	$	☐	☐	☐	☐	☐	☐	☐	☐
2	Willamette River Bridge	OR	$	☐	☐	☐	☐	☐	☐	☐	☐
3			$	☐	☐	☐	☐	☐	☐	☐	☐
4			$	☐	☐	☐	☐	☐	☐	☐	☐
5			$	☐	☐	☐	☐	☐	☐	☐	☐
6			$	☐	☐	☐	☐	☐	☐	☐	☐
7			$	☐	☐	☐	☐	☐	☐	☐	☐
8			$	☐	☐	☐	☐	☐	☐	☐	☐

APPENDIX D: GEORGE SELLAR BRIDGE PROJECT, WASHINGTON STATE

Project Overview

Basic Information

Project Name: SR285 George Sellar Bridge (GSB) Additional EB Lane Project

Name of Agency: Washington State Department of Transportation (WSDOT)

Location: MP 0.16 to MP 0.39 over the Columbia River between the towns of Wenatchee and East Wenatchee in the state of Washington

Project Delivery Method (*DBB, DB, CM/GC, PPP, etc.*): DBB

Procurement Procedure (*QBS, Best-Value, Low Bid*): A + B + C bidding (cost, working days, and number of total bridge closures)

Contract Payment Provisions (*Lump Sum, GMP, Cost +*): Lump Sum with limited disincentive provisions

Methodology

The case study interview was conducted on September 7, 2011 in a conference call format. The interview used Cisco's WebEx to record the call and allowed participants to see answers being recorded in real time via their computer to verify accuracy. The group interview included the lead project manager/engineer from WSDOT, the lead bridge engineer for the project from WSDOT, and the project manager from the contractor, the Max J. Kuney Company. Participants had previously filled out the case study questionnaire developed as part of the protocol for the project. Following a brief introduction to the research project and its objectives, discrepancies between the three sets of questionnaire responses were cleared up. With the remaining time scheduled for the interview, additional open-ended questions from the protocol were asked to develop a better understanding of the project. Following the interview, several additional documents were received by the research team in addition to those provided prior to the interview.

Project Description

The city of Wenatchee, WA has very limited access as it is bounded to the north by the Wenatchee River, to the West and South by mountains, and to the East by the Columbia River. The SR 285 Senator George Sellar Bridge (Stevens St.) was built in 1950 and is one of only two major access points to the city and carries 50,000-60,000 vehicles a day into and out of the city. Originally built to carry two lanes of traffic in each direction, WSDOT decided to increase the capacity of the bridge by reducing lane widths and adding a third eastbound lane to the through-truss bridge.

Project Scope

- Removal of the sidewalks on either side of the roadway to make way for a fifth lane
- Expansion of bridge deck from 54' to 61' wide to accommodate five 11' wide lanes, a 2' wide median, and 2' wide shoulders

- To carry the increased load, significant strengthening of 100 truss members was required involving either the addition of steel plates or replacement of the members
- The truss strengthening required the removal of 10,000+ rivets near active lanes of traffic and the installation of 35,000 high strength bolts
- The parabolic portals on either end of the bridge had to be cut and strengthened to raise their clearance height to accommodate truck traffic further from the centerline of the bridge
- Sway frames at either end of the bridge had to be removed and replaced (this was performed without bridge closure)
- Construction of a 10 foot wide cantilevered pedestrian and bike pathway on the south side of the bridge
- Construction of a tunnel below the East side approach to accommodate the nearby Apple Capital Recreational Loop Trail.
- Widening of the bridge approaches on both sides of the bridge and modification of three approach/exit ramps in addition to general civil site work
- Construction occurred above an active BNSF railroad line (30+ trains/day) on the West end of the bridge and maintained four open lanes of traffic during the day.

Project Financial and Schedule Information

Original Total Awarded Value of construction contract: $12,884,988

Final Total Awarded Value of construction contract: $12,700,000 (still processing final payments)

Total project cost (including design): $18,420,000

Project Schedule Length: 19 months

Project Approved to start process: 11/23/2005 (design funds authorized)

Initial Advertising: 1/26/2009 (originally set for 10/2008)

Construction Contract Award: 3/24/2009

Original Project Delivery Period: Project to be complete December 2010; 322 working days

Final Project Delivery Period: Project completed July 21, 2010; 388 total working days

Project Completion Deadline: The owner set the maximum number of total working days to 360 in the bid documents

> **Comments**: The owner originally intended to advertise the project for bids in October of 2008. However, strengthening the truss members was found to more complex than originally anticipated and the advertisement date was pushed back to January of 2009 to allow for further development of the strengthening designs and process. This also pushed back the anticipated completion date.

Project Delivery Method

Agency Project Delivery Experience

Table D1 – Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10; ☒ > 10
CMGC	☒NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10
DB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☒5-10; ☐ > 10
PPP	☒NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10
Other	☒NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10

Table D1 lists WSDOT's legal authority to use and experience with the major project delivery methods. WSDOT has decades of experience with the traditional DBB method but is limited in alternatives that it can use. While the agency cannot use the CM/GC or PPP methods, it is authorized by the Washington state legislature to use the design-build delivery method at its discretion without the need to seek legislative approval.

Project delivery method used on this project: DBB with early contractor involvement

Reasons for Selecting Project Delivery Method (most significant reason)

A DBB project delivery method was chosen for this project because at the time it was authorized, all WSDOT projects of this size were constructed using DBB

Procurement Process

Prequalification

WSDOT does not utilize prequalification for design firms and performs 70% of its design internally. However, as shown in Table D2, performance based prequalification is required on all WSDOT construction projects. Construction contractors are prequalified at the state level, not on a project-specific basis. Contractors must be prequalified annually for each class of work they would to like bid for projects in and must submit examples of their qualifications and prior experience in that class of work. For firms with a net worth in excess of $100,000, pre-qualification includes the submittal of financial statements prepared by a certified and licensed public accountant and the financial opinion of the company by an independent auditor.

Table D2 – Administrative and Performance Based Prequalification Requirements

Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☒
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☒
Prequalification standards are different by project class	☐	☒

Procurement Method

WSDOT used an A + B + C bidding process in an attempt to get the job completed as quickly as possible. The three items under consideration were total cost, number of working days multiplied by a fixed dollar value per day, and number of total bridge closures multiplied by a fixed dollar value per closure. In the bid documents, WSDOT capped the total number of working days at 360 and the number of total bridge closures at 8. Of the bids submitted, most called for zero total bridge closures somewhat to the surprise of the project management staff.

Agency's Reasons for Choosing Procurement Method

This bidding method was chosen for two primary reasons:

- To minimize the impact of the project on the travelling public: WSDOT wanted to finish construction and remove any traffic restrictions as soon as possible and wanted to limit the number of total bridge closures to a minimum as this was one of two access points into the town
- To ensure supporting projects on either end of the bridge could begin on time: The addition of an eastbound lane to the GSB was one of a string of traffic improvement projects scheduled for the area. The construction of an eastbound bypass and the reconfiguration of adjacent intersections were both scheduled to begin as soon as this project was finished in order to minimize overlap of contractors and traffic delays

Although the winning bid called for 322 total working days and the agency specified a maximum of 360 allowable working days, the project was delivered late in 388 working days.

Required Document Submittals for Bidding

Table D3 lists the quality documents the construction contractor was required to submit as a part of its bid or later after the award of the project. There were very few required submittals including the qualifications and certifications of the construction inspectors and materials testing technicians, the construction testing matrix, and the roles and responsibilities of quality management personnel.

Table D3: Required Bidding Documents

Did your project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.) contain the following?	Required proposal/ bid package submittal?	If required, is it evaluated to make the award decision?	If not required, is it a required submittal after contract award?
Qualifications of the Design Quality Manager	N/A	N/A	N/A
Qualifications of the Construction Quality Manager	☐	☐	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	☐	☒
Design quality management plan	N/A	N/A	N/A
Design quality assurance plan	N/A	N/A	N/A
Design quality control plan	N/A	N/A	N/A
Construction quality management plan	N/A	N/A	N/A
Construction quality assurance plan	N/A	N/A	N/A
Construction quality control plan	☐	☐	☐
Quality management roles and responsibilities	☐	☐	☒
Design criteria checklists	N/A	N/A	N/A
Construction testing matrix	☐	☐	☒
Quality-based incentive/disincentive features	☐	☐	☐
Warranties	N/A	N/A	N/A
Optional warranties	N/A	N/A	N/A

Notes: The GSB project was designed in-house by WSDOT engineers eliminating the need for the submittal of design quality management documents. As a DBB project, prospective contractors were only required to submit the necessary bidding documents in order to be considered for the project and were not required to submit any document pertaining to quality management.

Quality Management Roles

Design Phase Summary

Table D4 lists the quality management responsibilities of the major project parties. As an internally designed project, design quality management was entirely controlled by the agency and its design and project management staff. The project was designed using standard agency quality management procedures and thus it did not require approval of a new design QMP. While the design and bridge engineering staff were the only ones to perform technical review the calculations, the project management staff assisted with review of the specifications and designs and performed the primary acceptance function.

Table D4: Design Quality Management Roles

	Responsible Party					
Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	☒	☒	☐	☐	☐	☐
Checking of design calculations	☒	☐	☐	☐	☐	☐
Checking of quantities	☒	☐	☐	☐	☐	☐
Acceptance of design deliverables	☐	☒	☐	☐	☐	☐
Review of specifications	☒	☒	☐	☐	☐	☐
Approval of final construction plans & other design documents	☐	☒	☐	☐	☐	☐
Approval of progress payments for design progress	N/A	N/A	N/A	N/A	N/A	N/A
Approval of post-award design QM/QA/QC plans	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

- As a project designed in-house by WSDOT, the design quality management process was conducted entirely by WSDOT design personnel. While the design project manager and construction project manager were the same for this project, technical review of the drawings was performed by WSDOT design personnel only.

Construction Phase Summary

Table D5 shows the division of construction quality management tasks. As a DBB project, WSDOT was actively involved in most tasks including participation in the construction quality control function. While technicians employed by the contractor were used to conduct verification testing (especially rotational capacity testing of installed bolts), this was done under the observation of a WSDOT inspector.

Table D5: Construction Quality Management Roles

	Responsible Party (select all that apply)					
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of construction shop drawings	☒	☒	☐	☒ cursory	☐	☐
Technical review of construction material submittals	☒	☒	☐	☒ cursory	☐	☐
Checking of pay quantities	☐	☒	☐	☒	☐	☐
Routine construction inspection	☐	☒	☐	☐	☐	☐
Quality control testing	☐	☒	☐	☒	☐	☐
Verification testing	☐	☒	☐	☒	☐	☐
Acceptance testing	☐	☒	☐	☐	☐	☐
Approval of progress payments for construction progress	☐	☒	☐	☒	☐	☐
Approval of construction post-award QM/QA/QC plans	☐	☒	☐	☐	☐	☐
Report of nonconforming work or punchlist.	☐	☒	☐	☐	☐	☐

- Cursory reviews of shop drawings and material submittals were performed by the contractor's staff, but for the most part were passed on from subcontractors to the agency for approval by either project management or design staff
- Quality control testing was performed by either agency or contractor personnel in different cases. Verification testing was typically performed by the contractor and witnessed by agency staff

Participants' Ranking of Impact on Quality

Table D6: Rankings of the Impact of Quality Factors

Factor	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact
Qualifications of agency design staff	☒	☐	☐	☐	☐
Qualifications of agency project management staff	☒	☐	☐	☐	☐
Qualifications of agency construction staff	☒	☐	☐	☐	☐
Qualifications of the design consultant's staff	N/A	N/A	N/A	N/A	N/A
Design consultant's past project experience	N/A	N/A	N/A	N/A	N/A
Qualifications of the construction contractor's staff	☒	☐	☐	☐	☐
Construction contractor's past project experience	☐	☒	☐	☐	☐
Submittal of Quality management plans prior to work start N/A	N/A	N/A	N/A	N/A	N/A
Level of agency involvement in the QM process	☐	☒	☐	☐	☐
Use of agency specifications and/or design details	☒	☐	☐	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☒	☐	☐	☐	☐
Use of manuals, standards and specifications developed for DBB type projects	☒	☐	☐	☐	☐
Allowing flexibility in choice of design standards and construction specifications	☐	☐	☐	☒	☐
Use of performance criteria/specifications	☐	☐	☐	☐	☒
Detailed design criteria	☒	☐	☐	☐	☐
Warranty provisions	N/A	N/A	N/A	N/A	N/A
Incentive/disincentive provisions	☐	☐	☐	☒	☐
Follow-on maintenance provisions	N/A	N/A	N/A	N/A	N/A
Innovative financing (PPP/concession)	N/A	N/A	N/A	N/A	N/A

The rankings shown in Table D6 represent the consensus of the three interview participants regarding the impact of various factors on the overall quality of the project. The table shows a clear emphasis on the importance of quality and project management staff and on the level of detail expressed in the design documents and agency specifications.

Quality Management Plans

- Neither the design nor the construction phases of this project had explicit quality management plans. Instead, quality requirements and processes were embedded either in Project Management Plans (PMPs) or in the contract and specifications

Design

The project used the standard design quality management plan used on all bridge projects designed by WSDOT and is included in Chapter 1.3 of the WSDOT Bridge Design Manual. The plan lays out the goals of the design process and their priority and lists the members of the design quality team and their responsibilities in the process.

As noted above, there was no explicit design quality management plan for this project. Instead, references to the QC/QA plans and deliverable expectations in WSDOT's manuals and websites were included in the design PMP along with the scope, the team and responsibilities, the change management plan, the communication plan, the schedule, the risk management plan, the budget, the engineer's estimate, and endorsements of the plan by all key participants from WSDOT. The

PMP was the focus of the planning effort but did not include the development of a separate QMP.

Construction

As noted above, the project did not have an explicit QMP in place. Instead, aspects of quality management were included in the construction PMP (separate from the design PMP) and in the construction contract and specifications. Important elements of the construction PMP included a team decision-making process, a safety plan, a communication plan (both internal and external), a change management plan, and a risk management plan. The contract required the contractor to conform to the standard specifications of WSDOT in addition to the special provisions included for this project. Included in these amendments to the standard specifications and special provisions were either specific material and testing requirements or references to WSDOT's standard specifications manual and materials manual which lay out the acceptable materials tests and certification criteria. The contractor was required to perform quality control testing to demonstrate compliance with these documents.

Incentives and Disincentives

The use of the A + B + C bidding technique and 360 working days cap were two attempts by WSDOT to encourage bidders to shorten the construction schedule as much as possible. In order to make sure bidders stuck to their submitted construction schedules and did not underbid just to win the project, WSDOT included liquidated damages in the construction contract. These damages worked out to just over $6000 per day for each working day the winning contractor went over their bid. As noted above, the project was delivered in 388 working days, above the cap in the bidding process and 66 days longer than the original bid of 322 days. However, no liquidated damages were charged to the contractor as WSDOT approved 57 change orders adding $247,873 to the project cost and an additional 66 working days.

There were no incentive or warranty provisions included in the construction contract.

Quality Management Organization Model

The George Sellar Bridge project was delivered using the traditional DBB delivery method. The use of this standard delivery method is reflected in its QMS as seen in Figure D1. This model is known as a Deterministic QAO would be considered a reactive form of quality management. For this project WSDOT, the agency, performed the design in-house and as a result controlled design QC, design QA, and the decision of when to release the drawings for construction.

In terms of construction quality management, WSDOT was responsible for construction QA and releasing construction for final payment, but it left the construction QC function in the hands of the contractor. Even though construction QC was theoretically controlled by the contractor, WSDOT still played a significant role in this function. The contractor was not required to submit a quality control or a QMP, instead they were required to adhere to the project specifications and special provisions and deliver what was shown in the project drawings. The project specifications reference WSDOT manuals regarding performance specifications and/or quality control testing requirements for virtually every material used on WSDOT's projects.

While projects utilizing the Deterministic QAO can sometimes turn adversarial due to the distribution of construction quality management functions, on the GSB project, agency representatives recognized and commented on an extremely high level of teamwork and cooperation between the contractor and the agency throughout construction and the various quality management processes.

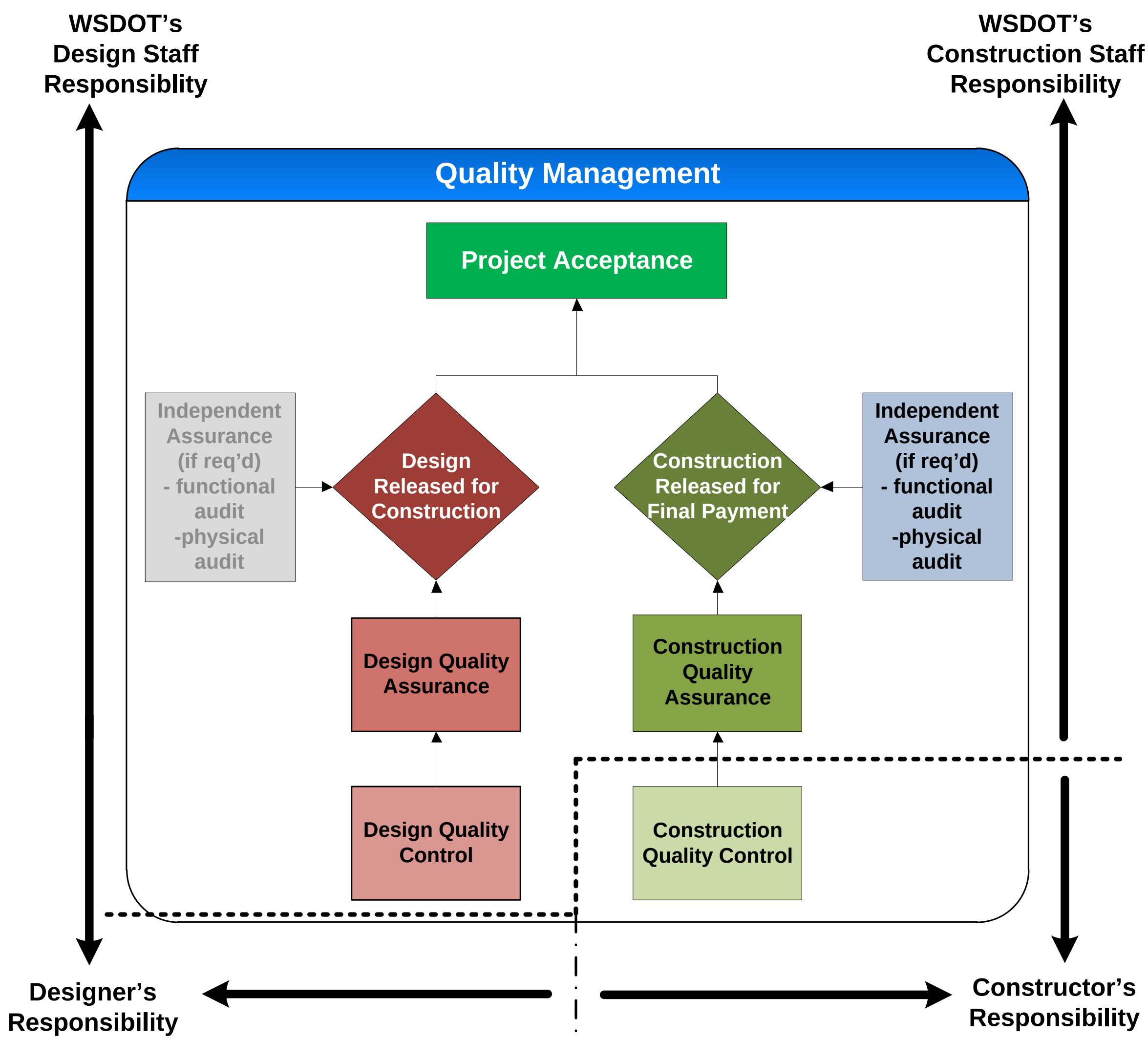


Figure D1: George Sellar Bridge QAO Model

Summary

Effective QM Practices

- Use of a joint AGC and WSDOT panel to inform the design process: Faced with the complex task of strengthening the truss members of the bridge while keeping the roadway open to traffic, project managers solicited the input of the joint WSDOT/AGC Bridge and Structures Team. The team is one of several focusing on different topics and is made up of a rotating list of members of volunteers from AGC members and WSDOT structures staff and meets on an as needed basis, though typically monthly. The panel covers planned topics at each meeting in addition to reviewing projects brought to them by WSDOT project managers.

- GSB project managers used to the panel both for assistance in drafting a traffic control plan that could adequately maintain a daily traffic load of 60,000 vehicles and to suggest a preferred alternative for the various portal modifications under consideration. In order to maintain a fair bidding process for projects that use the panel, contractors who sit on the panel are still allowed to bid on projects they've considered and all meetings are open to the public and have their minutes posted online.
- Specific recommendations from the panel included the use of a quick-change movable traffic barrier to rapidly change lane configurations (to take extra lanes at night) in-between daytime and nighttime construction shifts. The project manager noted effective traffic control as one of the key successes of this project and credited this system with much of that success. The panel also recommended one of several portal modification alternatives to use. Although the designers originally believed the bridge would have to be fully closed to make the modifications, none of the contractors included a full closure in their bids and none were needed.
- Use of pre-bid meetings for clarification: Several days after the plans were advertised for construction bids, WSDOT held a pre-bid meeting which was advertised in the special provisions of the contract. The project engineer was on hand to answer any questions contractors might have regarding the designs and their intent and interested contractors were invited to visit the site. As the meeting was open to the public, attendance by prospective bidders was not required, though the contractor who won the bid indicated it was extremely useful in preparing the bid.

Observations of the Researcher

The George Sellar Bridge project was a very successful project and met most of its goals. While the project was delivered late due to the unforeseen complexity of strengthening the truss members, it was delivered slightly under budget and with minimal disruption to the traveling public. In the interview, all of the project representatives agreed the project was a success, though to varying degrees. Part of this success is likely attributable to the communication between the contractor and the agency as the agency design representative and the agency project manager noted several times the high level of teamwork on this project and that while there were plenty of opportunities for things to go very wrong, they didn't.

The project manager attributed some of this success to an early informal partnering process which sought to set the expectation for good communication between the contractor and the agency. Some of this success is also likely due to the fact that the contractor knew what to expect on this project and understood the design process better as a result of the pre-bid meeting. While this project was traditional in terms of its QMS, the use of the joint AGC/WSDOT panel on structures was repeatedly acclaimed to have had a significant role in leading the project to success. The panel stands out as a noteworthy practice for consideration in that it allowed for the input of practicing contractors while maintaining a fair bidding process.

APPENDIX E: WILLAMETTE RIVER BRIDGE, OREGON

Project Overview

Basic Information

Project Name: Willamette River Bridge (WRB) Project

Name of Agency: Oregon Department of Transportation (ODOT)

Location: I-5 over the Willamette River in Lane County at the border of the cities of Eugene and Springfield, OR.

Project Delivery Method (*DBB, DB, CM/GC, PPP, etc.*): CM/GC

Design Procurement Procedure (*QBS, Best-Value, Low Bid*): Two stage best-value

Construction Procurement Procedure (*QBS, Best-Value, Low Bid*): Best-value (85% qualifications/15% preconstruction services price)

Contract Payment Provisions (*Lump Sum, GMP, Cost +*): GMP provided after substantial design completed

Project Parties

Owner: ODOT

Owner's Program Manager: Oregon Bridge Delivery Partners (OBDP) is a joint venture of HDR and Fluor hired by ODOT in 2003 to help manage its multi-billion dollar OTIA III bridge infrastructure program of which the WRB project is a part. OBDP acts both in an advisory and management role for ODOT and is in some cases actively involved with the quality management process on a project.

Designer: OBEC Consulting Engineers/T.Y. Lin International

CM/GC: Hamilton Construction (joint venture with Slayden Construction)

Methodology

The case study interview was conducted on June 23, 2011 in the Hamilton Construction trailer at the project site. The interview was conducted simultaneously with representatives from all four project parties who had some experience with the QMS on the project: ODOT, OBDP, OBEC Consulting Engineers, and Hamilton Construction. The interview was conducted in accordance with the case study protocol developed by the research team and approved by both an industry panel and the NCHRP review panel. Interviewees were introduced to the research and given a brief summary of the research objectives. The primary interview tool was the questionnaire developed as part of the protocol which focused on generating information that could be readily compared across case studies. As questions were asked and the interviewees responded, a summary of their answers was recorded and projected on the wall of the conference room to ensure that all respondents were satisfied with the summary of their answers.

After the interview was concluded, follow-up questionnaires were delivered to each interviewee electronically to capture their demographic information and prior experience in addition to asking clarifying questions from the in person interview. The data collection process concluded with a request for relevant project documents which were mailed to the research team on a CD for later review. Interviewees volunteered their time and were not compensated by the research team in any way.

Project Description

In 2002 ODOT bridge inspectors discovered shear cracks in the existing bridge carrying I-5 over the Willamette River. As a result, weight restrictions were imposed immediately and heavy trucks were forced to detour 200 miles off this crucial freight corridor until a sufficient replacement could be built. A temporary bridge was constructed and opened to traffic by 2004, but it utilized materials and methods that, while quick to construct, resulted in a structure which was not sufficient for environmental, seismic, or modern design considerations.

The primary purpose of the Willamette River Bridge (WRB) project is to replace the temporary 2004 bridge.

Project Scope

- Construction of an 1800+ foot long arch bridge capable of carrying three lanes of traffic
- Demolition of the existing temporary bridge built to replace the original Willamette River bridge in 2004
- Construction of a second 1800+ foot long arch bridge also capable of carrying three-lanes of traffic within the footprint of the temporary bridge
- Repair or replacement of the 100 foot long Canoe Canal Bridge also on I-5
- Realignment and grading work to match I-5 to the new bridges
- Construction of sound walls along the southern approach
- Construction of associated pedestrian trails
- Preservation of historic and natural areas on both sides of the river and both sides of the bridge
- Installation of extensive artwork in the adjacent park
- Safely conducting all work while keeping Franklin Blvd., an exit ramp to Franklin Blvd, and an active Union Pacific Railroad corridor open

Project Quality Profile

What makes the QM system on this project different from a traditional project?

- Presence of Oregon Bridge Delivery Partners (OBDP): OBDP is a joint venture of HDR and Fluor hired by ODOT in 2003 to help manage its multi-billion dollar OTIA III bridge infrastructure program of which the WRB project is a part. OBDP acts both in an advisory and management role for ODOT and is in some cases actively involved with the quality management process on a project. The presence of OBDP resulted in several deviations from traditional quality management systems. While construction quality management was largely similar to the traditional system, OBDP performed construction engineering and inspection (CEI) tasks interchangeably with ODOT staff, neither overlapping nor replacing ODOT's own inspections. In contrast, OBDP represented an additional level of design quality control on this project as noted below.

- Inclusion of the contractor in earliest design phases of the project: The presence and input of the contractor early in the design process (in the role of construction manager (CM)) was a significant deviation from the traditional design-bid-build system. Working with potential subcontractors, the CM/GC was able to identify constructability issues in the designs and suggest alternatives when changes were most easily and cheaply made.
- Multiple, simultaneous layers of design quality control: The design process on this project both benefited from and was burdened by four layers of quality control. In addition to technical review being performed by the designer, it was also performed by the contractor, OBDP, and ODOT for differing purposes.

Owner's reasons for using alternate QM system

The presence of OBDP on this project was not a choice, but rather a result of the project's inclusion in the OTIA III program of infrastructure repair which OBDP was chosen to help manage. Inclusion of the contractor early in the design phase of the project was one of the two primary reasons project managers selected the CM/GC delivery method on this project. ODOT wanted the final bridge to be an iconic arch structure and wanted contractor involvement in the design process in order to make the bridge more constructible which in turn would likely reduce costs. Finally, the multiple layers of design quality control were a result of several overlapping priorities. In order to have a meaningful impact on the design, the contractor performed constructability reviews on a regular basis and was responsible for checking certain technical aspects of the plan. In addition, ODOT wanted to have a direct role in reviewing aspects of the technical design as the Willamette River Bridge required exemptions from a number of ODOT standards for its bridges.

Project Financial and Schedule Information

Original Total Awarded Value of project: $135,000,000 (including $16 million for design, $2.3 million for preconstruction, $27 million for OBDP's CEI and design quality assurance)

Final Total Awarded Value of project: On-going

Project Schedule Length: 7 years

Project Approved to start process: 2007

Initial Advertising: August 2007

Design Contract Award: May 7, 2008

Preconstruction Contract Award: June 17, 2008

Notice to Proceed with Construction: January 2009

Original Project Delivery Period: Roadway open December 12, 2012, 5 years.

Final Project Delivery Period: Ongoing; Southbound bridge opens August 2011; project design completes November 2011; project completion anticipated by October 2014 for a 7 year project length

Project Delivery Method

Agency Project Delivery Experience

Table E1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10;☒ > 10
CMGC	☐NA; ☒Pilot projects only; ☐General authorization	☐NA; ☒1-5; ☐5-10;☐ > 10
DB	☐NA; ☒Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☒ > 10
PPP	☒NA; ☐Pilot projects only; ☐General authorization	☒NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10

Table E1 lists ODOT's length of experience with the most common project delivery methods. As with most agencies, ODOT has decades of experience using the DBB method and has only recently begun experimenting with new methods. However, the OTIA III program – which the WRB project is a part of – is almost entirely composed of DB projects and has allowed ODOT to develop extensive experience with this method despite the continuing legal requirement to justify its use. This project is the first CM/GC project ODOT has been authorized to undertake and the PPP method has still not been approved for used in Oregon.

Reasons for Selecting Project Delivery Method

ODOT selected the CM/GC delivery method for a number of reasons. The primary motivation to use this method was to reduce the length of the project schedule thereby reducing the impact on the traveling public. In addition, ODOT also wanted the contractor to be involved in the design from its earliest stages as they wanted the WRB to be a unique and signature bridge. Project managers recognized that in addition to providing constructability advice, the contractor could improve the design process by informing designers of the schedule and cost impacts of various design alternatives which also allowed the design team to be more flexible when working with local stakeholders.

Procurement Process

Prequalification

Table E2: Administrative and Performance-based Prequalification Requirements

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance-based**
Prequalification required for all projects	☒	☐
Prequalification required for selected projects only	☒	☒
Prequalification standards are the same for all projects	☒	☐
Prequalification standards are different by project class	☐	☒
Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance-based**
Prequalification required for all projects	☒	☐
Prequalification required for selected projects only	☒	☒
Prequalification standards are the same for all projects	☒	☐
Prequalification standards are different by project class	☐	☒

Design

ODOT traditionally self-performs roughly 70% of its own design work in-house and outsources the remainder to engineering firms in Oregon. However, in the last 10 years, Oregon's multi-billion dollar OTIA III infrastructure initiative has reversed those numbers with the bulk of design being performed by private engineering firms to provide a stimulus to the state economy. As shown in Table E2, all design firms seeking to perform work for ODOT must meet minimum administrative prequalification requirements. In addition, design firms competing for work using alternative delivery methods (DB or CMGC) must also undergo performance-based prequalification.

Performance-based prequalification involves evaluating firms based on their ability to complete the necessary work using the proposed delivery method and relies heavily on past experiences and on the strengths and competencies of the design team. In the case of the WRB project, design teams were required to submit evidence of their ability to design seven different bridge types utilizing four different structural materials since the concept for the bridge design wasn't finalized yet.

Construction

As shown in Table E2, all general contractors seeking to construct ODOT projects must meet minimum administrative prequalification requirements including demonstrating sufficient bonding capacity and being on a list of ODOT approved bidders. In addition, contractors seeking to bid for projects using alternative delivery methods must also meet certain performance based prequalification requirements. While these requirements are project specific, typically companies are evaluated based on their prior experience building the particular type or class of work and the experience and compatibility of the project team. For projects utilizing DB as the delivery method, after the initial set of prequalified parties is identified, the field is then narrowed down, based on prior experience and the responses to the RFQ, to a shortlist of companies who will be asked to submit proposals.

Contractor-Designer Evaluations

ODOT also utilizes an evaluation process to ensure that contractors and designers work well together during projects and to give them a chance to bring problems with a project party to the attention of ODOT. At the end of every project, the designer (if private) fills out an evaluation about the builder and vice versa. In order to remain on the list of approved bidders or designers, parties must maintain a certain score which is based on these evaluations. While it appears to place the success of a company in the hands of another, it is reportedly rare that these scores result in the disqualification of a designer or contractor or their removal from the approved bidders list.

Procurement Method

Design

ODOT used a two stage best-value method to procure the design team. First, ODOT issued a request for qualifications (RFQ) which included several pass/fail criteria and was scored based on qualification only. From the RFQ submissions, a shortlist of top scoring designers was generated. Those on the shortlist were invited to submit proposals in response to the request for proposals (RFP) ODOT issued. Top scorers from the RFP process – which was again judged predominantly on qualifications with some pass/fail criteria – were then invited to participate in an interview. The final design team was selected from this interview process which included both questions the interviewees had seen, and some they had not.

As part of the RFQ process, significant submittals related to the design quality management process were required. Interested parties were required to submit their QMPs in addition to the qualifications of the design quality manager as part of their project proposal, both of which factored into the award decision. Once selected, the design team was later required to include a design QMP template to be used by all of its design consultants as part of its contract with ODOT.

Construction

Shortly after the design contract was awarded, ODOT used a scoring system to select a preconstruction manager based 85% on the ability of a firm to advise on and eventually construct the project. The remaining 15% of the score was based on the proposal price for the preconstruction phase of the project. While the expectation from all parties was that the construction manager would likely receive the construction contract, ODOT was under no contractual obligation to offer it.

During the design phase of the project, the CMGC wasn't actually producing any work and was therefore not required to submit any quality management or control plans with its preconstruction phase proposal. However, once the construction contracts were awarded, Hamilton Construction was required to submit these documents along with the qualifications of the construction quality manager.

Agency's Reasons for Choosing Procurement Method

Due to the iconic nature of bridge and the anticipated complexity of the design, ODOT project managers wanted to be certain that the designer and the contractor were qualified to design or build the Willamette River Bridge. The procurement processes for both the designer and contractor revealed this priority in their emphasis on qualifications rather than price.

Required Document Submittals for Bidding

Table E3: Required Bidding Documents

Did your project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.) contain the following?	**Required proposal/ bid package submittal?**	**If required, is it evaluated to make the award decision?**	**If not required, is it a required submittal after contract award?**
	Yes	Yes	Yes
Qualifications of the Design Quality Manager (OBEC/TYLin)	☒	☒	☐
Qualifications of the Construction Quality Manager (Does not fit CMGC)	☐	☐	☒
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☒	☒	☐
Design quality management plan	☒	☒	☐
Design quality assurance plan	☒	☒	☐
Design quality control plan	☒	☒	☐
Construction quality management plan	☐	☐	☒
Construction quality assurance plan	☐	☐	☒
Construction quality control plan	☐	☐	☒
Quality management roles and responsibilities	☐	☐	☒
Design criteria checklists	☒	☒	☐
Construction testing matrix	☐	☐	☒
Quality-based incentive/disincentive features	☐	☐	☐
Warranties	☐	☐	☒
Optional warranties	☐	☐	☐

Table E3 lists the various documents which were required submittals during the proposal processes for both the designer and the CMGC on the project. As the table demonstrates, only the design firms competing for the project were required to submit their quality plans and qualifications prior to the award of the design contract. In contrast, because the companies competing to win the CM/GC contract were competing primarily based on preconstruction management abilities and costs, they were not required to submit their quality plans or credentials ahead of time. Instead, these documents were required submittals just before the start of construction.

Quality Management Plans and Roles

Design

As noted above, the design team for the WRB project was required to provide a copy of their standard QMP to be used by its internal quality managers and those of its subcontractors and consultants. Given the unique nature of the project for ODOT in terms of its CM/GC delivery method and the use of an outsourced design consultant, the design QMP for this project was relatively new for the agency. Rather than the standard 2-3 parties participating in the process – the owner, the designer (could be the owner), and potentially an independent QC consultant – the WRB project involved four separate parties in the design QC process each with unique roles which are shown in table E4.

Table E4: Design Quality Management Roles

Responsibility allocation for design management tasks	Agency Design Staff	Agency PM Staff	Design Consultant Staff	Constructor's Pre-const. Staff	Agency-hired QA/oversight Consultant	Other, specify below
Technical review of design deliverables	☐	☒	☒	☐	☐	☐
Checking of design calculations	☐	☐	☒	☐	☐	☐
Checking of quantities	☐	☒	☒	☒	☐	☐
Acceptance of design deliverables	☐	☒	☐	☐	☐	☐
Review of specifications	☐	☒	☒	☒	☐	☐
Approval of final construction plans & other design documents	☒	☒	☒	☐	☐	☐
Approval of progress payments for design progress	☒	☐	☐	☐	☐	☐
Approval of post-award design QM/QA/QC plans	☒	☐	☐	☐	☐	☐

As initial designs were produced, they were simultaneously distributed to the designer's CAD managers and discipline checkers, and senior independent reviewers from OBDP, in addition to the CM/GC construction liaison for constructability reviews at key milestones. Quantity checks and technical reviews were also performed by agency staff from ODOT. Involvement by ODOT was largely due to the unique nature of the bridge which required a large number of ODOT standards in their Bridge Design and Drafting Manual to be evaluated and overruled, decisions that could only be made by ODOT personnel.

OBDP was responsible for gathering the comments and responses from all the parties involved, organizing them, and presenting that information to ODOT. Every comment from ODOT, OBDP, or the construction liaison required a response from the designer. While OBDP was in charge of issuing the "final disposition," a recognition that all comments were accurately responded to, ODOT was ultimately in charge of accepting design deliverables for construction. These four levels of design quality checks resulted in a design QC process that was significantly more rigorous than that performed by agency staff for in-house design work.

Construction

In contrast to the design quality management on the WRB project, the construction QMP was a set of documents from the contractor indicating its compliance with the standard ODOT QMP and testing procedures. The details of this plan are spelled out in ODOT's standard provisions and specifications and in the Manual of Field Test Procedures.

Table E5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	Agency Design Staff	Agency PM Staff	Design Consultant Staff	Constructor's Construction Staff	Agency-hired QA/oversight Consultant	Other, specify below
Technical review of construction shop drawings	☐	☒ no OBDP	☒	☐	☐	☐
Technical review of construction material submittals	☐	☒ no OBDP	☒	☐	☐	☐
Checking of pay quantities	☐	☒ no OBDP	☒	☐	☐	☐
Routine construction inspection	☐	☒ OBDP & agency	☒	☐	☐	☐
Quality control testing	☐	☐	☐	☒	☐	☐
Verification testing	☐	☒	☐	☐	☐	☐
Acceptance testing	☐	☒	☐	☐	☐	☐
Approval of progress payments for construction progress	☐	☒	☐	☐	☐	☐
Approval of construction post-award QM/QA/QC plans	☐	☒	☐	☐	☐	☐
Report of nonconforming work or punchlist.	☐	☒ OBDP & agency	☒	☐	☐	☐

As seen in Table E5, construction quality management on this project appeared different from that used on traditional DBB projects due to the presence of OBDP's construction engineering inspection staff. In reality, OBDP and ODOT staffs were interchangeable from the contractor's perspective and did not add an additional layer of QA testing or inspections, but rather each performed some of the functions without overlap.

Participants' Ranking of the Impact of Quality Factors

Table E6: Rankings of the Impact of Quality Factors

Please rate the following factors for their impact on the quality of this project:	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact
Qualifications of agency design staff	☐	☐	☐	☐	☒
Qualifications of agency project management staff	☐	☒	☐	☐	☐
Qualifications of agency construction staff	☐	☒	☐	☐	☐
Qualifications of the design consultant's staff	☒	☐	☐	☐	☐
Design consultant's past project experience	☐	☒	☐	☐	☐
Qualifications of the construction contractor's staff	☒	☐	☐	☐	☐
Construction contractor's past project experience	☒	☐	☐	☐	☐
Submittal of Quality management plans prior to work start	☐	☐	☐	☒	☐
Level of agency involvement in the QM process	☐	☐	☒	☒	☐
Use of agency specifications and/or design details	☐	☒	☐	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☐	☐	☐	☒	☐
Use of manuals, standards and specifications developed for DBB type projects	☒	☐	☐	☐	☐
Allowing flexibility in choice of design standards and construction specifications	☐	☐	☐	☐	☒
Use of performance criteria/specifications (N/A)	☐	☐	☐	☐	☒
Detailed design criteria	☐	☒	☐	☐	☐
Warranty provisions(N/A)	☐	☐	☐	☐	☒
Incentive/disincentive provisions(N/A)	☐	☐	☐	☐	☐
Follow-on maintenance provisions (N/A)	☐	☐	☐	☐	☐
Innovative financing (PPP/concession) (N/A)	☐	☐	☐	☐	☐

The rankings shown in Table E6 represent the consensus of the four interview participants regarding the impact of various factors on the overall quality of the project. The most highly ranked factors were those related to the qualifications of project staff members – both from the agency and the designer and contractor as well – and the detailed requirements and specifications used on the project.

Quality Management Organization Model

The Willamette River Bridge project was the first ODOT project of its kind to be delivered using the CM/GC delivery method. Despite the ground breaking nature of its delivery method, the quality management structure on the project was similar to traditional DBB projects. In fact, in terms of construction quality management, the process and structure was generally identical to that utilized by ODOT on its DBB projects. As seen in Figure E1, the QAO model for this project, ODOT retained the construction quality assurance function and is ultimately responsible for releasing final payment for the project when it is satisfied with the construction. Hamilton Construction, the constructor/contractor, performed the construction QC functions itself (via its subcontractors and subcontracted testing labs). The one piece of construction quality management on this project that was unique was the presence of OBDP CEI staff. However, due to their interchangeable role with ODOT CEI staff, there was little perceived difference to the contractor in terms of oversight or construction QA.

Where the model deviates from traditional DBB quality management is on the design side. As shown by the dashed line intersecting the lower left hand box, while design QA was performed by ODOT's staff, design QC was shared between the design team, the contractor, and ODOT/OBDP's design staff. As seen in Figure E2, the design QC flow chart, the designer provided initial drawings for review and QC to its own discipline checkers and managers and to the contractor's team as well for constructability reviews. In addition, drawings were also provided to ODOT and OBDP staff for technical review and comments, and additionally to ensure that all necessary design checks were performed by the designer as part of the design quality assurance function. The interview and questionnaire confirm that both ODOT and OBDP performed separate QA reviews of key deliverables and that each was actively involved with design QC at different points in the design process. The presence of constructability reviews and four party reviews in the QC process and the two levels of design QA are two of the primary differences between the quality management structure on this project and that used on traditional DBB projects as seen in figure E1.

One of the recurring themes in the WRB project interview was that the project team tried to maintain ODOT's traditional quality management structure whenever it made sense to do so. As a result, while owner verification testing and independent assurance for construction were not explicitly mentioned in the interview, they are still included in the model. This is because ODOT's traditional quality management structure requires that they be there. Independent assurance for design on the other hand is not common on ODOT's projects and is not referenced in any of the case study information. While this function does exist on some projects, it does not appear to on the WRB project and has been masked in the model as a result.

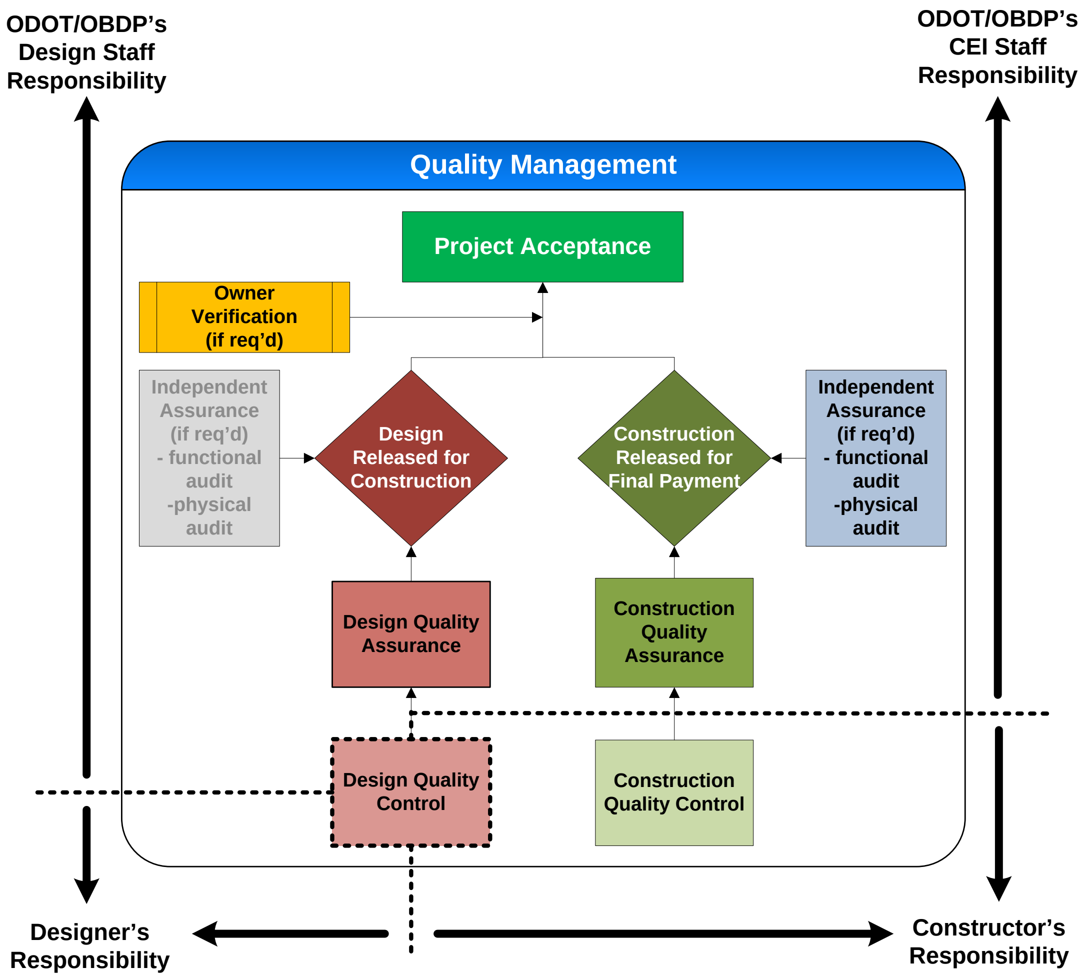


Figure E1: WRB QAO Model

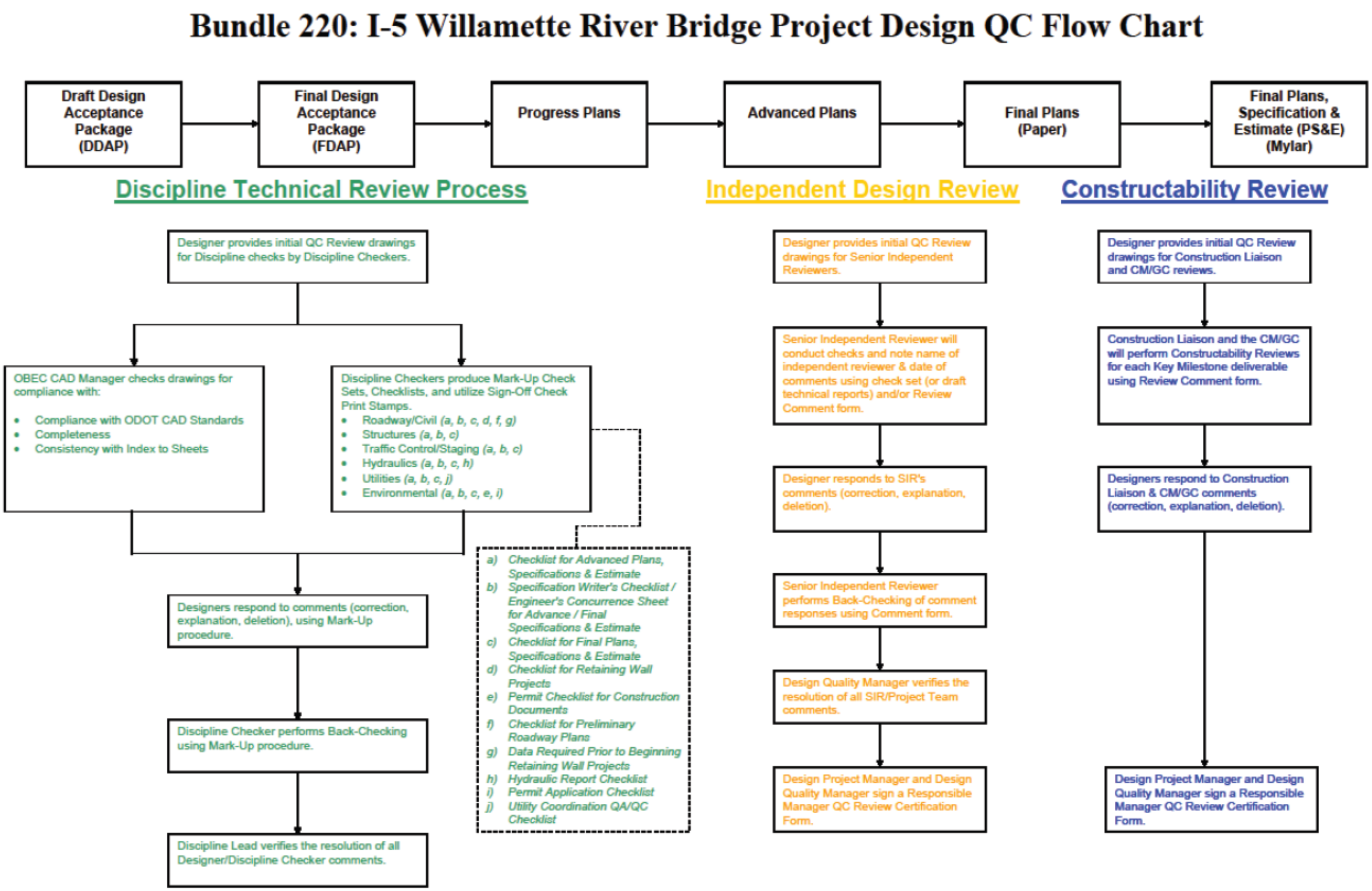


Figure E2 – Willamette River Bridge Design QC Chart

Summary

Effective QM Practices

- Incorporation of the contractor in the design process: Incorporating the contractor in the design process was cited again and again by project participants as a successful technique for improving the project. As a consultant rather than general contractor early in the design phase, the CMGC informed designers of the consequences of design decisions in terms of cost, schedule, constructability, and even permitting requirements and was able to make holistic design recommendations which provided the agency with the most value.

  More importantly, the CMGC's in-depth knowledge of the design and intent allowed it to specifically emphasize detailed and complex aspects to subcontractors. The result was more accurate bids from subcontractors and a more accurate estimate from the CMGC throughout the design process. This close coordination and understanding was especially helpful in the complex sequence required to install the rebar for the arches of the bridges and was cited as one of the chief successes of the project.

- Flexibility afforded by the CMGC method: The CMGC method created a cooperative rather than adversarial relationship between the contractor and the agency. This relationship was further strengthened because the contractor's staff had experience working with ODOT previously and was involved with the design process from the beginning. As a result, the contractor was able to suggest changes to the specifications that reduced sampling frequencies and requirements where appropriate, saving the contractor and the agency time and expense. One particular example was in the reduction of testing frequencies for the hot mixed asphaltic cement (HMAC) on the project. While ODOT has rigorous standards for testing HMAC pavements, on the WRB project, it was only used for pedestrian and bike paths. The contractor recommended scaling back the submittals and testing frequencies for the HMAC which were designed for interstate highway applications. The result was a product in line with the requirements of the local park agencies tailored to the project.

- No competitive pricing requirement for subcontractors: The first bridge across the Willamette River was complex and difficult to construct. However, because the construction contract did not require the general contractor to seek competitive bids from subcontractors (a common requirement on CM/GC projects), the contractor was able to use the same subcontractors on the second bridge span without having to go through a second bidding process. Reusing the same subcontractors made it possible to utilize lessons learned from the first bridge span to ease construction of the second.

Observations of the Researcher

The contractor experienced two primary deviations from a traditional project. First, the presence of OBDP on this project added an extra entity to interface with. However, when it came to construction, OBDP functioned simply as an extension of ODOT and did not add any additional steps to the construction quality management process. Second, the contractor was able to fully participate and contribute to the project from its earliest design phases as a member of the pre-construction team. This participation led to a high level of knowledge of the project when it came time to provide a GMP to the owner and resulted in a more accurate project budget and schedule and allowed the contractor more time to identify and avoid complicated pitfalls and possible mistakes.

While still similar to the design quality management processes for a DBB project, the process used on this project had some notable differences. First was the addition of OBDP to the design review process. Unlike in the construction phase of the project, during design, OBDP functioned largely independently of ODOT in terms of design review and acted as a single point of contact to consolidate all the pertinent information before distributing it to ODOT. Additionally, unlike on a DBB project, both ODOT and OBDP were involved in the design QC aspect of this project with their reviewers providing input and commentary at key milestones. This resulted in four simultaneous layers of design quality control which several project parties found burdensome and which slowed the design process, a key consideration since schedule reduction was a priority. Given the needed input of the owner and the favorable impact of including the contractor in the design process, the burden of multiple reviewers may have been an unavoidable side effect of what was an otherwise successful design quality management process.

APPENDIX F: PORTLAND TRANSIT MALL REVITALIZATION, OREGON

Project Overview

Basic Information

Project Name: Portland Transit Mall (Greenline) Revitalization

Name of Agency: Tri-County Metropolitan Transportation District of Oregon (TriMet)

Location:

Project Delivery Method (*DBB, DB, CM/GC, PPP, etc.*): CM/GC

Design Procurement Procedure (*QBS, Best-Value, Low Bid*): Two stage best-value

Construction Procurement Procedure (*QBS, Best-Value, Low Bid*): Best-value (85% qualifications/15% preconstruction services price)

Contract Payment Provisions (*Lump Sum, GMP, Cost* +): Cost plus fee with a GMP

Project Parties

Owner: TriMet

Designer: URS Corporation

CM/GC: Stacy and Witbeck/Kiewit Pacific – A Joint Venture

Methodology

The primary case study interview was conducted on September 28, 2011 at TriMet's main office in Portland, OR. The interview was conducted with TriMet's QA manager and Stacy and Witbeck's QC manager for the project. Additional follow up questions were directed to URS's project manager for the project. The interview was conducted in accordance with the case study protocol developed by the research team and approved by both an industry panel and the NCHRP review panel. Interviewees were introduced to the research and given a brief summary of the research objectives. Interviewees were asked to fill out the project specific questionnaire developed as part of the protocol before the interview. During the interview, discrepancies in answers to the questionnaires were clarified and additional questions from the case study protocol were asked. As questions were asked and the interviewees responded, a summary of their answers was recorded and projected on the wall of the conference room to ensure that all respondents were satisfied with the summary of their answers.

The data collection process concluded with a request for relevant project documents which were provided on a CD for later review. Interviewees volunteered their time and were not compensated by the research team in any way.

Project Description

The installation of light rail transit in Portland's Transit Mall was part of a larger revitalization project. The Portland Mall was redeveloped in the 1970s as part of a series of urban renewal projects. It was praised when it first opened for its foresight, design, and execution. In the intervening years, the condition of the Portland Mall and its fixtures deteriorated. While the full revitalization project improved road and walk ways both physically and aesthetically and encouraged and resulted in a number of storefront improvements and nearby development, this case study deals with the installation of the light rail line along the full length of the Portland Transit Mall. The project allows for simultaneous operation of an extensive bus and light rail transit system along the same corridor. The project extends from Portland's Union Station south along SW 5th and 6th Avenues to I-405.

Project Scope

- Construction of 1.4 miles of light rail track, gantries, and supporting systems along both SW 5th and SW 6th Avenue (2.8 miles total)
- Construction of a triple track turnout loop at the southern extent of the project
- Tie-in of the new lines to existing light rail lines
- Installation of 12 new light rail stations along with signage and shelters
- Extensive utilities relocation

Project Quality Profile

What makes the QM system on this project different from a traditional project?

- <u>Inclusion of the contractor early in the design phase</u>: The presence and input of the contractor early in the design process (in the role of construction manager (CM)) was a significant deviation from the traditional design-bid-build system. Working with potential subcontractors, the CMGC was able to identify constructability issues in the designs and suggest alternatives when changes were most easily and cheaply made
- <u>Multiple, simultaneous layers of design quality control</u>: The design of the project benefited from multiple levels of quality control. In addition to the quality control function performed by the designers on their own work, TriMet also had its design staff reviewing designs and calculations and the contractor was actively involved in reviewing designs for potential conflicts on a weekly basis.

Owner's reasons for using alternate QM system: Working in the constricted urban environment of Portland's downtown, TriMet recognized the need early on for contractor involvement in the design process in order to streamline the construction process and minimize potential disruptions to the public. This priority was specified in the project RFP issued to potential bidders. In addition, the RFP also specified TriMet's desire that the CM/GC provide design reviews to ensure an economical and efficient design.

Project Financial and Schedule Information

Original Total Awarded Value of project: $103,000,000

Final Total Awarded Value of project: $113,000,000 ($7 million for design)

Project Schedule Length: 5 years

Preliminary Design Contract Award: November 2004

Design Contract Award: December 2005

Preconstruction Contract Award: March 2006

Construction Contract Award: January 2007

Original Project Delivery Period: September 2009

Final Project Delivery: September 2009

Project Delivery Method

Agency Project Delivery Experience

Table F1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10; ☒ > 10
CMGC	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10; ☒ > 10
DB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10; ☒ > 10
PPP	☐NA; ☒Pilot projects only; ☐General authorization	☐NA; ☒1-5; ☐5-10; ☐ > 10
Other	☒NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10

Project delivery method used on this project

Construction Manager/General Contractor (CM/GC).

Reasons for Selecting Project Delivery Method

TriMet selected the CM/GC method for a multitude of reasons including: to reduce the project delivery period; to encourage innovation and value engineering; to redistribute risk; due to the complexity of the project; and for the increased flexibility afforded during construction. While these were all considered when selecting the delivery method, the primary reasons were to reduce the lengthy project schedule and for the flexibility afforded during construction.

DB was also considered as it offers a shortened delivery period, but the CM/GC method was chosen for its ability to rapidly respond to local problems during construction. This flexibility was crucial in the urban environment of the project where uncertainty was high and managers in the field needed authority to make quick decisions which ultimately would affect the project budget and schedule and resulted in a variable scope, conditions the CM/GC method is well suited for.

Procurement and Prequalification Process

Prequalification

Table F2: Administrative and Performance Based Prequalification Requirements

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☒
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☒
Prequalification standards are different by project class	☐	☐
Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☒
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	☒
Prequalification standards are different by project class	☐	☐

Design

TriMet traditionally only self-performs preliminary engineering on their projects before handing them off to engineering consultants for more detailed design and completion. When procuring a designer, TriMet uses a standard two-stage process beginning with a request for qualifications. After establishing that interested designers are qualified for the project, the field is narrowed to a shortlist for further consideration and interviews before a final selection is made. TriMet has no formal administrative prequalification, but does require performance based prequalification for all designers in the first round of procurement.

Construction

As with design, TriMet has no formal administrative prequalification requirements for contractors interested in working on TriMet projects. The only real prequalification is the request for qualifications process which TriMet uses when procuring contractors on most of their projects. On this project in particular, the initial request for qualifications phase allowed TriMet to narrow the field of interested contractors to a qualified shortlist. Contractors on the shortlist were issued a request for proposals and then evaluated using a best-value process which primarily focused on their qualifications but also considered cost of preconstruction services and fee for construction services.

Agency's Reasons for Choosing Procurement Method

TriMet uses an in-house guidance document to help project managers select the optimal procurement method for their project. Despite being a semi-public agency, TriMet is bound by the same contracting rules as the Oregon Department of Transportation and must justify its use of any contracting methods other than competitive low-bid in accordance with the Oregon Revised Statutes. In the case of the CM/GC delivery method, there is only one procurement method recommended by TriMet's guidance document for this delivery system. Once the CM/GC method was selected and its exemption publicly justified, the resulting choice of procurement method was automatic.

Required Document Submittals for Bidding

Table F3: Required Bidding Documents

Did your project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.) contain the following?	Required proposal/ bid package submittal?	If required, is it evaluated to make the award decision?	If not required, is it a required submittal after contract award?
	Yes	Yes	Yes
Qualifications of the Design Quality Manager	☐	☐	☐
Qualifications of the Construction Quality Manager	☒	☐	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	☐	☒
Design quality management plan	☐	☐	☒
Design quality assurance plan	☐	☐	☒
Design quality control plan	☐	☐	☒
Construction quality management plan	☐	☐	☒
Construction quality assurance plan	☐	☐	☒
Construction quality control plan	☐	☐	☒
Quality management roles and responsibilities	☐	☐	☒
Design criteria checklists	☐	☐	☐
Construction testing matrix	☐	☐	☒
Quality-based incentive/disincentive features	☐	☐	☐
Warranties	☐	☐	☐
Optional warranties	☐	☐	☐

Notes: The owner required very little in terms of quality plans from either the designer or the contractor in their proposals besides the qualifications of the construction quality manager(s). The construction quality manager was required to have five years of construction related quality experience and a minimum of two years of experience managing quality programs.

Quality Management Plans and Roles

Design

TriMet maintains a formal design quality assurance program in accordance with Federal Transit Administration requirements. TriMet's program documents require design consultants and TriMet's own in-house design staff to submit a robust design QA program for approval. TriMet always retains the design QA function, and often assists with design QC as well. On this project drawings and design calculations were submitted to TriMet not just for approval, but for technical review as well. However, because TriMet only participated in preliminary design, there wasn't a separate design team reviewing the drawings. Instead, TriMet's resident engineer was an integrated part of the project management team as see below.

TriMet requires design consultants to utilize standard agency specifications which are then updated for each project specifically. In addition, the agency issues a 500+ page Design Criteria manual to the designers which express TriMet's expectations for the design effort in addition to standard drawings.

Table F4: Design Quality Management Roles

		Responsible Party (select all that apply)				
Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	N/A	☒	☒	☒	☐	☐
Checking of design calculations	N/A	☒	☒	☐	☐	☐
Checking of quantities	N/A	☒	☒	☒	☐	☐
Acceptance of design deliverables	N/A	☒	☒	☐	☐	☐
Review of specifications	N/A	☒	☒	☒	☐	☐
Approval of final construction plans & other design documents	N/A	☒	☒	☐	☐	☐
Approval of progress payments for design progress	N/A	☒	☐	☐	☐	☐
Approval of post-award design QM/QA/QC plans	N/A	☒	☐	☐	☐	☐

Construction

TriMet maintains on-call contracts with several surveying entities and independent materials test/inspection labs. These labs perform confidence testing and quality assurance functions at the discretion and direction of TriMet's resident engineer rather than some set percentage. As seen below, many construction quality management functions had multiple parties participating in either primary or secondary roles. In addition to the parties shown, inspectors from several city agencies also performed a QA function and performed their own QC tests when dealing with their own utilities.

The construction QMP was no different from a standard DBB quality plan as TriMet always performs the QA function, regardless of delivery method.

Table F5: Construction Quality Management Roles

	Responsible Party (select all that apply)					
Responsibility allocation for construction management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Construction Staff**	**Agency-hired QA/oversight Consultant**	**Other**
Technical review of construction shop drawings	N/A	S	P	☐	☐	☐
Technical review of construction material submittals	N/A	P	S	☐	☐	☐
Checking of pay quantities	N/A	P	☐	☐	☐	☐
Routine construction inspection	N/A	S	☐	P	☐	☐
Quality control testing	N/A	☐	☐	P	S	☐
Verification testing – Note 1	N/A	P	☐	☐	P	☐
Acceptance testing	N/A	☐	☐	P	☐	☐
Approval of progress payments for construction progress	N/A	P	☐	☐	☐	☐
Approval of construction post-award QM/QA/QC plans	N/A	P	☐	☐	☐	☐
Report of nonconforming work or punchlist.	N/A	S	S	P	☐	☐

P – Primary responsibility; S – Secondary responsibility

Participants' Ranking of Impact on Quality

Table F6: Rankings of the Impact of Quality Factors

Factor	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact
Qualifications of agency design staff	☐	☒	☐	☐	☐
Qualifications of agency project management staff	☐	☒	☐	☐	☐
Qualifications of agency construction staff	☐	☒	☐	☐	☐
Qualifications of the design consultant's staff	☐	☒	☐	☐	☐
Design consultant's past project experience	☐	☒	☐	☐	☐
Qualifications of the construction contractor's staff	☒	☐	☐	☐	☐
Construction contractor's past project experience	☐	☒	☐	☐	☐
Submittal of QMPs prior to work start	☐	☒	☐	☐	☐
Level of agency involvement in the QM process	☐	☒	☐	☐	☐
Use of agency specifications and/or design details	☐	☐	☒	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☐	☒	☐	☐	☐
Use of manuals, standards and specifications developed for DBB type projects	☐	☐	☐	☒	☐
Allowing flexibility in choice of design standards and construction specifications	☐	☐	☐	☒	☐
Use of performance criteria/specifications	☐	☒	☐	☐	☐
Detailed design criteria	☐	☒	☐	☐	☐
Warranty provisions	☐	☐	☒	☐	☐
Incentive/disincentive provisions	☐	☐	☒	☐	☐
Follow-on maintenance provisions	☐	☐	☐	☒	☐
Innovative financing (PPP/concession)	☐	☐	☐	☐	☒

QAO Analysis

The QAO for this project lies somewhere between a deterministic and an assurance model. On this project, construction QC was run by the contractor with inspections and assurance and verification testing performed by the owner. Design QC on the other hand was shared jointly with the owner, designer, and contractor. While the designer necessarily performed the bulk of the QC function, both the owner and the contractor performed technical reviews of drawings, calculations, or feasibility.

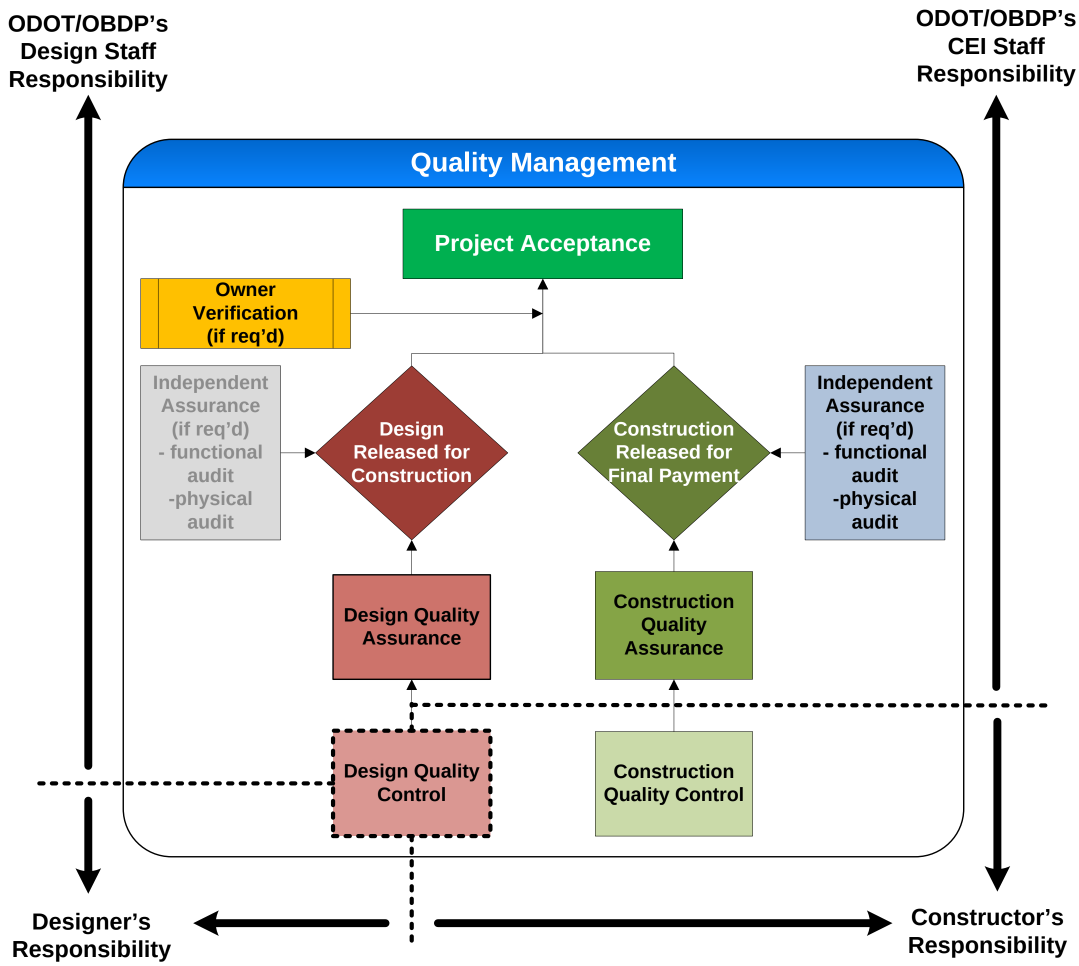


Figure F1: Portland Transit Mall QAO

Summary

Effective QM Practices

- Contractor involvement early in the design: Given the urban nature of the project, the inclusion of the contractor in the design process was recognized as a necessity. The input provided by the CM/GC proved valuable in identifying potential problems early in design before they were encountered in the field. In addition, by involving the contractor early on, they were able to procure long lead items early which required substantial quality control tests like light poles and gantry supports preventing potential delays due to failed quality tests later on. The early involvement also allowed the contractor to begin relocating conflicting utilities during design before the official construction contract was issued. This pre-work allowed the subsequent construction effort to move much more rapidly through downtown, minimizing the disruption to the public and preventing costly mistakes due to poor utility relocation in the process.

- Electronic recording and submission of daily reports: Quality control inspectors from the general contractor were equipped with electronic recording devices and very comprehensive checklists to complete their daily inspections and reports. The extensive checklists ensured that multiple features of every item of work were physically checked and attested to in the daily reports before being listed as complete. Electronically submitting the daily reports to TriMet's resident engineer streamlined the reporting process and provided easy access to a searchable database of reports to consult if need be including field reports and laboratory testing results.
- Allowing contractor to utilize own inspectors for QC testing: Typically TriMet requires that their contractors hire an outside laboratory to perform QC testing for them. On this project however the agency allowed the contractor to use their own inspectors and technicians to do the QC testing. TriMet's willingness to do this was based in part on the reputations for quality and integrity of both parties in the contracting joint venture and in part on their requirement that all inspectors and technicians be nationally certified to perform their field inspections. This decision saved the contractor money and streamlined the scheduling process by removing the inherent scheduling complications which occur when dealing with an independent firm.
- Use of the CM/GC delivery method: TriMet utilized a cost plus fixed fee payment provision to pay the CM/GC and also required a GMP the contractor could build the project for. This combination of delivery and payment methods resulted in very high levels of flexibility and autonomy for the managers in the field. Rather than requesting a change order for each deviation from the project plans (i.e. encountering a utility in an unexpected location) and then waiting for it to be submitted and approved, managers in the field could make rapid decisions without fear of assuming more risk.

Observations of the Researcher

The selection of the CM/GC delivery method and the resulting consequences dominate most of the unusual and successful features of the quality management of this project. While it may be difficult in some cases to determine where exactly quality management ends and project management begins, it's safe to say that the two are linked in some way. On this project the contractor demonstrated high levels of integrity and clearly warranted the latitude it was given to employ its own quality control inspectors.

APPENDIX G: TUTTLE CREEK DAM SAFETY ASSURANCE PROJECT, KANSAS

Project Information

Project Name: Tuttle Creek Dam Safety Assurance Project

Name of Agency: US Army Corps of Engineers (USACE)

Location: Tuttle Creek, north of the Manhattan, Kansas, along the Big Blue River

Project Delivery Method (*DBB, DB, CM/GC, PPP, etc*.): CM/GC

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best-Value

Contract Payment Provisions (*Lump Sum, GMP, Cost +*): Progressive GMP using FAR Clause 16.403-2 Fixed-price incentive (successive targets) contracts

Project Description

The Tuttle Creek Dam Safety Assurance Project is the largest Dam Safety, ground modification project on an active Dam that has ever been performed. This project consisted of multiple contracts to make various repairs to the dam. The Ground Modification base contract was awarded in 2005 to Treviicos South for $49M (this was the ECI/CMGC Contract). A contract to provide structural reinforcement and bearing rehabilitation on the 18 Spillway Tainter Gates was awarded in 2007 and completed in 2010 for $10M. The wire ropes for the Tainter Gates will be replaced in 2011 and 2012.

The Tuttle Creek Dam Safety Assurance Project included the following activities:

- Construction of cement slurry walls for stabilization of the downstream foundation
- Construction of a relief well buried collector system
- Construction of an upstream riprap overlay
- Spillway rehabilitation
- Structural lead paint and repainting

Project Quality Profile

The QMS that was used on this project was not substantially different from that used by other agencies. USACE has documentation outlining the approach to QA and quality procedures on projects. Also, an individual project specific QMP was written for the Tuttle Creek Dam project. In addition, the construction, design and project management organizations were all ISO certified.

Owner's reasons for using alternate QMS

There was an implication or thought that if the construction contractor is involved throughout the design process, the design quality, and construction quality should both be better. However, the construction contractor was brought in early for technical expertise more than quality concerns.

The belief was that the quality had to be better than going with a traditional method, but it was difficult to quantify.

Project Financial and Schedule Information

Original Total Awarded Value of project: Original Program Amount was $206M ($250M when adjusted for inflation to mid-point of construction)

Final Total Awarded Value of project: $175M ($122M for the ECI Portion of Work)

Project Schedule:

Project Approved to start process: Design period was from June 2004 to Dec 2007

Contract Award: 09/07/2005 Construction Contract Award. No date for design contract award as design was in-house by the District Engineering Staff.

Original Project Delivery Period: 2012 days

Final Project Delivery Period: 2391 days

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table G1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10; ✔ > 10
CMGC	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ✔5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
PPP	✔NA; ☐Pilot projects only; ☐General authorization	✔NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

The primary delivery method was Early Contractor Involvement, which is the USACE version of CM/GC. However, it should be noted that this contract contained multiple Contract Line Items, some of which were 100% designed at the time of construction solicitation. The selected delivery method had a positive result on the outcome of the project. The project delivery team felt the project was so complex that it would benefit from having real time construction contractor feedback as the design progressed.

A formal acquisition plan was not created for this solicitation. Early Contractor Involvement (ECI) was the selected delivery method because the Project Delivery Team (PDT) felt it needed the construction expertise of a contractor to be a part of the development of the design. This was an in-house design so ECI was the chosen delivery method that could provide the real-time constructor feedback. This feedback was especially necessary given the fact that this was a high risk active dam. Per the solicitation, the contractors experience in working on high risk dams was taken into account. The interaction between the Corps and Contractor during the design process helped the PDT develop a design that resulted in an economical fix ($75M under budget) that minimized dam safety concerns with few frivolous/costly modifications. Market research and a pre-solicitation meeting were held. The market research indicated there were offerors available to execute this type of work.

Reasons for Selecting Project Delivery Method

The most significant reason for choosing the selected project delivery method was to get early construction contractor involvement. Additional reasons included:

Reduce/compress/accelerate project delivery period

Get early construction contractor involvement

Encourage innovation

Facilitate Value Engineering

Redistribute risk

Complex project requirements

Flexibility needs during construction phase

Case Study Project Risk Analysis Process

Formal Risk Analysis Areas: Cost, schedule and scope

Project Cost Estimate Uncertainty Analysis: Yes

Risk Identification Techniques Used: Risk Register

Risk Assessment Techniques: Monte Carlo Simulation

Risk Management Techniques: Contingencies for cost and time, schedule simulation

Risk Technique used to Draft Contract: Climatology analysis to assign average number of weather days per month and asphalt, diesel and steel escalation clauses.

A 2002 Evaluation Report and Environmental Impact Statement indicated that the Tuttle Creek Dam was at an unacceptable level of risk if an earthquake was to occur. The consequences of an earthquake-induced breach would include the loss of the dam, extensive downstream damage and a high potential loss of life.

As is typical for USACE projects, contracts include terms and conditions to allocate risk to the appropriate project parties. The required risk assessment process involves two steps, a detailed definition of the problem, and the development of an event tree to provide a framework for analyzing the annual economic risk of various alternatives. Once the risk assessment process has been followed the most feasible alternative can be selected.

USACE may deem a risk analysis or risk assessment of the slope stability of a project to be appropriate due to changes in performance of the slope, changes in design criteria, or changes to the loading conditions. Examples of risk analyses utilized by USACE include:

- Poisson Distribution
- The Six Sigma Rule

- Expert Elicitation in Geological and Geotechnical Engineering - the formal quantification of expert opinion into judgmental probabilities.
- Weibull Distribution - the most general method for developing a historic frequency of occurrence model. This method of reliability analysis is used to determine the probability of failure, reliability, or hazard function of a component with time using unsatisfactory performance data.
- Monte Carlo simulation - a method of reliability analysis that should be used only when the system to be analyzed becomes too complex for use of simpler methods of reliability analysis.

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table G2: Administrative and Performance Based Prequalification Requirement

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	✔	✔
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐
Construction prequalification program factors	**Administrative**	**Performance Based**
Prequalification required for all projects	☐	☐
Prequalification required for selected projects only	✔	✔
Prequalification standards are the same for all projects	☐	☐
Prequalification standards are different by project class	☐	☐

Table G3: Required Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	☐	☐	☐
Qualifications of the Construction Quality Manager	☐	☐	✔
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.) **(Note 1)**	✔	✔	✔
Design quality management plan **N/A (Internal)**	☐	☐	☐
Design quality assurance plan **N/A (Internal)**	☐	☐	☐
Design quality control plan **N/A(Internal)**	☐	☐	☐
Construction quality management plan **N/A(Internal)**	☐	☐	☐
Construction quality assurance plan **N/A(Internal)**	☐	☐	☐
Construction quality control plan	☐	☐	✔
Quality management roles and responsibilities	☐	☐	✔
Design criteria checklists **N/A (Internal)**	☐	☐	☐
Construction testing matrix	☐	☐	✔
Quality-based incentive/disincentive features **(Note 2)**	☐	☐	☐
Warranties	☐	☐	☐
Optional warranties	☐	☐	☐

Note 1: The advisory staff was required to submit their qualifications and that was a factor in the award of their consulting contract. The construction contractor had a design office liaison position that had qualification requirements that were required by the contract but not evaluated.
Note 2: The government created an incentive on this contract that attempted to recognize the construction contractor's efforts during pre-construction services. This was tied to quality and if specific kinds of changes did not occur, the construction contractor would share in the remaining funds of the incentive. This was stipulated by the government at the outset but during contractor performance was renegotiated by the government and the contractor to better align with contract performance specifics (wanted to properly incentive the contractor)

Design Phase Summary

Table G4: Design Quality Management Roles

Responsibility allocation for design management tasks	Agency personnel	Consultant design staff	Constructor's preconstruction staff	Agency-hired QA/oversight consultant
Technical review of design deliverables	✔		✔	✔
Checking of design calculations	✔			
Checking of quantities	✔		✔	
Acceptance of design deliverables	✔		✔	✔
Review of specifications	✔		✔	✔
Approval of final construction plans & other design documents	✔			✔
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			

All tasks involving the Agency-hired QA/oversight consultant also involved construction field staff/Division HQ staff.

Construction Phase Summary

Table G5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	Agency personnel	Consultant design staff	Constructor's construction staff	Agency-hired QA/oversight consultant
Technical review of construction shop drawings	✔		✔	
Technical review of construction material submittals	✔		✔	
Checking of pay quantities			✔	
Routine construction inspection			✔	
Quality control testing			✔	
Verification testing			✔	
Acceptance testing			✔	
Approval of progress payments for construction progress				
Approval of construction post-award QM/QA/QC plans				
Report of nonconforming work or punchlist.			✔	

All tasks, excluding acceptance testing, also included construction field staff.

Quality Management Planning

QA/QC Plans

The design QMPs used on this project were different from DBB projects because this was a one of a kind design that involved both an advisory panel of experts as well as allowing for the construction contractor to participate in the design review process to help improve quality. The QMP was not different as such, but it emphasized how heavily the government intended to rely on the construction contractors input.

The construction QMPs used on this project were no different from the QMPs used on traditional DBB construction projects.

Use of mandated agency quality management plans

USACE requires designer prequalification standards only for selected projects and standards are determined specific to that project. The design for this project was an in-house design; therefore no prequalification standards were needed. That said this project did employ an Advisory Panel of Experts that provided consulting throughout. These experts were from the design, construction, and academia fields. There were not specific qualifications that would preclude someone from submitting a proposal for this panel, but the selection criteria was specific to discourage submission except only the highest qualified people.

Also, USACE did not mandate the use of standard agency specifications. The technical specifications were anything but standard given the nature of the project. However, the government did rely on some standard "front end" contract specifications such as QC program requirements.

USACE did not mandate the use of standard agency construction means or methods. One of the primary reasons for bringing the construction contractor on board early was to foster "outside the box" means and method.

Quality staff qualifications

The agency mandated a specific set of qualifications for the quality management staff of design consultants and construction contractors on this project. The qualifications for the advisory panel were designed to try and capture experts in the field for this kind of work. The construction contractors Construction Quality Control (CQC) manager needed to be a graduate engineer or construction manager with five years of experience.

Contractor quality assurance test results

USACE utilized contractor QA test results for acceptance on this project.

General Quality Management Procedures

Standard of Care

The agency did not hold the Contractor's quality management staff to a higher standard of care than it set for the internal staff. This was a very unique project and everyone was held to a higher standard.

Alternate QMS

The QMS used on this project was taken from USACE Regulations such as Regulation No.1180-1-6. This regulation specified the following roles and responsibilities for project parties:

Contractor Responsibility:

- General: Contractors shall be made responsible for all activities necessary to manage, control, and document work so as to ensure compliance with the contract plans and specifications. The contractor's responsibility includes ensuring adequate QC services are provided for work accomplished on and off site by his/her organization, suppliers, subcontractors, technical laboratories and consultants. The work activities include safety, submittal management, and all other functions relating to the requirement for quality construction.

- Staffing: It is the contractor's responsibility to carefully examine the contract requirements for CQC and provide personnel capable of complying with the CQC requirements of the contract clauses and technical provisions. The CQC staff must be of sufficient size and have the qualifications necessary to ensure contract compliance. The CQC system manager must report directly to the project superintendent or someone higher in the contractor's organization.

- Quality Control Plans and Procedures: Contractors will be required to prepare a quality control plan for all projects except those excluded under the discretionary authority described in USACE regulations.

Government Responsibilities:

- General: Quality assurance is the process by which the government assures end product quality. The process starts well before construction and includes reviews of the plans and specifications for biddability, constructability, operability and environmental responsibility, plan-in-hand site reviews, coordination with using agencies or local interests, establishment of performance periods and QC requirements, field office planning, preparation of QA plans, reviews of QC plans, enforcement of contract clauses, maintenance of QA and QC inspection and work records, and acceptance of completed construction.

- Planning: Prior to construction, the following activities will be performed:

  (1) Develop a written quality assurance organizational operating plan. This plan will be developed with input from the area/resident engineer and will address the overall QA operations of the district and field offices. The plan will be reviewed and updated as often as necessary but not less than annually.

  (2) Participate in pre-award activities.

    (a) Participate in the design review conference.

    (b) Conduct biddability, constructability, operability and environmental reviews.

    (c) Conduct site plan-in-hand reviews.

    (d) Establish the contract CQC requirements.

  (3) Review field office workloads and staffing needs.

  (4) Assure office and field personnel have a clear understanding of QA/CQC responsibilities. Training needs shall be identified and addressed through the appropriate combination of in-house and PROSPECT course attendance.

  (5) Review the contractor's CQC plan and assure affirmative answers to the following questions as a minimum:

    (a) Does the plan adequately cover control of all features of the contract?

    (b) Is the CQC staff adequately sized to maintain quality and accomplish tests required?

    (c) Have the persons responsible for each definable feature of work, all tests, and submittal control and review been identified?

    (d) Do the qualifications of the staff appear adequate for the control and test requirements?

    (e) Is the delegation of responsibility and authority to the CQC staff manager clear? Does this person report directly to the highest ranking contractor personnel on-site with responsibility for the overall management of the project?

    (f) Are the CQC organization lines of authority and responsibility clear?

    (g) Are individual control and test duties clearly assigned?

(h) Do the proposed control and test report forms include all the required features and reporting items? Are system commissioning procedures clearly detailed?

(i) Does it comply with the specific requirements established by the contract?

(j) Are definable features of work identified?

(6) Accept the CQC plan subject to satisfactory performance and reserve the right to require revisions to correct unsatisfactory performance.

- Implementation and Enforcement: During construction the following activities will be performed by quality assurance personnel (QAP):

(1) After the preconstruction conference, the area/resident engineer or other responsible designee shall conduct a coordination meeting with the contractor on the CQC/QA program.

(2) Delay construction start until after the coordination meeting and submittal and acceptance of at least the interim CQC plan, if required.

(3) Require revision of the CQC plan and its execution as necessary to obtain quality.

(4) Verify adequacy and calibration of test equipment, application of specified test standards and computation of test results.

(5) Spot check CQC approved submittals.

(6) Review contractor's daily quality control reports (QCR) to assure that they adequately document his/her quality control operations.

(7) Hold periodic job-site assurance conferences on CQC/QA interrelationship of activity and effectiveness.

(8) Participate in the three-phase control process as necessary to assure that the contractor is adequately conducting the required control processes.

(9) Conduct government QA tests at the job-site to assure acceptability of the completed work. A sufficient number of tests, but not less than five percent of the frequency of the CQC tests, should be scheduled to verify CQC test procedures and results. QA testing and inspection should be conducted at unannounced intervals. The contracting officer's representative should verify the accuracy and calibration of equipment, assure correct application of specified test standards, and verify the coverage and accuracy of required CQC tests by observing approximately ten percent of the CQC tests.

(10) Monitor contractor's procedures for tracking construction deficiencies to assure acceptable corrective action and that an audit trail is maintained.

(11) Ensure that new work is not placed on unacceptable work or that progress payments do not include the value of non-conforming construction.

(12) Prepare QA reports (QAR) and all other necessary QA documentation as detailed below:

(a) Quality assurance personnel will prepare a report for each visit day of construction on each contract and each project accomplished by government plant and hired labor.

(b) Quality Control/Quality Assurance report. As a minimum this combined form will cover project details, results of the QA comments pertaining to the CQC activities.

(c) The resident engineer/project engineer or their designees are responsible for assuring that the QAR contains all relevant items of information.

(13) The QAP will review the entries on the contractor's QCR. The QCR should contain information on the contractor's quality control operations and not be burdened with other information.

(14) Document contractor performance throughout the contract and initiate interim and final unsatisfactory ratings where necessary.

- QA for Procedural Specifications: Some QA testing in the case of certain critical earthwork and concrete dam structures must be conducted continuously. A comprehensive QA testing program is necessary on the part of the government when specifications limit the contractor to prescriptive procedures leaving the responsibility for end product quality to the government. Contracting officers must limit contractor responsibilities for tests to those which control the prescriptive procedures and strictly avoid any duplication of government testing.
- Performing Acceptance Inspections: Subsequent to CQC completion inspections, acceptance inspections of completed construction are a government responsibility.

Summary QA Project Approach

The Tuttle Creek project utilizes a Deterministic QAO, shown in Figure G1, in which USACE is responsible for the construction QA and the contractor is responsible for the construction QC. In this project the design was done in-house; therefore, the designer responsibilities of design QA and design QC also lie with USACE.

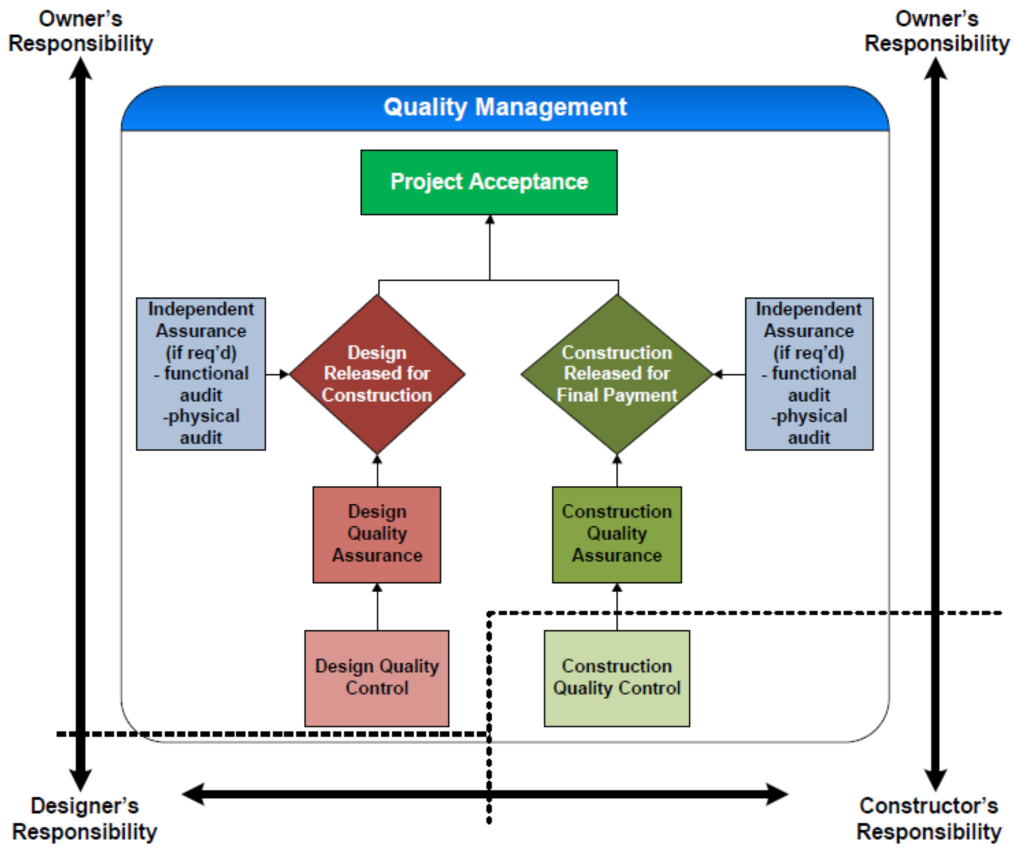


Figure G1: Deterministic QAO for Tuttle Creek Dam Safety Assurance

Example of Alternate QMS Used on This Project

Due to the rare technology used on the active Tuttle Creek Dam it was a challenge to develop a set of contract documents for this project. Similar quality management challenges arose during the design and construction phases in which specifications had to be reviewed or developed to cater to the unique project conditions. The quality management of the design phase required a new performance specification to be developed for a technology that had never been used for the required application before. Likewise, evaluating quality during the construction phase required careful review of the performance specifications as they were difficult to apply. For example, one test required a 90 day wait before it could be conducted. This brought up the question of whether or not the contractor should remain mobilized for 90 days in case of a failed test. This unique situation required USACE to review whether the testing/design could have been designed differently for these situations.

Observations of the Researcher

This project utilized an established USACE quality management system; therefore, quality procedures were detailed and understood. The QMS was enhanced by employing an Advisory Panel of Experts that provided consulting throughout the project. Conversely, the quality management system was difficult to implement when existing performance specifications did not cater to the rare technology used on the project.

Effective QM Practices

The following is a list of effective practices used on USACE projects.

- Advisory Panel: One of the biggest successes in quality management on this project was the involvement of an advisory panel as well as the construction contractor involved during the design development.
- Resident Management System (RMS): This is an automated system for submittal and document control. It allows for the creation of reports that are tailored for the project, office, fund type, customer as required. Key reports that can be created include Status of Construction Reports, Construction Placement Summaries, System Milestone Schedules and QA/QC Daily Narratives. In addition, custom reports can be created by utilizing data elements such as administration, finances, QA/QC, submittals and schedules.
- Design check: The designer must have his work checked by highly experienced technical person before each design submittal. This checking procedure is essential to the production of a quality product and must be incorporated into every QCP.
- Quality control checklists: These checklists enable designers and their checkers to ensure that all considerations are systematically addressed.
- Interdisciplinary checks: Interdisciplinary coordination is a key element of the QCP. It should be evident throughout the entire design process. The checks are usually conducted by the design team members who check each other's work for the purpose of assuring compatibility between drawings and specifications produced by the various disciplines.
- The following practices are reviews that may be utilized to ensure the timely delivery of cost-effective, quality services and products.
- District Quality Control (DQC) Review: A DQC review is a quality control measure in which an internal peer review is conducted by a technical element within a district. It consists of a formal procedure or set of procedures intended to ensure that the developed product adheres to a defined set of quality criteria or meets the requirements of the client, customer, and regulations. A DQC is similar to, but not identical to, QA.
- Agency Technical Review (ATR): Upper management may require an ATR. An ATR is an independent technical review, which is a critical examination by a qualified person or technical team outside the submitting district that is not involved in the day-to-day technical work that supports a decision document. The ATR can be performed at any stage of product development, even during construction as a measure of quality, confidence, and reliability. In order to receive a certification, the ATR process requires a formalized comment and resolution process.
- Independent External Peer Review (IEPR): Like the ATR, an IEPR may be required by upper management. An IEPR is an independent review of the technical efficacy of a

decision document by a review organization external to USACE. An IEPR is conducted on projects that meet mandatory or discretionary triggers.

- Quality management review: In order to assure that USACE Regulations are met USACE headquarters, conduct quality management reviews. These reviews assess the effectiveness and implementation of individual USACE command's quality management plans.

APPENDIX H: MOUNTAIN VIEW CORRIDOR, UTAH

Project Information

Project Name: Mountain View Corridor (MVC) Project

Name of Agency: Utah Department of Transportation (UDOT)

Location: The Mountain View Corridor encompasses Salt Lake County west of Bangerter Highway between I-80 and the Utah County border. It also includes northwest Utah County west of I-15 from the Salt Lake County border to the north shore of Utah Lake.

Project Delivery Method (*DBB, DB, CMR, PPP, etc*.): CM/GC

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best-Value

Contract Payment Provisions (*Lump Sum, GMP, Cost* +): GMP

Project Description

Initial construction includes building two outside lanes in each direction with signalized intersections where future interchanges will be located. This new roadway requires extensive grading and excavation (earthwork), relocating utilities, acquiring property, constructing drainage systems, building bridges and structures, and laying new pavement. Trail sections will also be built. Future construction will build out the remainder of the corridor by adding interchanges and more lanes to achieve a fully functional freeway.

The Mountain View Corridor (MVC) is a planned highway, transit-way, and trail system in western Salt Lake and northwestern Utah Counties that will serve13 municipalities in the Project area. The Project is planned to be built in phases as the infrastructure is needed and as funding becomes available. The initial build will provide two lanes in each direction with at-grade intersections. The CM/GC process being used by the Agency could enable the northern terminus of the initial build project to be extended to the north as far as possible.

Construction includes approximately 10 miles of new divided highway and frontage roads.

Further work may include, but is not limited to:

Utility adjustments
Removals
Clearing
Grading
Drainage
Structural aggregate courses
Paving
Striping
Signage, fencing, and other appurtenances
ATMS
Intersection construction
Reconstruction & realignment of cross streets

Mainline and overpass structures
Retaining walls
Seeding
Landscaping
Concrete flat work
Aesthetic treatments
Electrical
Lighting

Project Quality Profile

UDOT will provide some quality control and all quality assurance for the Project. The contractor is responsible for assuring the quality of the work of the subcontractors at all levels. UDOT or its designee will perform limited inspection and testing to audit and verify that all work and materials comply with the drawings, specifications, and all reference standards. Audits will be performed on a systematic basis and will be coordinated with the Quality Control Plan or as warranted by general quality trends.

Project Financial and Schedule Information

Original Total Awarded Value of project: $450 million construction proposal

Final Total Awarded Value of project: $730 million (project still on-going)

Project Schedule:

Project Approved to start process: 2005

Initial Advertising: June 13th, 2009

RFP Issued to Shortlist: June 11th, 2009

Contract Award: August, 2009

Original Project Delivery Period: Projected Construction Completion Date is December 2013

Final Project Delivery Period: On-going

The subsequent phases of MVC will be built as funding becomes available.

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table H1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
CMGC	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ✔5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
PPP	✔NA; ☐Pilot projects only; ☐General authorization	☐✔NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐15; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

The I-15 Project was taking place at the same time and was a Design-Build project. Therefore, UDOT could not afford the risk of doing another big DB project as the consulting community would not be available. The Project Manager was told that MVC had to be a CM/GC project instead.

Reasons for Selecting Project Delivery Method (most significant reason)

The most significant reason for selecting CM/GC for this project was Risk Management.

Case Study Project Risk Analysis Process

Formal Risk Analysis Areas: Cost and schedule.

The Contractor was required to participate in a formalized ongoing risk analysis and mitigation process established by UDOT. In general, this process consists of a series of workshops where risks and mitigation strategies are identified and implemented. UDOT expects that, as design, cost estimating, constructability reviews, and other pre-construction activities progress, risks and unknowns will be reduced by successfully implementing mitigation strategies in order to reduce both Project costs and Project contingencies. A key outcome of the risk workshops should be costs of the risks identified.

Project Cost Estimate Uncertainty Analysis

The Contractor's bid becomes the GMP with the exception of risks that were identified in design and for which UDOT has decided to take ownership. The contractor's final bid, or GMP, does not include the cost of these risks. The UDOT PM sets up Risk Contingency Funding to cover these known risks. The contractor's GMP combined with the Risk Contingency Funds represents the total GMP which must be within the Commission Approved Amount for the project.

Risk Identification Techniques Used

Risk Register and Opinion of Probable Costs.

Traditionally UDOT has addressed risk through a process of identification and mitigation that is not substantiated by rigorous analysis. However, with the implementation of large CM/GC projects, better analysis efforts have been established. MVC is a current state funded project that illustrates the capabilities of CM/GC to analyze and mitigate risks.

Risk Assessment Techniques

Risk assessment for the project involves reviewing the Baseline Cost and Schedule. Then, risks related to the Baseline (cost of risk and cost of delay) are identified and quantified.

Risk Management Techniques

UDOT plans to implement active risk management as a collaborative process for UDOT, the program management team, the design team, and the general Contractor to assess risks, opportunities, and benefits while controlling the Project's cost and schedule. UDOT's active risk management plan calls for an iterative process where all the parties involved (program management, design, and general contracting teams) identify and quantify risks; as well as develop mitigation strategies in a collaborative, consensus-based environment. In particular, the process consists of four key steps as follows:

Step 1: Baseline Risk Assessment

- Review Baseline Cost and Schedule
- Identify and Quantify Risks Related to Baseline (cost of risk and cost of delay)

Step 2: Risk Response Strategies

- Develop Recommendations to Mitigate/Avoid High Risks

- Develop Recommendations that Add Value

Step 3: Risk Analysis on Response Strategies

- Identify Risks Associated With Response Strategies
- Quantify Threats and Opportunities

Step 4: Tracking, Monitoring, and Control

- Identify Risk Owners, Monitoring Frequency
- Continuously update cost of risk and risk management plan
- Document and report progress
- At Key Milestones, Update Cost and Schedule

Risk Technique used to Draft Contract

In their response to the RFP contractors were instructed to explain how they will identify, price, and mitigate risk through the formalized risk management process that UDOT intends to use. Furthermore, proposers were required to explain how they will support the team during pre-construction and construction activities in achieving a cost at or below traditional projects.

In addition, the proposers were instructed to address the following points relating to risks associated to price:

Risks that would increase the unit prices

Mitigation that would decrease the unit prices

Amount of quantity change that would justify a change in unit prices

Assumptions used to create unit cost

Actions taken by the Contractor during pre-construction to identify and minimize risk

Effect of schedule on costs

Effect of work by others such as utilities or municipalities in the Project corridor

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table H2: Administrative and Performance Based Prequalification Requirement

Designer prequalification program factors	**Administrative**	**Performance Based**
Prequalification required for all projects	☐	✔
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	✔
Prequalification standards are different by project class	☐	☐
Construction prequalification program factors	**Administrative**	**Performance Based**
Prequalification required for all projects	☐	✔
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	✔
Prequalification standards are different by project class	☐	☐

Table H3: Required Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	☐	✔	☐
Qualifications of the Construction Quality Manager	☐	✔	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	✔	☐
Design quality management plan	☐	✔	☐
Design quality assurance plan	☐	✔	☐
Design quality control plan	☐	✔	☐
Construction quality management plan	☐	✔	☐
Construction quality assurance plan	☐	✔	☐
Construction quality control plan	☐	✔	☐
Quality management roles and responsibilities	☐	✔	☐
Design criteria checklists	☐	✔	☐
Construction testing matrix	☐	✔	☐
Quality-based incentive/disincentive features	☐	✔	☐
Warranties	☐	☐	☐
Optional warranties	☐	☐	☐

Note: The items above are not specifically asked for in the RFP, but they are evaluated.

Design Phase Summary

Table H4: Design Quality Management Roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔	✔	
Checking of design calculations		✔		
Checking of quantities		✔	✔	
Acceptance of design deliverables	✔			
Review of specifications	✔	✔	✔	
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			

Construction Phase Summary

Table H5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings		✔	✔	
Technical review of construction material submittals	✔		✔	
Checking of pay quantities	✔		✔	
Routine construction inspection	✔		✔	
Quality control testing			✔	
Verification testing	✔		✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔	✔		
Report of nonconforming work or punch list.	✔		✔	

Quality Management Planning

QA/QC Plans

The design QM plans are no different from the QM plans used on traditional design projects. For UDOT the delivery method does not affect the quality methods. The quality methods are driven by the size of the project.

The contractor was required to develop, implement, and maintain a Quality Control Plan that assures equipment and material conformance to the applicable requirements of every section of the specifications. The Quality Control Plan had to focus on providing continuing attention to producing and installing error-free work that complies with the Contract.

The Quality Control Plan had to include, at a minimum, provisions for continued education and training, toolbox meetings, various meetings with subcontractors and suppliers, and other activities designed to accomplish the following:

- Emphasize the importance of high-quality work
- Stress the concept that quality is best achieved during initial installation of the Work
- Enhance the exchange of technical and other information pertaining to quality throughout the Contractor's organization
- Eliminate non-complying work requiring rework or replacement

In addition, the Quality Control Plan had to include the Contractor assuring the quality of the work of the subcontractors at all levels.

Use of mandated agency quality management plans

UDOT mandated the use of standard agency specifications, the same as those used on routine projects.

Quality staff qualifications

The following information had to be provided by each proposer:

- A narrative describing how the proposed key members of the team will meet the stated Project goals and build a professional and collaborative Project Team
- Project Team members' organizational chart
- A spreadsheet list of similar projects and details of projects completed by the contractor or are nearing completion during the last five years
- A discussion of the qualifications of the following Key Personnel:
    - Project Principal
    - Project Manager
    - Project Controls Manager
    - Construction Manager
    - Quality Manager
    - Lead Estimator
    - Utility Manager
    - Up to two other persons that the Proposer considers as key to the success of the Project

- A narrative that describes successful methods, approaches, and innovations implemented on the listed projects
- Resumes and two references for each Key Personnel

Contractor quality assurance test results

Yes. UDOT will provide all quality assurance for the Project while the contractor is responsible for assuring the quality of the work of the subcontractors at all levels.

General Quality Management Procedures

Standard of Care

There is no difference in standard of care for this project when compared with DBB projects.

Alternate Quality Management Systems

The integrated QMS is designed to provide adequate confidence and objective evidence that the work performed by Copper Hills Constructors (CHC) and its Subcontractors, for the Mountain View Corridor Project meets the requirements of the Contract Documents and the rules and regulations contained therein.

CHC uses a Quality Team approach to implement the Project Quality Control Plan. The CHC Project Manager is the Quality Team Leader. The Quality Team members include:

- Deputy Project Manager – Controls
- Construction Quality Manager (CQM)
- Quality Control (QC) staff
- The CHC Construction Staff
- Subcontractors
- Suppliers
- UDOT

The Project Manager is responsible to provide adequate resources to the CQM including the assignment of qualified and trained personnel for management and Quality verification activities including internal quality audits. The CQM is authorized to stop the Work if it is judged the Work is performed contrary to or in the absence of prescribed controls, safety requirements, or approved methods, and further would make it difficult or impossible to establish acceptability of the results. Upon issuance of a Stop Work Order, the CQM shall immediately notify the UDOT Resident Engineer, the CHC Deputy Project Manager - Controls, and the CHC Deputy Project Manager - Operations.

The CQM and staff will verify and document the quality and technical requirements of the project, which shall be achieved through selected inspections, surveillance, tests, and audits. Quality Record Documents that verify the achievement of the quality and technical requirements of the Contract and the rules and regulations contained therein shall be retained in the Project Quality Records File which will be the property of UDOT at Final Owner Acceptance.

The CQM will perform regular management reviews and quality audits of the implementation and maintenance of the Project Quality Management System to verify and document its effectiveness in controlling the quality of the Work performed by CHC, Subcontractors, and Suppliers for the Project.

The CQM will provide reports, as needed, to the CHC Joint Venture Board regarding the implementation and maintenance of the Project Quality Control Plan and its effectiveness in controlling the quality of the Work. These reports will form a basis for improvement of the CHC Quality Management System. The CQM is also responsible to provide as a liaison with external agencies participating in the Mountain View Corridor Project on matters relating to the Project Quality Control Plan.

Summary QA Project Approach

The Mountain View Corridor project follows the Assurance Quality Management Organization as the Owner is to perform all the quality assurance, with the exception of the subcontractor quality assurance being carried out by the contractor. The quality control is the responsibility of the designer and the contractor.

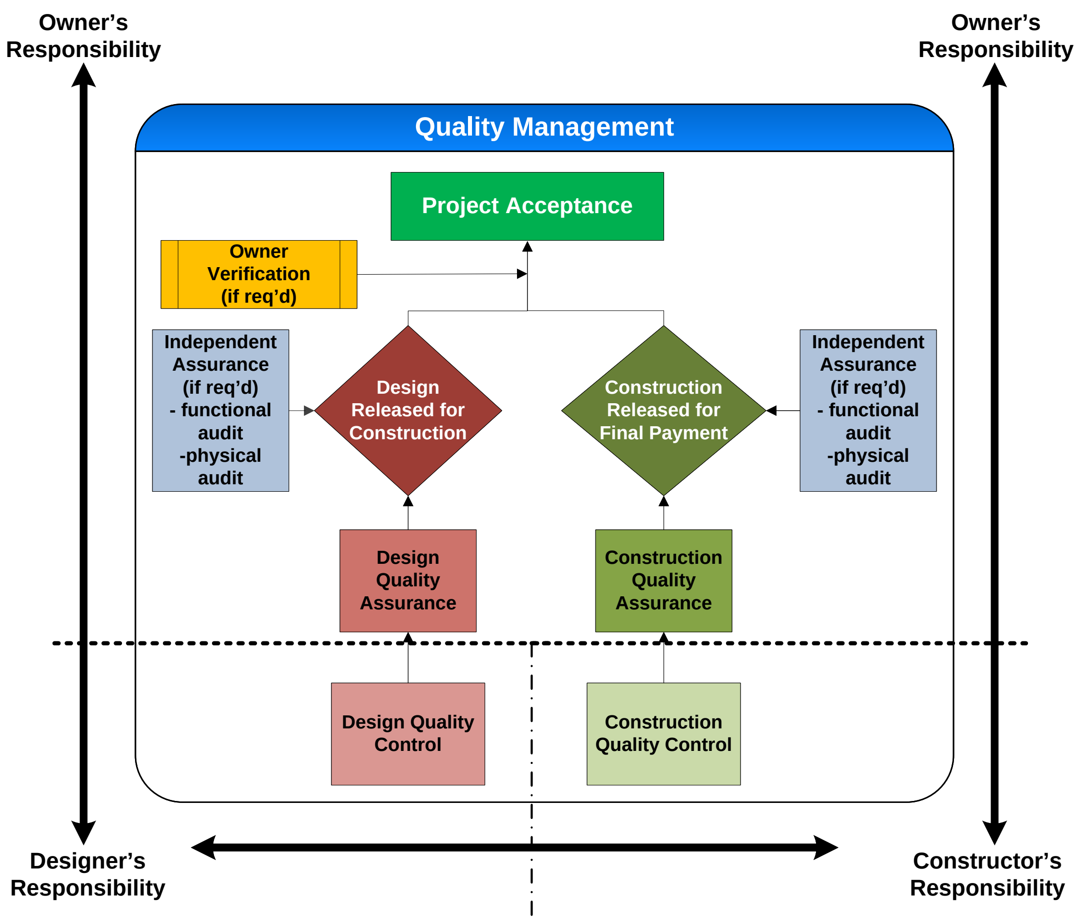


Figure H1: Mountain View Corridor QAO

Example of Alternate QM System Used on This Project

One quality method that has been beneficial to the MVC project is the everyday meetings of the project team. These collaborative discussions provided a forum for optimal solutions to be reached. For example the Juniper Canyon Bridge was originally designed to be a 3-span structure because it went over two mini canyons. The contractor asked if one of the canyons could be filled since it appeared that it did not carry any drainage. The environmental group finally looked into it at the contractor's urging and determined that one of the canyons could be filled and the other spanned. It is likely that this solution and the resulting reduction in bridge cost would not have been reached had the contractor not been able to question it the design in the meetings. The following outcomes were achieved:

- Design Optimization – Juniper Canyon Bridge
- Construction Optimization - Earthwork balance
- Utility Relocation Optimization – High pressure gas main protect in place, and design around conflict

Observations of the Researcher

The current success of this project could be attributed to the frequent collaboration of the project team. It has been identified that retaining the same project staff members throughout preconstruction and construction is important in order to maintain consistency and to avoid the loss or misinterpretation of assumptions made throughout the process. In terms of quality, emphasis is placed on maintaining quality records in an organized manner. This is seen as important record for this project as well as future projects with similar quality management systems. The large size of this project warranted a slightly different approach than other UDOT projects and a particular emphasis on risk management was required.

Effective QM Practices

The following practices are used on the MVC project and lead to enhanced quality:

<u>Project Records File and Distribution System:</u>

CHC will establish and maintain a Project Records File and Distribution System at the project office. This system is to include electronic data and hard copies. Records shall be filed in an organized manner, indexed, and retrievable. The Records file index system shall provide sufficient information to permit prompt retrieval and identification of the Record and the item(s) or activity to which it applies. Corrections to all Records shall be controlled and appropriately reviewed by the originating department. All corrections shall include the date and the identification of the person authorized to make the correction and the person making the correction.

<u>Regular Project Team Meetings:</u>

The RFP specified that all parties involved in the performance of the Project, including UDOT, the UDOT-selected Architecture/Engineering firm, the prime Contractor, and all subcontractors will meet together on a regular basis (at least monthly) to establish and maintain open lines of communication with the goal of ensuring relationships of trust and cooperation on the Project. Further meetings conducted throughout the project include pre-construction Meetings, Weekly Owners/Progress Meetings and Partnering.

Reviews:

The contractor is required to participate in formal constructability and material availability reviews that are conducted at up to four milestones throughout the Project. These formal reviews are to focus on identifying revisions to improve clarity for bidding, identifying potential design revisions that would reduce construction costs, and identifying elements to improve the time performance for the Project. This practice is not identified as a quality method initially; however, reviewing the elements to improve the time performance is likely to promote discussions about project quality throughout the duration of the project.

Quality Personnel Education and Training:

Personnel performing or managing activities that have an effect on quality are required to be familiar with specific requirements of the Contract Documents. They are also expected to have all necessary education, training, and certifications where applicable for each area of discipline, as required. The extent of training is to correspond with the following:

- Scope, complexity, and nature of the activity
- Education, experience, and proficiency of the person
- Specific requirements of the Contract Documents

Goal-Setting Session:

The Contractor was required to participate in an initial goal-setting session with UDOT. The intended outcome of this session was to review UDOT's goals to ensure that the Contractor understands these goals and to allow the Contractor to provide recommendations to UDOT regarding these goals. A session of this nature is important to the quality of the project as it ensures that the owner and the contractor are in alignment with their quality expectations and avoids future disagreements or misunderstandings at a later stage.

APPENDIX I: US 160 4TH LANE ADDITION, COLORADO

Project Overview

Project Name: U.S. 160 4th Lane Addition

Name of Agency: Colorado Department of Transportation (CDOT)

Location: U.S. 160 at Farmington Hill Interchange/Wilson Gulch in Grandview Colorado just east of Durango, CO

Project Scope: The Project included the design of 4 bridges in mountainous terrain, and crossing U.S. 160 and the environmentally-sensitive Wilson Gulch. Also the project included the addition of a 4th lane on U.S. 160 and the construction of portions of ramps.

Project Delivery Method (DBB, DB, CMR, PPP, etc.): Modified DB

Procurement Procedure (QBS, Best-Value, Low Bid): Low Bid

Contract Payment Provisions (Lump Sum, GMP, Cost +): Lump Sum

Methodology

The case study interviews were conducted on July 7, 2011 over the phone. Three independent interviews were conducted with CDOT employees with responsibility for the overall project management, construction project management and design project management. The interviews were conducted independent of one another. The interviews were conducted in accordance with the case study protocol developed by the research team and approved by both an industry panel and the NCHRP review panel. The interviews began with an introduction to the research and given a brief summary of the research objectives. The questionnaire developed as part of the protocol was completed as a group by the interviewees prior to the interviews. This allowed the interviews to focus more on the questionnaire follow up questions within the case study protocol rather than answering the questionnaire.

The data collection process concluded with a request for relevant project documents. Interviewees volunteered their time and were not compensated by the research team in any way.

Project Quality Profile

The Design-build contractor is responsible for both design and construction QC. Overall CDOT states that the QM system does not differ between Project Delivery Methods

Owner's reasons for using alternate QM system

Because the design fell under the design-builder responsibility, resulting in the design builder being responsible for design QC.

Project Financial and Schedule Information

Original Total Awarded Value of project: $29,428,100

Final Total Awarded Value of project: $29,428,100 – Final contract amount was same as the original award, but additional work was done for the same budget due to savings in the force account items.

Project Schedule: completion by Nov. 30, 2010

Project Approved to start process: January 2007

Initial Advertising: June, 2007

Contract Award: April 3, 2008

Original Project Delivery Period: Contract required completion of the project by Nov. 30, 2010

Final Project Delivery Period: The project was 97% complete on December 30, 2009. Today the project is not considered "complete" because there is an issue with cracks in the abutments that is still being worked out.

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table I1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
CMGC	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
PPP	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; x General authorization	☐NA; X 1-5; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

This project was delivered with what CDOT calls a modified design build. CDOT's modified design build is a project delivery method where CDOT procures the services of a construction contractor for design and construct for the project through a single phase, low bid selection process. The design firm had to be selected from a list of CDOT pre-qualified firms.

In January 2007 CDOT was informed that the project was funded and it had to be advertised by June 2007. Some design was underway and could be finished by June, but other specialties could not be finished in that time frame. The modified design-build process was proposed, because it was the only way to get the project out for advertisement by June. When the project went out for advertisement it had a partial design complete and the contractor was responsible for designing the bridges, walls and drainage.

Reasons for Selecting Project Delivery Method (most significant reason)

Modified Design-build was chosen for this project to enable advertisement by June 2007.

Contractor Project Delivery Experience

The contractor had experience with large DB projects in the past, even DB projects with CDOT.

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table I2: Administrative Prequalification Requirement

Designer prequalification program factors	**Administrative**
Prequalification required for all projects	✔
Prequalification required for selected projects only	☐
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	☐
Designer prequalification program factors	**Administrative**
Prequalification required for all projects	✔
Prequalification required for selected projects only	☐
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	☐

Note: Anyone bidding or responding to a RFP has to be already on CDOTs prequalified list of designer or contractors. This project required a DB team with the contractor submitting the response to the RFP. The RFP required the proposed DB team to have both a CDOT prequalified contractor and a CDOT prequalified designer. CDOT's prequalification process is primarily based on financial capabilities.

Table I3: Required Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	☐	☐	☐
Qualifications of the Construction Quality Manager	☐	☐	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	☐	✔
Design quality management plan	☐	☐	✔
Design quality assurance plan	☐	☐	✔
Design quality control plan	☐	☐	✔
Construction quality management plan	☐	☐	✔
Construction quality assurance plan	☐	☐	✔
Construction quality control plan	☐	☐	✔
Quality management roles and responsibilities	☐	☐	✔
Design criteria checklists	☐	☐	✔
Construction testing matrix	☐	☐	☐
Quality-based incentive/disincentive features	☐	☐	☐
Warranties	☐	☐	☐
Optional warranties	☐	☐	☐

Lesson Learned

Put language in the contract that helps the designer and contractor avoid pitfalls. Such as more design review to be conducted by an independent contractor or another office of the same firm.

Design Phase Summary

Table I4: Design Quality Management Roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔		
Checking of design calculations			✔	
Checking of quantities	✔	✔	✔	
Acceptance of design deliverables	✔			
Review of specifications		✔		
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			

Construction Phase Summary

Table I5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔	✔		
Technical review of construction material submittals	✔	✔		
Checking of pay quantities	✔			
Routine construction inspection	✔			
Quality control testing	✔			
Verification testing	✔		✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔			

Quality Management Planning

Design QM/QA/QC Plans

The only Quality Plan created specifically for this project is the contractor created Design Quality Control Plan (DQCP). In Section 3 – Quality Management of Book 2 (CDOT technical requirements) the contractor is assigned responsibility for creating a Design Quality Control Plan (DCQP) for the project and submitting it to CDOT for approval two weeks before start of work. As specified in Section 3, the DCQP is required to include the following:

- Procedures that address all elements of design including, but not limited to, architectural, civil, structural, geotechnical, survey, hydraulic, environmental, traffic, safety, and temporary work.

- Identify the applicable computer programs to develop and check designs.
- Identify design input requirements and perform on-going audits of the design input requirements.
- Procedures to control and independently ensure that the design meets the requirements of the Contract Documents, including provisions for Sub-consultants' designs and configuration management activities.
- Procedures for approval of released for construction documents and revision control.
- A process to ensure that the design inputs are communicated to and accessible by, the relevant designers responsible for incorporating design inputs into the design.
- How changes to design inputs are identified, reviewed and approved by authorized personnel prior to their implementation.
- Procedures to identify and track design document deliverables.
- Procedures to identify, record and track field design changes.
- A description as to how the design team schedules the design efforts, including task force meetings, design reviews, constructability reviews, design meetings, independent design checks and a scheduled for Release for Construction Documents and final Design Documents.
- A process for the contractor's Engineer responsible for the design to prepare, review, and approve all changes, including field design changes, to Release for Construction Documents and Final Design Documents.
- A process to communicate design changes to the construction site on a timely basis consistent with the progress of construction activities.

Construction QM/QA/QC Plans

The CDOT Special Provisions US 160 4th lane issued February 4th 2008 has a requirement for a contractor created quality control plan (QCP). This plan is separate from the design quality control plan and must also be reviewed and approved by the Engineer (which is CDOT) prior to the start of work. The QCP shall address all of the following:

- The name, qualifications, duties, responsibilities and authorities of each person assigned a QC function.
- A description of the responsibilities and authority , and a resume of experience, of the QC Manager.
- Procedures for preparing, reviewing and presenting materials submittals, including those of subcontractors, vendors, offsite fabricators, suppliers and purchasing agents, for assuring they conform to contract requirements. The schedule in the CDOT Field Materials Manual will govern minimum submittal requirements.

- QC inspection methods and procedures for all stages of operations. At a minimum, the items in the CDOT inspectors Checklist and CDOT Construction manual shall be inspected.
- Reporting procedures, including proposed reporting formats for inspection for all phases of the work.
- Names of testing and engineering firms to be used, if any.
- Procedures for identifying, evaluating, and reporting non-conformance discovered during QC/QA inspections and testing.

The contractor was also required to prepare a Paving Quality Control Plan outlining the steps taken to minimize segregation of HMA. The plan was required to be submitted to the Engineer (CDOT) and approved before beginning the paving operations.

The contractor was only specifically assigned QC responsibilities for concrete and asphalt paving.

Use of mandated agency quality management plans

The agency did supply Book 2, the field materials manual, and design requirements for the project. These references do include some quality management procedures. A specific agency quality management plan was not identified during the case study.

Quality staff qualifications

Design Quality Control Manager – fully qualified to act as the contractor's representative in authorizing the drawings for construction.

Contractor Shotcrete quality control technician – must hold the appropriate ACI certifications.

Contractor QC Manager – Shall not be the contractor's superintendent.

Contractor testing staff – As stated by CDOT's Book 2 "the Contractor shall have properly qualified testing staff on site to test permanent material items incorporated into the work where required by the CDOT specifications and the CDOT Filed materials Manual. At a minimum the tester(s) shall be certified to test material items using testing procedures as shown in the CDOT Field Materials Manual (FMM) in effect at the time of bidding."

Contractor quality assurance test results

The contractor tests can be used by the agency for quality assurance testing and acceptance. However this was not common practice on this project.

General Quality Management Procedures

Project QM system overview

Same as DBB project, except the designer was contracted through the contractor.

No independent assurance on the project

No owner verification testing performed on the project

Final acceptance still has not been granted on the project because of cracking abutments. CDOT did award partial acceptance on the majority of the project by the end of 2009.

Standard of Care

Yes, CDOT did hold the DB staff to a higher standard of care.

Alternate Quality Management Systems

The design was conducted by the design builder on this team which required the typical CDOT quality management system to be modified by assigning design QC to the design builder and requiring the design builder to create the design quality control plan (DQCP) for submittal and approval by CDOT. The design reviews and the design forms were two of the topics of the DQCP that came up during the interviews. Further information on each of these topics is discussed below.

Design Review

Formal design reviews between CDOT and the Design-build team were conducted at the 30, 60 and 90% stages of the completion of the design development process. Four types of reviews were conducted as appropriate during the formal design reviews. The four types of reviews are listed below:

- *Constructability review* – Performed by the construction management and project engineers. The scope of the constructability review is in accordance with the corresponding stage of design development. The CR considers:
    - Consistency with design concept objectives.
    - Adequacy of information on the plans and specifications to construct the work.
    - Ability of the design to be constructed within the required schedule given site restrictions, economics of the proposed construction, availability of materials, construction equipment requirements, and local work force availability.
    - Consistency with environmental mitigation requirements.
    - An assessment of the design details relative to the practicality of achieving specified tolerances, access needed to properly install or construct work elements, and interdisciplinary conflicts.
    - Proper incorporation of review comments from prior constructability review (if any).
- *Design coordination review* – Addresses the design approach, suitability, completeness, interferences, and conformance with Contract requirements. The design coordination review will be conducted by the design task lead.
- *Final package review* – Performed after design quality checks have been completed and is verification that the package is complete and approved for construction.

- *Quality Assurance Audit* – A QA audit will be performed by the Project Quality Assurance Officer at the end of each completed final package to assure that plans, specifications, calculations and design reports have been checked, reviewed, and properly signed-off in conformance with the DQCP.

Design Quality Forms

Design quality forms were included as part of the appendix of the DQCP. These forms were incorporated into the different QC processes detailed in the DQCP and were enacted during the project. These forms helped to organize and track different aspects of the project. These forms were also considered to be a very successful element of the quality management system.

Factors impacting the quality of the project

Table I6: Rankings of the Impact of Quality Factors

Factor	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact
Qualifications of agency design staff	☐	✔	☐	☐	☐
Qualifications of agency project management staff	☐	✔	☐	☐	☐
Qualifications of agency construction staff	☐	✔	☐	☐	☐
Qualifications of the design consultant's staff	☐	✔	☐	☐	☐
Design consultant's past project experience	☐	☐	✔	☐	☐
Qualifications of the construction contractor's staff	☐	✔	☐	☐	☐
Construction contractor's past project experience	☐	☐	☐	☐	✔
Submittal of Quality management plans prior to work start	☐	☐	☐	☐	✔
Level of agency involvement in the QM process	☐	✔	☐	☐	☐
Use of agency specifications and/or design details	☐	✔	☐	☐	☐
Level of detail expressed in the procurement documents (IFB/RFQ/RFP)	☐	✔	☐	☐	☐
Use of manuals, standards and specifications developed for DBB type projects	☐	✔	☐	☐	☐
Allowing flexibility in choice of design standards and construction specifications	☐	☐	✔	☐	☐
Use of performance criteria/specifications	☐	☐	☐	☐	☐
Detailed design criteria	☐	✔	☐	☐	☐
Warranty provisions	☐	☐	☐	☐	✔
Incentive/disincentive provisions	☐	☐	☐	☐	✔
Follow-on maintenance provisions	☐	☐	☐	☐	✔
Innovative financing (PPP/concession)	☐	☐	☐	☐	✔

Summary QA Project Approach

The Assurance QAO was used for this project and is shown in Figure I1.

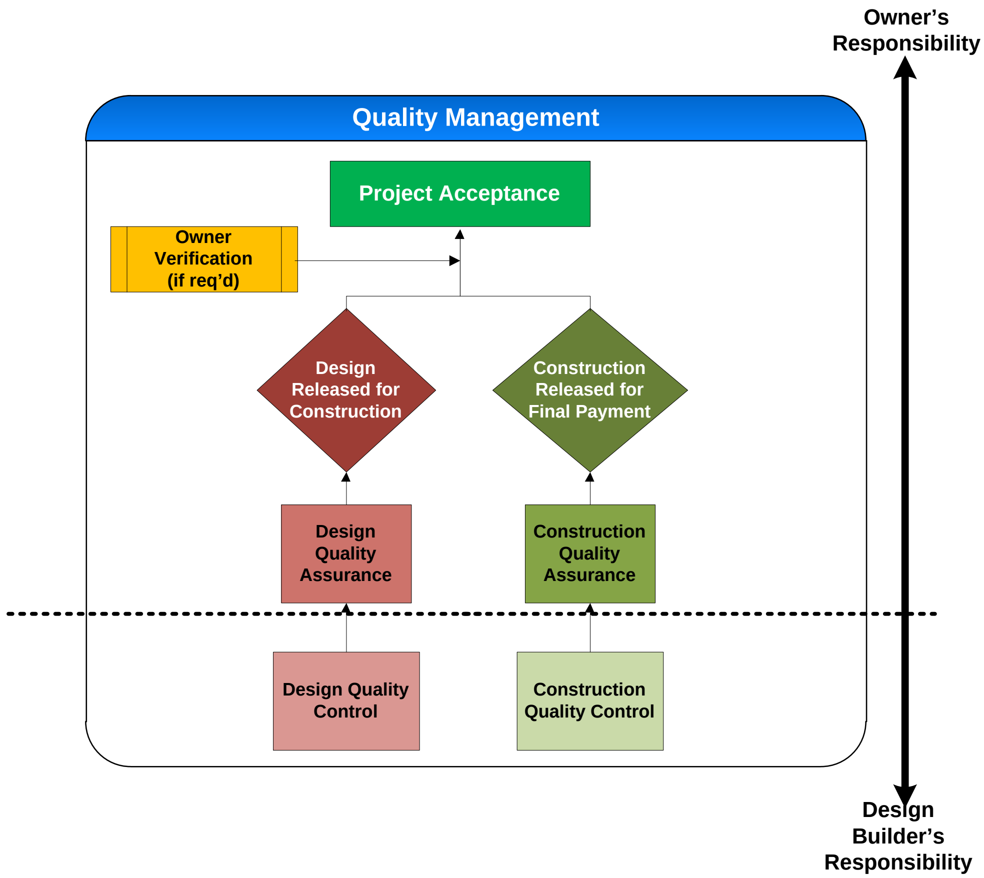


Figure I1 - U.S. 160 4th Lane Expansion, Assurance Quality Management Organization

Observations of the Researcher

Overall all discussions of project quality encompassed design quality and the design quality control plan. Even though the CDOT special provisions document requires the contractor to provide a QCP that appears to be specific to construction, everyone refers to the design quality control plan for the project whenever asked about any kind of quality plan (management, assurance or control).

The innovation on the project was limited due to the CDOT constraints on the project. CDOT dictated the type of bridges, the aesthetics of the bridges and even completed some of the designs before the contractor was brought on board. Additionally CDOT retained control of some aspects of the design such as lighting, and landscaping. CDOT Staff Bridge had a difficult time relinquishing control over the bridge designs. Staff Bridge would have preferred more design reviews. However with the number of design reviews already required for the project it was challenging to manage the number of submittals and have CDOT respond within two weeks. One thing that helped this process was getting commitments up front from internal CDOT/Staff bridge personnel for the project and the project requirements.

Another difficulty with design was gaining an understanding within Staff Bridge personnel as to the difference between a design requirement and a design preference. If it was a preference and CDOT accepted the "change" then the contractor is entitled to additional monies to implement the preference. A specific example is that of the size of the monuments on the abutments. Originally they were very small, but met the requirements. CDOT wanted larger monuments and eventually approved them.

Due to the apparent lack of a construction quality control plan and the fact that CDOT performed testing on all materials, it appears that the QMS for the construction phase of this project was the traditional approach, heavily directed by the agency. CDOT does allow for the use of contractor test results for QA and acceptance testing, but did not do so on this project.

Originally in the RFP there was a requirement for the contractor to provide a full-time third party inspector on the project for the duration of the project. However this was removed due to the costs associated with providing this service (approx. $150,000 - $200,000). Originally this was included in the RFP to take some of the burden off of CDOT and shift it to the contractor. The third party inspector was going supposed to be on the ground adding another layer of inspection to the project. Instead CDOT became responsible for the task of a full-time inspector looking over the shoulder of the contractor. In the end it is believed that CDOT spent more to internally provide the full-time construction inspector than they would have had the contractor hired a third party inspector. But at the time of contract award there was no budget to do so.

The project overall is considered a success, however currently there are on-going negotiations between CDOT and the design builder regarding cracks on the abutments. The contractor found the cracks during inspections and now there are negotiations as to how to fix the cracks and prevent future ones. This is considered to be the main quality issue on the project, but everyone is working together on resolving the issues (it is mostly agreed to be a design issue).

Lessons learned/changes for future projects

- Add into the RFP process an interview of the design consultants and shift the responsibility of design review and checking the drawings to the consultants.
- Add a requirement that a third party or different office of the design firm review the drawings.
- Hire additional consultants to help man the project for CDOT. The amount of paperwork was enormous even though it was design-build.
- It depends on the project, but change the design requirements so more innovation could be implemented on future projects. Have Staff Bridge loosen design requirements rather in addition to a reduction in the number of design reviews.
- Assign QC responsibility for earthwork in addition to asphalt and paving.

APPENDIX J: I-15 WIDENING, BECK STREET PROJECT, UTAH

Project Information

Project Name: I-15; Widening, 500 North to I-215

Name of Agency: Utah Department of Transportation (UDOT)

Location: I-15, 500 North to I-215, Utah

Project Delivery Method (*DBB, DB, CMR, PPP, etc*.): DB

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best Value

Contract Payment Provisions (*Lump Sum, GMP, Cost* +): Lump Sum

Project Description

The project consists of the reconstruction of Interstate 15 from 500 North in Salt Lake City to the I-215 overpass in Davis County. The project includes the design, reconstruction, and widening of the mainline highway to include an Express Lane and three general purpose lanes in each direction. The project is approximately 4.1 miles long, and upon completion will add a northbound and southbound Express Lane on I-15. The work includes the total reconstruction of Mainline I-15 between 500 North and the I-215 overpass, as well as Portland Cement Concrete Pavement (PCCP) structures, bridge structures, earthwork, storm drainage, and the reconstruction of Automated Traffic Management System (ATMS) infrastructure necessary to accommodate the highway and bridge construction.

The existing Beck Street Bridge will be removed and replaced with twin 600-feet, four-span bridges. Additionally, the 1100 North and U.S. 89 bridges will be replaced with two-span rapid bridges—the first two-span accelerated bridge construction (ABC) structures to be completed in the country. The 800 North Bridge will be removed permanently.

The Case Study project includes:

- <u>I-15 Mainline:</u> Reconstruct I-15 from 500 North in Salt Lake City to the I-215 overpass of I-15 in Davis County. The project includes the design, reconstruction, and widening of the mainline highway to include an Express Lane and three general purpose lanes in each direction. The work includes the widening of Mainline I-15 from 500 North in Salt Lake City to the I-15 overpass of Beck Street in Portland cement concrete pavement overlaying the existing pavement section; and mill, overlay and widening of the existing asphaltic concrete section from the Beck Street overpass to the I-215 overpass of I-15. The mainline I-15 work includes the total reconstruction of the I-15 overpass of Beck Street. The mainline I-15 work includes: pavement structures; bridge structures (this includes building the abutment walls for the structures to allow a future fifth lane in each direction); necessary earthwork; necessary retaining walls; storm drainage; interstate signing including new Express Lanes; interstate (highmast) lighting; necessary barriers; utility relocations; and the reconstruction of ATMS infrastructure necessary to accommodate the highway and bridge construction.

- I-15 Ramp Reconstruction: Ramps connecting to I-15 will be reconstructed to only the extent necessary to tie in the existing ramps to the new I-15 mainline alignments and grade.
- US 89 Bridge Reconstruction: The southbound US 89 bridge overpass of I-15 in Davis County will be fully reconstructed to accommodate the new I-15 cross-section. This work includes building the abutment walls to accommodate an ultimate 5 lane section in each direction.
- 800 North 1100 North Bridge Reconstruction: The 800 North and 1100 North bridges will be demolished and all unnecessary approach fills removed. These structures will be replaced with a single structure. The reconstruction of this structure will be a part of this project; however, it will not be included in the DB proposals including the Price Proposal.

Project Quality Profile

The QMPs used on this project were the same as those used on traditional UDOT projects, except the tracking and administration was handled differently. This was because the goals were the same with regards to testing requirements etc. except payment was not by quantity. Lump Sum payment was used; therefore quantities were recorded separately for verification testing.

Project Financial and Schedule Information

Original Total Awarded Value of project: $110 million

Final Total Awarded Value of project: $ $135,112,020.00

Project Schedule: 2 years

Initial Advertising: 2008

RFP Issued to Shortlist: May 6, 2008

Contract Award: September 29, 2008

Original Project Delivery Period: 2 years, September 30, 2010

Final Project Delivery Period: 2 years, September 30, 2010

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table J1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
CMGC	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ✔5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
PPP	✔NA; ☐Pilot projects only; ☐General authorization	✔NA; ☐1-5; ☐5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

The project was politically popular. Money was given by the Legislator and they wanted the project built soon. DB allowed for a shortened project delivery period.

Reasons for Selecting Project Delivery Method (most significant reason)

The two major reasons for selecting DB as the delivery method were:

- Reduce/compress/accelerate the project delivery period.
- Establish the project budget at an early stage of design development.

Case Study Project Risk Analysis Process

Formal Risk Analysis Areas: Roadway/Drainage/Floodway, Structures/Geotechnical, Utilities and Cost

Project Cost Estimate Uncertainty Analysis: NA

Risk Identification Techniques Used: Risk Register

Risk Assessment Techniques: Risk Register

Risk Management Techniques: ATC Process

Risk Technique used to Draft Contract: A fuel price adjustment provision was included in the RFP to minimize risk to the Design-Builder and to UDOT due to price fluctuations for fuel and asphalt materials occurring throughout the duration of the Contract. Contract price adjustments were to be made to reflect increases or decreases in the prices of gasoline, diesel fuels, and asphalt products from those in effect on the Proposal Due Date.

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table J2: Administrative and Performance Based Prequalification Requirement

Designer prequalification program factors		
	Administrative	**Performance Based**
Prequalification required for all projects	☐	✔
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	✔
Prequalification standards are different by project class	☐	☐
Construction prequalification program factors		
	Administrative	**Performance Based**
Prequalification required for all projects	☐	✔
Prequalification required for selected projects only	☐	☐
Prequalification standards are the same for all projects	☐	✔
Prequalification standards are different by project class	☐	☐

Table J3: Required Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	✔	✔	☐
Qualifications of the Construction Quality Manager	✔	✔	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	✔	✔	☐
Design quality management plan	✔	✔	☐
Design quality assurance plan	☐	☐	☐
Design quality control plan	✔	✔	☐
Construction quality management plan	✔	✔	☐
Construction quality assurance plan	☐	☐	☐
Construction quality control plan	✔	✔	☐
Quality management roles and responsibilities	✔	✔	☐
Design criteria checklists	☐	☐	☐
Construction testing matrix	☐	☐	☐
Quality-based incentive/disincentive features	☐	☐	☐
Warranties	☐	☐	☐
Optional warranties	☐	☐	☐

Note: Warranties and incentive/disincentive features are outlined in the RFP, but are not required in the proposal or evaluated.

Design Phase Summary

Table J4: Design Quality Management Roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔	✔	
Checking of design calculations		✔		
Checking of quantities		✔		
Acceptance of design deliverables	✔			
Review of specifications	✔	✔	✔	
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			

Notes:

- This project did not involve an Agency-Hired QA/Oversight Consultant.

- The Project Design Consultant was required to do their own QC before submitting deliverables.
- Agency Personnel included Design staff, a Project Manager and Construction staff.

Construction Phase Summary

Table J5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔			
Technical review of construction material submittals	✔			
Checking of pay quantities	✔			
Routine construction inspection	✔			
Quality control testing			✔	
Verification testing			✔	
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔			

Quality Management Planning

QA/QC Plans

Utah Department of Transportation specified that the Quality Management Plan (QMP) had to include procedures for:

- Design-Builder Construction Quality Control
- Design Quality Control and Assurance
- Agency Inspection and Testing

In addition, the QMP had to include methods and procedures to ensure the quality of project elements, including management, administration, design and testing for geotechnical and other disciplines.

Use of mandated agency quality management plans

The agency mandated the use of standard agency QM plans.

Quality staff qualifications

The Quality Program set out by Utah Department of Transportation specified the following qualifications:

<u>Construction Quality Manager (CQM):</u>

Must have no less than four years of experience in construction quality management and inspection and testing after having become a licensed P.E.

Must be a licensed P.E. in the State of Utah by the time of Notice To Proceed (NTP)

The CQM shall not be replaced without prior written approval from the Agency

<u>Design Quality Manager (DQM):</u>

- Must have no less than eight years of total design engineering experience on projects with similar scope and complexity and four years of continuous experience as a licensed P.E.
- Must be a licensed P.E. in the State of Utah by the time of Notice To Proceed
- The DQM shall not be replaced without prior written approval from the Agency.

Proposers had to submit an organization chart showing the planned Quality Control (QC) organizations with the names of independent sampling and testing laboratories included. The chart also had to state who the QC staff would report to within the Proposer's organization.

The number of project quality staff members was to be appropriate for the complexity and composition of the construction activities consistent with the schedule, the location, and geotechnical and environmental factors relating to the work. The Agency reviewed and approved staffing levels for adequacy.

Furthermore, the Quality Management Plan (QMP) had to specify procedures that:

- Familiarize all Project staff with their requirements and responsibilities according to the Contract Documents
- Educate, train, and certify Project staff performing activities affecting or measuring the quality of the Work and ensure that they achieve and maintain reasonable proficiency

Contractor quality assurance test results

The Agency conducted the quality assurance testing.

<u>General Quality Management Procedures</u>

Standard of Care

No different to DBB projects.

Alternate Quality Management Systems

The Design-Builder had the primary responsibility for the overall quality of the work on the I-15 Widening Project. This included the quality of work produced by subcontractors, fabricators, suppliers, and vendors.

An IQF was not required for this project. Utah Department of Transportation was to conduct oversight and inspection for the project.

Agency Authority:

The Agency's roles in the Quality Program were to:

- Provide inspection and testing for quality checkpoint (QCP) on-site meetings and plan and specification reviews
- Monitor and audit the Design-Builder's Quality Program activities to ensure adherence to the QMP
- Conduct owner oversight inspection and testing (oversight, sampling, inspection, and evaluation) as part of owner independent assurance (OIA), including the off-site oversight inspection and testing of the fabrication of precast and prestressed concrete structures and of structural steel
- Conduct all acceptance testing
- Perform the final walk-through, final audit of records, and final acceptance of Work

The Agency also coordinated its quality activities through the following components:

Owner Design Oversight (ODO): The ODO was to oversee the design of the Project by participating in the design reviews, providing documentation, and coordinating with the Design-Builder and the Agency to ensure that the design met the requirements of the Contract.

Owner Oversight Inspection and Testing (OIT): OIT comprised the inspection of all on-site work performed to verify that all work had been constructed in reasonable conformance with the Released-for-Construction plans, specifications, and approved shop drawings. OIT is on-site material sampling and testing.

Owner Independent Assurance (OIA): OIA comprised split sampling and testing performed by the Agency's Region Laboratory. These tests and observations of the sampling and testing procedures were to be performed to confirm that all testers were qualified and certified and that the test methods and procedures are performed accurately.

Summary QA Project Approach

For this project the Agency retains the traditional QA roles. The Agency was responsible for the project quality assurance, while the Design-Builder was responsible for design QA, design QC, construction QA and construction QC.

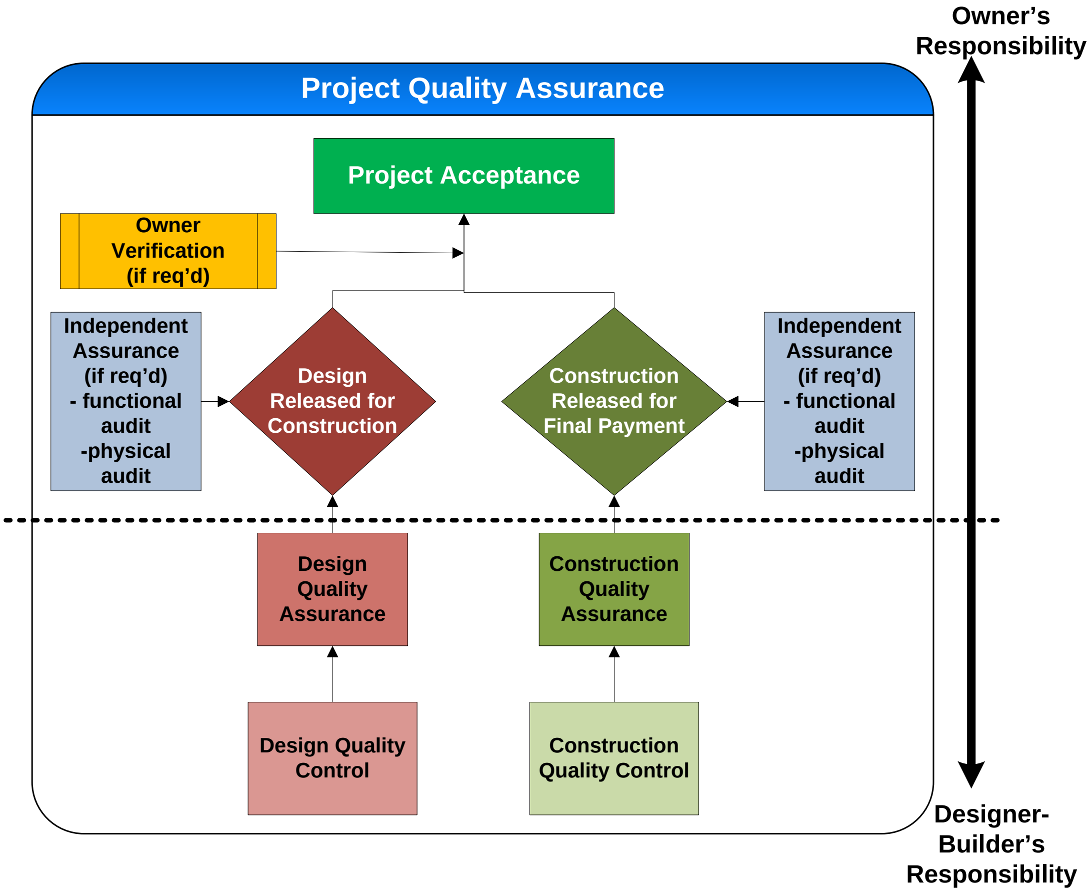


Figure J1: I-15 Widening QAO Model.

Example of Alternate QM System Used on This Project

One-on-one interviews with proposers during the procurement phase and discussions between UDOT and the Design-Builder during the pre-construction phase were successful for the I-15 Widening Project. This communication was valuable to the project because the budget was very tight on this project. Therefore, it was important for the Agency to be able to sit down with the Design-Builder early on in the project and review ways to reduce cost. In addition, the project involved a particularly complex bridge which needed to be discussed individually. Components such as this were further addressed in the specifications for the Quality Management Plan (QMP). The QMP had to specify those elements of the Contract Documents, Design Documents, and Construction Documents that require special attention to or emphasis on quality, including applicable standards of quality or practice to be met, level of completeness, and/or level of detail required. It also had to specify the process for any necessary Design Exceptions for the project. This process should include the packaging and submittal to UDOT for review.

Observations of the Researcher

UDOT ensured the quality of the I-15 Widening Project by enabling frequent communication and specifying complete documentation processes from procurement through to project completion. Documentation seemed to be emphasized throughout the Project documentation. This is not only important for the quality of the I-15 Widening Project, but it provides a reference for future projects.

Effective QM Practices

The following Quality Management practices were used on the I-15 Widening Project and achieved enhanced quality through increased communication and documentation.

- One-on-One Meetings:

  The Agency conducted one-on-one meetings with each Proposer to discuss issues and clarifications regarding the RFP and Proposer's ATCs. The Agency reserved the right to disclose to all Proposers any issues raised during the one-on-one meetings, except to the extent that the Agency determines, in its sole discretion, that such disclosure would impair the confidentiality of an ATC or would reveal a Proposer's confidential business strategies. Participation at such meetings by the Proposers was mandatory. If any one-on-one informational meeting was held, the Agency reserved the right to disclose to all Proposers any issues raised during the one-on-one meetings. However, the Agency was not to disclose any information pertaining to an individual Proposer's Proposal, ATCs, or other technical concepts to other Proposers.

- Alternative Technical Concept (ATCs) Process:

  A process for pre-Proposal review of Alternative Technical Concepts (ATCs) that conflict with the requirements for design and construction of the Project, or otherwise require a modification of the technical requirements of the Project, was set forth to:

  - Allow Proposers to incorporate innovation and creativity into the Proposals
  - Allow the Department to consider Proposer ATCs in making the selection decision
  - Avoid delays and potential conflicts in the design associated with the deferring of reviews of ATCs to the post-award period
  - Obtain the best value for the public

  The Agency was able to respond with one of the following statements:

  - The ATC is acceptable for inclusion in the Proposal;
  - The ATC is not acceptable for inclusion in the Proposal;
  - The ATC is not acceptable in its present form, but may be acceptable upon the satisfaction, in the Agency's sole discretion, of certain identified conditions which must be met or clarifications or modifications that must be made; or
  - The submittal does not qualify as an ATC but may be included in Proposer's Proposal because it appears to be within the requirements of the RFP.

- Competitive Range:

  The term "Competitive Range" means a list of the most highly rated Proposals, based on initial Technical Proposal ratings and evaluations of Price Proposals, which were judged by the Agency to have a reasonable chance of being selected for award. Borderline

Proposals were not to be excluded from further consideration if the Proposers had a reasonable chance of being selected if meaningful discussions were conducted and appropriate improvement was achieved.

The Agency could meet with and receive presentations and conduct interviews with Proposers prior to determining the Competitive Range. This allowed Proposers to provide clarifications to their Proposals or otherwise to address issues that might prevent the Proposal from being placed in the Competitive Range.

The Agency reserved the right to hold discussions and to issue a request for Proposal Revisions (otherwise known as Best and Final Offers [BAFOs]), but was under no obligation to do so. If discussions were held, they were to be held with all Proposers in the Competitive Range and were intended to allow Proposers to revise their proposals.

If the Agency requested BAFOs, Proposers in the Competitive Range could be informed of and requested and/or allowed to revise their Proposals, including correction of any Weaknesses, minor irregularities, errors, and/or Deficiencies identified to the Proposers by the Agency following initial evaluation of the Proposals. Upon receipt of the Proposal Revisions, the process of evaluation was to be repeated. The process was to consider the revised information and re-evaluate and revise ratings, as appropriate.

- <u>Summary of Innovation and Enhanced Quality:</u>

The Proposers were to prepare a summary of no more than three pages that outlined the specific areas in which the Proposer had introduced innovation and provided enhanced quality in long-term performance, durability, or maintainability through the information submitted with its Proposal. The Proposer had to state in the summary the specific sections of the Technical Proposal in which the proposed innovations and enhancements were discussed.

- <u>Document Control:</u>

The QMP had to specify procedures for meeting documentation requirements and document control for the filing of design criteria, reports and notes, calculations, plans, specifications, schematics, supporting materials, etc. and for the specific responsibilities of personnel to satisfy these requirements. The Design-Builder had to maintain these documents for the duration of the Contract; organize, index, and deliver them to UDOT for Final Acceptance. Also, the Design-Builder had to maintain a record of internal quality activities and summarize internal quality activities in monthly progress reports.

The QMP had to identify (by name) the Document Control Supervisory personnel for the maintenance and management of records and documents pertinent to Agency activities. The Agency required electronic documentation of the Project and strongly encouraged the use of video documentation where appropriate.

Furthermore, the Design-Builder had to maintain daily manpower and equipment reports for construction-related activities as well as for each Subcontractor. They also had to maintain a Daily Occurrence Log of construction activities in narrative form and document all significant occurrences on the Project, including:

  - Unusual weather

- Asserted Force Majeure events
- Events and conditions causing or threatening to cause any significant delay, disruption, or interference with progress of Work
- A general overview of the current Project activities, including MOT
- Significant injuries to a person or property
- A listing of all activities on the current Monthly Plan Update that are being actively prosecuted
- A daily record (in a standard format) of all labor, materials, and equipment expenses incurred for each activity

The Design-Builder had to document all quality, inspection, and test activities, including any delays encountered, work that did not conform to the requirements of the Contract and design, and the corrective actions taken regarding such nonconforming work.

In addition, the DQM was to maintain a written record of all design reviews and oversight visits. The written record was to:

- List the participants in each review or visit
- Report all items discussed
- Identify discrepancies noted and report on corrective action(s) taken or planned
- Identify follow-up action items, due dates, and the responsible party
- Identify items needing resolution and time constraints for resolution

- <u>Over-the-Shoulder Design Reviews:</u>

  The DQM was to conduct design reviews, and UDOT could participate in these reviews and comment as requested or as it otherwise deems necessary. The DQM, design staff, and UDOT jointly determined the materials to be compiled for each review. If mutually agreed upon for specific review items, these over-the-shoulder reviews may be facilitated by the transfer of electronic files.

- <u>Milestone (30% and 60%) Reviews:</u>

  The DQM was to conduct formal milestone reviews at the 30% (Concept) and 60% (Intermediate) stage of Project elements to determine whether the Contract requirements and design criteria were being followed and that QC/QA activities were following the approved QMP. The DQM and UDOT may have agreed that 30% and 60% reviews may be waved for certain elements.

- <u>Incentive/Disincentive:</u>

  An incentive program was established to provide the Design-Builder the opportunity to earn an incentive award (“Incentive Award”) for superior performance in certain components of the Project. The program was designed to encourage and reward consistent excellent achievement of the technical specifications, workmanship, and the administrative program requirements. The Incentive Award could be earned only by clear and constant superior performance over the term of the Contract. It was the Agency's desire that the Design-Builder perform in such a superior manner so as to ultimately earn the maximum possible Incentive Award.

The maximum pool of the Incentive Award under the

Contract was One Million, Two Hundred Thousand dollars ($1,200,000). This amount was not to be increased if work was added to the Project, but could be reduced if Work was deleted.

Incentive criteria were established to measure the actual achievements of the Design-Builder. The various incentive criteria were predefined for each Incentive Period and weighted appropriately to encourage Design-Builder achievements in the Project elements that were the most critical to the Agency.

A Performance Evaluation Team was to prepare Evaluation Reports for all performance areas and evaluate the Design-Builder's performance using the identified criteria. Performance and activities was continuously observed and evaluated.

Material and Ride Quality Incentives were also included and followed the Agency's 2008 Standard Specifications for Road and Bridge Construction.

APPENDIX K: HASTINGS RIVER BRIDGE

Project Information

Project Name: TH61 Hastings Bridge Design-Build Project

Name of Agency: Minnesota Department of Transportation (MnDOT)

Location: T.H. 61 over the Mississippi River along the border of Washington and Dakota County, Minnesota within and near the City of Hastings.

Project Delivery Method (*DBB, DB, CMR, PPP, etc*.): DB

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best Value

Contract Payment Provisions (*Lump Sum, GMP, Cost +*): Lump Sum, subject only to certain specified limited exceptions.

Project Description

The Project scope is to design and construct a new four-lane bridge over the Mississippi River, remove the existing 2-lane bridge, and construct the approaches on the north and south sides of the new bridge.

The Case Study project includes:

A free-standing arch main span segment with low maintenance, robust and highly redundant concrete tie girders and knuckles.

A south approach segment protected with a secondary wearing course. The south approach segment includes two side-by- side bridges that are five-span, solid cast-in- place post-tensioned concrete slabs with an arched soffit over Second Street and a constant 5-ft.-deep cross section for the remainder of the spans.

The north approach segment is a low-maintenance five-span precast concrete girder bridge.

A north approach roadway constructed on a column-supported embankment, with a *performance criterion of less than 2 inches of total settlement complete within three months of embankment construction.* The subgrade geotechnical conditions of this approach are extremely high risk. The old bridge was jacked up a number of times in its life due to differential settlement.

A main span is a 545-ft. tied arch with free-standing, trapezoidal vertical steel arch ribs and post-tensioned concrete knuckles and tie girders. It is erected using a low float-in operation to maximize public safety.

The addition of an independent quality firm during steel fabrication with computed radiography.

Testing capabilities.

Project Quality Profile

<u>Contractor (design-builder) responsibility for all QA and QC – MnDOT audit of QM activities:</u> The overall quality approach required the Contractor to develop, implement, and maintain a quality management system that encompassed the design and construction

quality aspects, as well as documentation requirements for the Project. MnDOT audited the Contractor's quality management system to determine whether quality activities were being carried out and were implemented effectively. The Contractor was to perform Quality Control and Quality Assurance activities for the design of the Project in accordance with the Quality Manual. MnDOT's oversight role was to entail design audits on the products of the design. The Contractor was to perform construction quality testing and inspection activities. MnDOT then performed construction quality acceptance testing and inspection for verification that the Work met Contract requirements. The Contractor was to document quality activities and maintain quality data in accordance with the policies and procedures defined in the Quality Manual.

<u>Negotiated Design Quality Criteria via Confidential Preapproval of Alternative Technical Concepts (ATCs):</u> ATCs were used to permit the design-builder to literally negotiate the design quality criteria and the process for submitting and evaluating them was set forth in the Instructions to Proposers (ITP). No changes to the Contract requirements were permitted in the proposal except through the ATC process. ATCs were defined as being "alternative concepts to the Basic Configuration that are equal or better in quality or effect as determined by MnDOT in its sole discretion and which have successfully been used elsewhere under comparable circumstances", and "a concept is not an ATC if it merely seeks to reduce quantities, performance, or reliability, or seeks a relaxation of the Contract requirements". Proposers were able to submit ATCs to MnDOT prior to the proposal due date for MnDOT's comments. MnDOT's comments were limited to one of the following:

- The ATC is acceptable.
- The ATC is unacceptable.
- The ATC is unacceptable in its present form, but may be acceptable upon the satisfaction, in.
- MnDOT's sole judgment, of certain identified conditions that must be met or clarifications or modifications that must be made.
- The submittal does not qualify as an ATC, but may be included in the proposal (that is, the concept complies with the baseline RFP requirements).
- The submittal does not qualify as an ATC and may not be included in the proposal.

MnDOT then conducted one-on-one meetings with proposers to discuss ATCs and the Proposers were able to incorporate one or more acceptable ATCs in to their proposal. These approved ATCs were known as Pre-Approved Elements (PAEs). MnDOT was careful not to coach the Proposers through the PAE process and provided evaluations rather than scores for each ATC. Furthermore, MnDOT ensured that the people that evaluated the PAEs were not the same people that evaluated the proposals.

Owner's reasons for using alternate QM system

Implementing a PAE process allowed the Owner to get a "sneak-peek" at the contractor's bid before submittal. The confidentiality of the process provided each competitor with the ability to retain advantages that it developed. The major area where innovation was desired was the foundation of the north approach. The column-supported fill that was proposed came through the ATC/PAE process. It is also interesting to note that this project had a not-to-exceed value of $220 million and it was awarded at a $100 million below that amount. Much of the savings are ascribed by the design-builder to the impact on cost and schedule risk of the ATC/PAE process. MnDOT believes that PAEs are valuable for high risk bridges such as the Hastings River Bridge.

Project Financial and Schedule Information

Original Total Awarded Value of project: $119,830,890

Final Total Awarded Value of project: On-going

Project Schedule: 4 years

Project Approved to start process: 2008

Initial Advertising: August 31, 2009

RFP Issued to Shortlist: 13 Jan 2010

Contract Award: July 1, 2010

Original Project Delivery Period: Roadway open Oct 1st 2013, Final Cleanup Jun 2014, 4 years.

Final Project Delivery Period: Achieving the Intermediate Completion Deadline and opening TH 61 in its final configuration by May 31, 2013.

Substantial Completion Deadline: Contractor shall achieve Substantial Completion by June 1, 2014.

Intermediate Completion Deadlines: The Contractor shall complete all Work required to open all roadways, sidewalks, trails in their final configuration by October 1, 2013.

Final Acceptance Deadline: Contractor shall achieve Final Acceptance within two years (730 Calendar Days) following Substantial Completion.

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table K1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
CMGC	✔NA; ☐Pilot projects only; ☐General authorization	✔NA; ☐1-5; ☐5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ☐1-5; ☐5-10;✔ > 10
PPP	✔NA; ☐Pilot projects only; ☐General authorization	✔NA; ☐1-5; ☐5-10;☐ > 10
Other Best Value DBB	☐NA; ☐Pilot projects only; ✔General authorization	☐NA; ✔1-5; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

A design-build project delivery method was chosen for this project because the Interim Highway Commissioner directed the acceleration of the project.

Reasons for Selecting Project Delivery Method (most significant reason)

Design-build was chosen for this project to accelerate the project delivery period as schedule was most significant on this project.

Case Study Project Risk Analysis Process

Formal Risk Analysis Areas: Cost, schedule, geotechnical scope

Project Cost Estimate Uncertainty Analysis: NA

Risk Identification Techniques Used: Risk register

Risk Assessment Techniques: Risk register

Risk Management Techniques: ATC/PAE process

Risk Technique used to Draft Contract: To allow MnDOT to budget for the Project and reduce the risk of cost overruns, the Contract included restrictions affecting the Contractor's ability to make claims for an increase to the Contract Price or an extension of the Completion Deadlines. The Contractor had agreed in the Contract to assume such responsibilities and risks and had reflected the assumption of such responsibilities and risks in the Contract Price.

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table K2: Administrative Prequalification Requirement

Designer prequalification program factors	**Administrative**
Prequalification required for all projects	☐
Prequalification required for selected projects only	✔
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	✔
Construction prequalification program factors	**Administrative**
Prequalification required for all projects	✔
Prequalification required for selected projects only	☐
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	✔

Table K3: Required Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	✔	✔	☐
Qualifications of the Construction Quality Manager	✔	✔	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	✔	✔	☐
Design quality management plan	☐	☐	✔
Design quality assurance plan	☐	☐	✔
Design quality control plan	☐	☐	✔
Construction quality management plan	☐	☐	✔
Construction quality assurance plan	☐	☐	✔
Construction quality control plan	☐	☐	✔
Quality management roles and responsibilities	✔	☐	☐
Design criteria checklists	☐	☐	☐
Construction testing matrix	✔	☐	☐
Quality-based incentive/disincentive features	✔	☐	☐
Warranties	✔	☐	☐
Optional warranties	☐	☐	☐

Lesson Learned: For future projects MnDOT would like to have a designated document control manager. This would work to eliminate the difficulty getting everyone notified of changes.

Design Phase Summary

Table K4: Design Quality Management Roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables	✔	✔		
Checking of design calculations		✔		
Checking of quantities		✔		
Acceptance of design deliverables	✔			
Review of specifications		✔		
Approval of final construction plans & other design documents	✔			
Approval of progress payments for design progress	✔			
Approval of post-award design QM/QA/QC plans	✔			

Construction Phase Summary

Table K5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings	✔	✔		
Technical review of construction material submittals	✔			
Checking of pay quantities				
Routine construction inspection	✔		✔	
Quality control testing			✔	
Verification testing	✔			
Acceptance testing	✔			
Approval of progress payments for construction progress	✔			
Approval of construction post-award QM/QA/QC plans	✔			
Report of nonconforming work or punchlist.	✔		✔	

Quality Management Planning

QA/QC Plans

The quality management process used on this project was a formal one that was project specific.

The Contractor's quality management system had to contain a Quality Manual (QM) that encompassed all Contract requirements with regard to design, construction, and documentation for all quality processes.

<u>Design Quality Management Plan:</u>

At a minimum, the Design Quality Management section included:

Define sound Design Quality Control and Quality Assurance review processes

Describe how all design criteria, Contract requirements, and other design inputs are defined, reviewed, and approved

Describe the design and verification activities separately.

Describe how the design team schedules the design efforts, including design reviews, verification and checking stages, and issue dates of design deliverables.

Include details as to the level of involvement of MnDOT, local, and regulatory agencies in the design development and design review process. The Contractor is encouraged to involve MnDOT in all design development processes, including Independent Technical Reviews, and Constructability Reviews.

Describe how the security of documents will be controlled during the Project.

Describe the coordination of the design with construction

Describe how the Contractor will maintain an accessible, centrally controlled manual, database, or list that contains all relevant design inputs or references to design inputs to be used by design personnel to incorporate into the design.

Define the design outputs (i.e., the specific plans and specifications) to be produced.

Include quality measures and encourages continuous improvement of the design deliverable products

Describe how changes to design are identified, reviewed, and approved by authorized personnel prior to their implementation.

Describe the method of communicating changes or revisions made in the field.

The following design reviews were specified by the Contractor:

Discipline Coordination Reviews (DCR): These reviews assure that all aspects of the design are considered as the design progresses.

Independent Technical Reviews (ITR): This review provides the technical expertise of senior staff to the design. Reviewers are not involved directly in the project design; their reviews focus on assuring that the design meets all project requirements, utilizes the best technology and methodology available, and includes client-specific preferences.

Constructability Reviews (CR): These reviews assure that construction-related expertise is incorporated into the design. The construction engineers and project manager or designee will complete these reviews, adding practical construction considerations to the design.

Construction Quality Management Plan:

The Quality Manual also had to include a Construction Quality Management section that accomplished the following:

Provides quality measures and encourages continuous improvement of the construction phase

Educates all construction staff of their role in the quality management system and ensures they understand their role is to build the Work in accordance with the Released for Construction Documents and the Project requirements

Ensures all construction quality staff understand their role is to determine whether the Work meets the Project requirements

Integrates all Subcontractors and Suppliers in the construction quality management system

Involves MnDOT throughout the entire construction process

The Quality Manual also included an Inspection and Testing Plan describing all of the proposed inspections and tests to be performed throughout the construction process. MnDOT had provided a Construction Quality Inspection and Testing Plan in the Quality Manual Template. The Contractor was to tailor the Inspection and Testing Plan to meet the Project requirements.

The Design Quality Management Plan was required before Notice To Proceed (NTP) was granted. The Contractor wanted to get going on the project, so enough of a plan was given to get early approval and then revision was done to the plan later. An audit was also done to and mismatches were found when compared to the manual. The audit was necessary after Design QM plan approval, but it was not tied to payments.

In addition, the Contractor had to ensure that internal quality audits, for each element of the quality management system, were performed at least every six months. The Contractor specified that internal audits to be completed during the Project would include the following:

Audits of deliverables to the Owner or other stakeholders before they are delivered

Audits of the document control system

Periodic informal spot-audits of Owner comment forms, internal comment forms, RFIs, and Design Change paperwork to spot trends, problem areas, or inefficiencies

Audits of quality activities

Use of mandated agency quality management plans

A specific set of qualifications for the quality management staff of design consultants and construction contractors was mandated for this project. Standard agency specifications, design details and construction means and/or methods are sometimes used on MnDOT projects.

MnDOT required that the Quality Management System (QMS) to be comprised of the Contractor's quality policy, quality objectives, design and construction quality plans, quality procedures, work instructions, and records. The QMS had to:

Establish comprehensive quality management processes and procedures

Integrate the quality goals of both the design and construction elements of the Project

Define the minimum standards and procedures for quality management

Assign the responsibilities for specific quality management functions

The Contractor was to be responsible for all Work for the design and construction quality of the Project and for fully complying with the Project's scope of work and their Quality Manual.

Quality staff qualifications

The overall Quality Manager had to have a PE. However, MnDOT had difficulty finding someone with a good knowledge of the process. The Design Quality Manager (DQM) had to be different from the Designer-of-Record and was supposed to be a full-time person. The person did not end up being full-time as expected indicating that the role of the DQM was not clear.

In addition, the Contractor and its design Subcontractor(s) were required to maintain all required authority, license status, professional ability, skills and capacity to perform the Work.

General Quality Management Procedures

Standard of Care

No different from DBB projects.

Alternate Quality Management Systems

The Contractor specified that Quality Control was the responsibility of the design team, construction team, and Environmental Compliance Team. The Design QA staff performed audits to ensure that the design activities for the design of the Project conformed to the policies and procedures defined in the Quality Manual.

The construction quality staff was to perform quality inspection and testing to ensure that materials and the constructed Work meet Contract requirements. MnDOT performs construction quality acceptance testing and inspection for verification that the Work meets Contract requirements.

The Project Quality Assurance organization was to operate under the oversight of the Quality Manager, who had to report directly to the Executive Management Committee and also to MnDOT.

The Construction Quality Manager (CQM) had the overall responsibility for quality activities performed prior to and during construction. The CQM was to be responsible for:

supervising field testing and inspection personnel,

auditing suppliers' quality management systems and ensuring that production testing and inspection is being carried out and is providing quality results,

reviewing test records from previous production,

coordinating the flow of quality information from the supplier and subcontractors to the Project,

evaluating and analyzing quality data from all sources to determine trends and compliance with Project requirements, and to assess the effectiveness of the Project's construction quality activities,

assisting the Quality Manager in training workers in the Quality Management System

ensuring Critical Activity Point Managers perform at Critical Activity Points.

The Design Quality Assurance Manager (DQAM) was to assist the Quality Manager with the design-related training, audits, and implementation of the Quality Management System. The DQAM was to perform day-to-day assurance activities, including audits of deliverable packages and review of design inputs. For this Project, it was specified that the Quality Management System review team was to meet monthly. The group was to include:

Executive Management Committee

Quality Manager

Design Quality Assurance Manager

Construction Quality Manager

Summary QA Project Approach

MnDOT deliberately chose a hands-off approach to quality management in this project. The RFP contained a clause that encouraged over-the-shoulder review of design products and tasked the designer-of-record to be involved in the construction quality management process. The QAO for this project is an Oversight QAO and is shown in Figure K1.

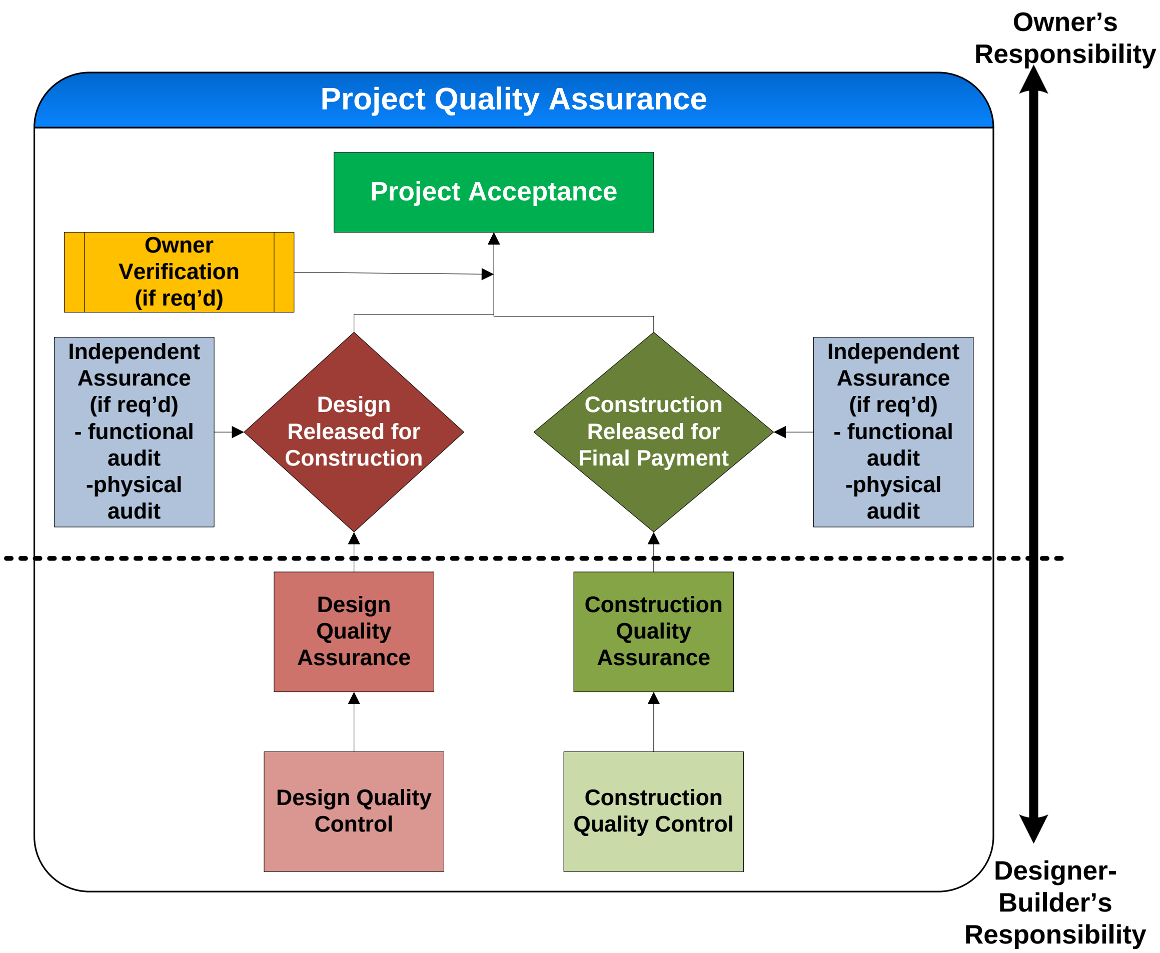


Figure K1: Hastings Bridge QAO.

Example of Alternate QM System used on this Project

Geotechnical issues were the major quality challenge in this project. DB project delivery did not allow MnDOT to complete a thorough subsurface investigation and therefore, it chose to transfer the risk to the design-builder. The pre-proposal submission interactivity via the ATC/PAE process was effective in both stimulating an innovative solution to the project's greatest quality problem and in ensuring the long term quality of the project. Their approach to managing the long-term settlement of the north approach segment involved the use of a column-supported embankment (CSE) constructed using driven steel pipe piles. The piles support the load of the new embankment materials and transfer the stress from this load to the dense soils below the clay and immediately overlying the bedrock. The design represents the best solution with respect to long-term settlements and the potential impact of settlements on the project schedule. The column-supported embankment allowed for a three year warranty for settlement. The design-builder also proposed to install an instrumentation package to permit MnDOT to monitor settlement for the life of the warranty and beyond. The use of the settlement performance criterion instigated this uncalled for feature, and the instrumentation package gave MnDOT personnel a much higher level of confidence in the ultimate performance of the column-supported fill, a technique with which MnDOT had no prior experience.

The following Alternative Technical Concepts (ATCs) were incorporated into the design and construction approach:

ATC 02 • Tied-Arch Alternative

ATC 08 • Structural Concrete

ATC 03 • Continuous Settlement Monitoring

ATC 09 • South Approach Structure Fixity

ATC 04 • Vessel Collision Loads

ATC 10 • Hanger Corrosion Protection System

ATC 06 • Bridge Geometrics

ATC 11 • PI Coordinator

Observations of the Researcher

The success of this project appeared to be due to the amount of communication allowed by the Owner before the proposals were submitted. Proposers were given the opportunity to discuss their ideas with the Owner and gain evaluation of these ideas. This was valuable because the Owner had an idea of what to expect from the proposals and the Contractors were not "guessing" what the Owner wanted. It also allowed design and construction quality criteria to be clarified and renegotiated if necessary.

Effective QM Practices

The following practices were implemented for the project and contributed to managing the quality of the project. These practices were thought to be effective largely because they increased the communication between project parties allowing for better collaboration.

ATC/PAE Process: Approved ATCs were known as Pre-Approved Elements (PAEs). MnDOT then conducted one-on-one meetings with proposers to discuss ATCs and the Proposers were able to incorporate one or more acceptable ATCs in to their proposal.

Disciplinary Task Forces: Each task force will focus on a specific discipline of work with the involvement of individuals in more than one task force to ensure proper and consistent cross discipline coordination. Each task force will meet weekly with the meetings documented by meeting minutes and time phased action items.

Over-the-shoulder design reviews: These were informal examinations by MnDOT of design documents during the project design process. They mainly assessed whether the requirements and design criteria of the Contract Documents were being followed and whether the contractor's design quality management plan activities were being undertaken in accordance with the approved Quality Manual.

In-Progress Design Workshops: Throughout the design process, the Contractor or MnDOT could request (with at least five Working Days' notice) in-progress design workshops to discuss and verify design progress and to assist the Contractor and/or its designer(s) in resolving design questions and issues.

Quality Oversight Visits: Throughout the design process, MnDOT could make oversight visits to discuss and verify design progress and ascertain the overall progress of the Project with respect to the Contractor's Quality Manual.

Disincentive: Subject to MnDOT's determination, MnDOT could assess the Contractor a $100-per-hour monetary deduction for failure to facilitate satisfactory progress or completion of the Work. Hourly charges were able to be applied during periods during which MnDOT determined the Contractor had not satisfactorily responded to a documented non-compliance. No charge was to be assessed if the deficiency was corrected by the Contractor within one hour of written notification from MnDOT.

APPENDIX L: I-595 EXPRESS CORRIDOR, FLORIDA

Project Information

Project Name: I-595 Express Corridor Improvements Project

Name of Agency: Florida Department of Transportation (FDOT)

Location: Broward County, Florida

Project Delivery Method (*DBB, DB, CMR, PPP, etc*.): PPP

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best Value

Contract Payment Provisions (*Lump Sum, GMP, Cost* +): Lump sum

Project Description

The I-595 Express Corridor Improvements Project consists of the reconstruction of the I-595 mainline and all associated improvements to frontage roads and ramps from the I-75/Sawgrass Expressway interchange to the I-595/I-95 interchange, for a total length along I-595 of approximately 10.5 miles, and approximately 2.5 miles on Florida Turnpike from Peters Road to Griffin Road. The design and construction cost of the project is approximately $1.2 billion. The major project components include:

- Three ground level reversible express toll lanes, serving express traffic to/from the I-75/ Sawgrass Expressway from/to east of S.R. 7, with a direct connection to the median of Florida Turnpike. These lanes will be operated as managed lanes with variable tolls to optimize traffic flow, and will reverse direction during peak travel times (eastbound in the a.m. /westbound in the p.m.).
- Continuous connection of S.R. 84 frontage road between Davie Road and S.R. 7.
- The addition of auxiliary lanes on I-595 along with combined ramps, cross-road bypasses, and grade-separated entrance and exit ramps to minimize merge, diverge and weaving movements.
- Widening / reconstruction of 2.5 miles of the Florida Turnpike mainline and improvements to theI-595/Florida Turnpike interchange.
- Construction of the New River Greenway, a component of the Broward County Greenway System.
- 13 sound barriers providing noise abatement for 20 communities.
- Implementation of an Express Bus Service within the corridor.

Project Quality Profile

What makes the QMS on this project different from a traditional project?

Because the project is PPP, and the concessionaire will also be operating the project for 30 years, the concessionaire held the majority of the responsibility of the quality responsibilities, which equates to the acceptance QAO, as shown in Figure L1. FDOT did hire several engineering consultants such as the design manager and the Oversight Construction Engineer Inspector

(OCEI). Overall, the design manager's responsibility was to make sure that the produced design met the requirements of the contract. FDOT and the design manager did have more involvement in the design when it came to elements of the project that were related to safety or long term assets. The OCEI was responsible for conducting statistical sampling verification testing regarding the Concessionaire's Construction Engineering Inspection.

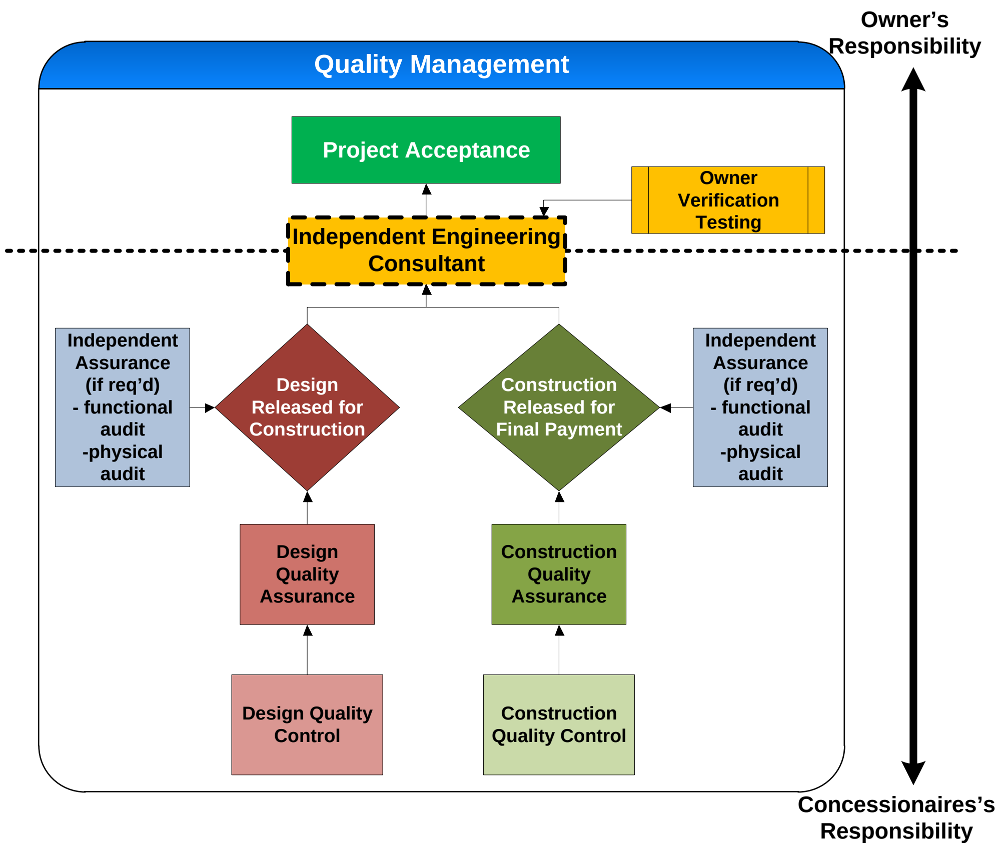


Figure L1: I-595 Express Corridor Improvements Project – Acceptance Quality Management Organization

Owner's reasons for using alternate QM system

Because of the project delivery method, the QM had to be changed. The concessionaire is responsible for operating and maintaining the project for 30 years, thus the much of the risk has been shifted to the concessionaire, including quality management.

Project Financial and Schedule Information

Original Total Awarded Value of project: $1.2 billion design and construction, $1.6 Billion includes operation and maintenance

Final Total Awarded Value of project: Same as above

Project Schedule:

Initial Advertising: October 1, 2007

RFP Issued to Shortlist: April 18, 2008

Contract Award: March 3, 2009

Original Project Delivery Period: substantial completion March 26, 2014

Final Project Delivery Period: June 23, 2014

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table L1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☐5-10; ☒ > 10
CMGC	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10
DB	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☐1-5; ☒5-10; ☐ > 10
PPP	☐NA; ☐Pilot projects only; ☒General authorization	☐NA; ☒1-5; ☐5-10; ☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10; ☐ > 10

Reasons for Selecting Project Delivery Method (most significant reason)

Florida requires all projects to "pay as you go" or have all the money required to complete a project in the bank before a project can begin. For the I-595 project there was a 50% funding shortfall. This funding shortfall was going to require the total project to be split into 15 different projects and be completed piecemeal based on the amount of available funding. FDOT decided to use PPP because it resolved the funding shortfall resulting in the ability to complete the project as one project and 15 years ahead of the traditional method.

Case Study Project Procurement Process Summary

Procurement Phase Summary

The agency used a two-step process to procure the concessionaire team. First was a request for qualifications (RFP) that resulted in a shortlist of four teams. These four teams then responded to the request for proposals (RFP). The final contract was awarded based on a best value approach that scored the proposals based on bid price availability payment and the technical elements of the proposal. Quality management programs were a required element of the proposal submittal and were evaluated as part of the procurement process. The proposal also clearly stated that the concessionaire was responsible for all quality management staff on the project. The fact that the concessionaire is responsible for operation and maintenance on the project under the lump sum proposals essentially created quality incentive/disincentive elements. There were some disincentives also included in the proposal based on if the project didn't meet the specifications/requirements of the contract.

Table L2: Administrative and Performance Based Prequalification Requirements

Designer prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☒	☐
Prequalification required for selected projects only	☐	☒
Prequalification standards are the same for all projects	☒	☐
Prequalification standards are different by project class	☐	☒
Construction prequalification program factors	**Prequalification Type**	
	Administrative	**Performance Based**
Prequalification required for all projects	☒	☐
Prequalification required for selected projects only	☐	☒
Prequalification standards are the same for all projects	☒	☐
Prequalification standards are different by project class	☐	☒

For this case study independent questionnaires were received from the design builder (D), the concessionaire (C), the agency (A) and the engineer (E). Not all four responded the same way to the questionnaire, thus each of these tables shows how each party responded.

Table L3: Required Bidding Documents

Did your project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.) contain the following?	**Required proposal/ bid package submittal?**	**If required, is it evaluated to make the award decision?**	**If not required, is it a required submittal after contract award?**
	Yes	Yes	Yes
Qualifications of the Design Quality Manager	☒	☒	☐
Qualifications of the Construction Quality Manager	☒	☒	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	☐	☐	☒
Design quality management plan	☒	☒	☐
Design quality assurance plan	☐	☐	☒
Design quality control plan	☐	☐	☒
Construction quality management plan	☒	☒	☐
Construction quality assurance plan	☐	☐	☒
Construction quality control plan	☐	☐	☒
Quality management roles and responsibilities	☒	☒	☐
Design criteria checklists	☒	☒	☐
Construction testing matrix	☐	☐	☒
Quality-based incentive/disincentive features	☐	☐	☒
Warranties	☒	☐	☐
Optional warranties	☒	☐	☐

Design Phase Summary

For this case study independent questionnaires were received from the design builder (D), the concessionaire (C), the agency (A) and the engineer (E). Not all four responded the same way to the questionnaire, thus each of these tables shows how each party responded.

Table L4: Design Quality Management Roles

	Responsible Party (select all that apply)					
Responsibility allocation for design management tasks	**Agency Design Staff**	**Agency PM Staff**	**Design Consultant Staff**	**Constructor's Pre-const. Staff**	**Agency-hired QA/oversight Consultant**	**Other, specify below**
Technical review of design deliverables	☐	☐	☒	☐	☐	☒1
Checking of design calculations	☐	☐	☐	☐	☒	☒2
Checking of quantities	☐	☐	☐	☐	☐	☒2
Acceptance of design deliverables	☐	☒	☐	☐	☐	☐
Review of specifications	☐	☒	☒	☐	☒	☒2
Approval of final construction plans & other design documents	☐	☒	☐	☐	☐	☐
Approval of progress payments for design progress	☐	☐	☐	☐	☐	☒2
Approval of post-award design QM/QA/QC plans	☐	☒	☐	☐	☐	☒2
Other: 1 – Is FDOT design construction; 2 – Is the Concessionaire						

Construction Phase Summary

For this case study independent questionnaires were received from the design builder (D), the concessionaire (C), the agency (A) and the engineer (E). Not all four responded the same way to the questionnaire, thus each of these tables shows how each party responded.

Table L5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	Agency Design Staff	Agency PM Staff	Design Consultant Staff	Constructor's Construction Staff	Agency-hired QA/oversight Consultant	Other, specify below
Technical review of construction shop drawings	☐	☐	☒	☒	☒	☐
Technical review of construction material submittals	☐	☐	☒	☒	☒	☐
Checking of pay quantities	☐	☐	☐	☐	☐	☒
Routine construction inspection	☐	☐	☐	☒	☐	☐
Quality control testing	☐	☐	☐	☒	☐	☐
Verification testing	☐	☐	☐	☐	☐	☒
Acceptance testing	☐	☐	☐	☐	☒	☐
Approval of progress payments for construction progress	☐	☐	☐	☐	☐	☒
Approval of construction post-award QM/QA/QC plans	☐	☐	☐	☐	☐	☒
Report of nonconforming work or punchlist.	☐	☐	☐	☒	☒	☐
Other: Concessionaire and Concessionaire CEI						

Quality Management Planning

QA/QC Plans

The concessionaire holds most of the risk associated with gaining a quality product, in that they are responsible for operation and maintenance of the corridor for 30 years after construction. To ensure that quality was a priority, as part of the contract FDOT required a QA and QC plans for both design and construction be submitted and approved before work began. The concessionaire created an overall QM plan, while the designer created the design QM, QA, and QC plans and the design builder created the construction QM, QA, and QC plans.

Use of mandated agency quality management plans

There were no requirements to use agency quality management plans. But the agency did mandate numerous non-traditional checklist and procedures such as; witness and hold; IRT (inspection and testing Request, Pre-activity meetings….) and direct auditing by OCEI and the Concessionaire were mandated.

Quality staff qualifications

The resumes of the Concessionaire's quality managers, showing their qualifications, were required to be submitted to FDOT. All others did not have to submit their resumes, but they had to meet the standard FDOT design and construction requirements; P.E. and CTCQP certification.

Contractor quality assurance test results

Yes, contractor test results were used for quality assurance. This is due to the fact that the concessionaire team was responsible for all quality assurance on the project, and thus they decided to use the contractors test results.

General Quality Management Procedures

Standard of Care

FDOT held the Concessionaire team to the same standard of care as of a traditional DBB project or a DB project.

Alternate Quality Management Systems

The agency was responsible for independent assurance and had an oversight construction engineering Inspector. The concessionaire team was responsible for all other elements of quality management.

Summary QA Project Approach

Overall on the project a PPP approach was used on the project. Because the concessionaire was responsible for the long term (30 year) operation and maintenance of the project they held the majority of the responsibility regarding quality. The agency did hire two separate consultants, one for design and one for construction. The primary responsibility of both was to audit the concessionaire team. If the QA approach is investigated from the perspective of the concessionaire it was more of a DB approach because the design builder had the primary responsibility for QA and QC even though there was a concessionaire CEI on the project.

Example of Alternate QM System Used on This Project

- The PPP project delivery method shifts the majority of the risk for quality onto the concessionaire team. This inherently requires a different QM system from that of DBB. Also FDOT decided to go with two oversight consultants, one hired by the agency – Owner Construction engineering Inspection (OCEI) and one hired by the concessionaire- Construction Engineering Inspection (CEI). The OCEI role is to give the agency reporting on the concessionaire adherence to the contract for completing the job. The OCEI is essentially auditing the CEI based on a statistical representation of the construction activities. There are no requirements as to a minimum score the OCEI results have to meet. The project currently has a 93% OCEI average score, which is higher than the agency expected.
- During the construction phase the design builder implemented a quality management system for all subcontractors to follow. Two major procedures of the quality system which affect all project work are the witness and hold procedure and the testing and sampling (TSR) procedure. Between these two processes all work and materials used to advance the project are recorded and regulated by multiple parties (contractor's QC staff, CCEI, OCEI) with regard to quality.
- The concessionaire performed training of more than 160 subcontractors on project quality management system, despite unfamiliarity of south Florida subcontractors with PPP and

overall ISO requirements (The ISO requirements were only used as reference materials for the this project).

- Higher level of Construction Engineering Inspection (CEI) oversight. The Concessionaire's CEI (CCEI) conducts all onsite and offsite verification inspection and testing. The Oversight CEI (OCEI) that was hired by FDOT performs audits on a regular basis.

Observations of the Researcher

This project is the first PPP or design-build finance operate maintain project that the state of Florida has undertaken. Since 2000 FDOT has been outsourcing more and more of what would have been considered a core competency for DOTs, essentially shifting the core competency for FDOT more towards project management rather than project design and construction inspections etc. Also FDOT has been using the DB project delivery method for ten years which has also broadened the experiences of FDOT when it comes to shifting FDOT's role to more project management. Because of these experiences it appears that FDOT was able to shift relatively smoothly to an understanding of their role in a PPP project, which is very hands off.

PPP was selected primarily because the project would be delivered 15 years earlier than through any other project delivery method. FDOT also saw that an advantage of PPP is that by the nature of the delivery method is that quality inherently is built into the project because the concessionaire is responsible for the operation and maintenance of the project for 30 years after the completion. There are a few provisions for the condition of the asphalt, structures, concrete, etc. for when the corridor is turned over to FDOT in 30 + years, but ultimately it is the concessionaire's best interest to complete a quality project to minimize operation and maintenance costs over the duration of the contract.

The selected concessionaire project team has experience internationally with PPP project and also several of the team members have ISO certifications in Europe. This concessionaires experience provided for a minimal learning curve with the overall quality responsibility. The bulk of the learning curve was learning the local subs and understanding what sorts of education and partnering were needed to ensure that the subs are producing the level of quality needed by the project.

Partnering was a large effort on this project because of the tight timeline for the entire project everyone had to find a way to work well together. At the highest level there were partnering exercises between FDOT and the concessionaire to make sure everyone understood the roles and expectations on the project. Similar partnering exercises also were necessary between the OCEI and the CEI because this was this first time this sort of arrangement was implemented on a project and both needed to gain a better understanding of how the two were to work together. Lastly there were partnering exercises held between the design builder and the subs to make sure that everyone was on the same page with the expectations of the project from a quality, budget and schedule standpoint. Even the training exercises regarding quality can be viewed as a partnering exercise. Currently there are no claims on the project, everyone is working well together, the project is on schedule, and the budget in still on track. Much of this success is due to the partnering efforts by all.

Effective Quality Management Practices

- OCEI and CEI practice. The Concessionaire is still responsible for the day to day CEI practice, while the OCEI is statistically auditing the results.
- Training of subs on quality management practices, expectations and creation of assurance/control plans for the project. This training focused on FDOT expectations and the concessionaires expectations. The ISO guidelines were also discussed and offered to the subs as reference materials.
- Witness and hold process.
- Custom developed database and communications software for the project. The entire concessionaire team indicated that it would be useful to implement the software on future projects.
- Long-term concessionaire agreement inherently builds quality into the project due to the long term nature of the contract
- Continuous internal process audit conducted by the Concessionaire team.
- All of the work on the project was not contracted out at one time by the design builder. Subs had to keep their quality up to high levels in order to have future opportunities on the project.

APPENDIX M: SH130 TURNPIKE EXTENSION, TEXAS

Project Information

Project Name: SH 130 Turnpike Project Exclusive Development Agreement

Name of Agency: Texas Department of Transportation (TxDOT) – Texas Turnpike Authority

Location: SH 130 through Travis and Williamson Counties, Texas

Project Delivery Method (*DBB, DB, CMR, PPP, etc*.): PPP

Procurement Procedure (*QBS, Best-Value, Low Bid*): Best-Value

Contract Payment Provisions (*Lump Sum, GMP, Cost* +): Guaranteed Lump Sum

SH130 was constructed using an Exclusive Development Agreement (EDA), which was a guaranteed lump sum, guaranteed completion-date contract obligating the Developer (contractor) to perform all work necessary to complete the Development Work.

Project Description

State Highway (SH) 130 is an approximately 49-mile new toll-way extending from IH-35 near SH 195, north of Georgetown, Texas Southward to US Highway 183 southeast of Austin. It is an eastern bypass for the City of Austin, Texas, located generally parallel to and east of IH-35, through the Texas counties of Travis and Williamson. SH 130 is a four-lane controlled-access toll-way with discontinuous frontage roads and directional interchanges where warranted, including interchanges at IH-35, SH 45 North, US 290, SH 71, and US 183.

The Case Study project includes:

Work for this project included the design, right-of-way acquisition, utility adjustment, construction, and fifteen years of capital maintenance (if elected by TxDOT). Preliminary estimates of quantities for this 49-mile project were as follows:

- 445 lane miles of pavement
- 35 million cubic yards of earthwork
- 2.7 million square yards of Portland cement concrete pavement
- 1.7 million tons of hot-mix asphalt concrete pavement
- 13 miles of pipes and box culverts
- 125 bridges of various sizes (5.2 million square feet)
- 4 mainline toll plazas
- 30 additional toll facilities on entrance and exit ramps

Project Quality Profile

The SH 130 project QC/QA program consisted of four inter-dependent components: the QC Program, the Owner Oversight Program, the Independent Assurance (IA) Program, and the independent Construction Quality Assurance (CQA) Program.

A project-specific quality assurance program (QAP) that addressed the Federal Highway Administration's (FHWA) requirements was developed for the SH130 project by TxDOT. The Program Manager worked with FHWA and TxDOT to develop the SH 130 QAP in compliance with Code of Federal Regulations (CFR) requirements. The QAP addressed the independent assurance and acceptance program requirements in the CFR with additional owner safeguards in the development agreement. In addition to the safeguards in the QAP, the EDA had several measures to ensure the quality of workmanship and materials incorporated into the project. The measures were broken into three basic categories which were quality control, acceptance testing and inspection, and owner verification.

The Owner representatives (FHWA, TxDOT, and its Program Manager) were responsible for compliance with the CFR and other applicable state and contractual requirements. The Owner Oversight program included Owner Verification testing (OVT), Owner Verification inspection (OVI), audits of Developer's records, and the authority to order a cessation or stoppage.

The Developer was responsible for submitting a Construction Quality Program for TxDOT's approval. The program outlined processes and procedures that the Developer and its Independent Construction Quality Firm would employ to ensure compliance with the construction specifications. All of the acceptance testing and inspection was performed by the Independent Construction Quality Firm (ICQF), who was selected and paid for by the Developer. Test results produced by the ICQF were statistically validated by the Program Manager's Materials Manager who managed the Owner Verification Testing (OVT) duties. The Program Manager also performed periodic audits of the ICQF's testing and inspection facilities, equipment, personnel, and records. In addition, the Construction Quality Control Manager (CQCM) and his quality control area staff may not be involved with any production activities and reports directly to the Developer's Management Team.

TxDOT reviewed and approved the Construction Quality Program prior to the start of construction. However, it was a living document which was updated periodically based on the circumstances encountered during construction. TxDOT was responsible for meeting the CFR and other state requirements including fulfilling Owner's oversight testing and inspection responsibilities.

FHWA performed federal oversight on the project. Given the size, scope, and national interest of the Central Texas Turnpike Project, FHWA conducted project level oversight rather than FHWA's traditional program level oversight. FHWA's Project Manager provided technical guidance during the development of, and was responsible for approving the project-specific QAP developed for SH 130. Throughout construction of the project, FHWA conducted independent reviews and inspections of ongoing construction operations, technician and laboratory certifications, and materials sampling and testing. On a quarterly basis the FHWA Project Manager reviewed the Materials Manager's quarterly statistical validation report and confirmed that material acceptance decisions on the project had been made in accordance with the approved QAP for the Project. At the end of the project, FHWA was to concur with the project Materials Certification, as required by the CFR.

The Construction Quality Assurance Manager (CQAM) had overall responsibility for the Construction Quality Assurance Firm (CQAF) operation with the Construction Quality Assurance Inspection Manager (CQAIM) and the Construction Quality Assurance Testing Manager (CQATM) assisting to form the CQAF Management Team. The CQAM reported to both TxDOT and the Developer project directors. The CQAIM provided oversight of the inspection operations, including the storm water pollution prevention plans (SW3P). Furthermore, the inspection organization was separated into three regional areas corresponding to the functional organization of the Developer. Each area was managed by a Construction Quality Assurance Area Manager (CQAAM) assisted by a graduate engineer with at least one senior inspector and a number of other inspectors relative to the amount of construction activities.

Material testing operations were managed by the CQATM. Laboratory Engineers and the

Laboratory Supervisor assisted the CQATM in on-site testing operations, such as laboratory accreditation, testing personnel training and certifications, material quality and trend statistical analyses, forensic investigations and pavement design assumption verifications. Technicians operated within the laboratory and were available for dispatch to areas along the development corridor to perform field and supplier sampling and testing, as well as plant inspections.

Project Financial and Schedule Information

Original Total Awarded Value of project: $1.1 billion

Final Total Awarded Value of project: $1.5 Billion

Project Schedule:

Project Approved to start process: June 2000

Project Office Established: April 2001

Contract Award: June 19 2002

Original Project Delivery Period: 50 months

Final Project Delivery Period: April 30 2008

The EDA was executed on June 19, 2002 and the first Notice to Proceed was issued on July 8, 2002. The project was divided into four segments. The first 12 miles of toll roads in Segment 2 were opened to traffic on November 1, 2006 and the approximately 11-mile-long Segment 1 was expected to be substantially completed by November 30, 2006, 37 months after ground breaking in October 2003. The remaining 23 miles were scheduled to open to traffic by November 2007.

Project Delivery Method Decision Rationale

Agency Project Delivery Experience

Table M1: Agency Project Delivery Method Experience

Project Delivery Method	Legislative/Legal Authority	Number of years of experience with PDM
DBB	☐NA; ☐Pilot projects only; ✓General authorization	☐NA; ☐1-5; ☐5-10;✓ > 10
CMGC	☐NA; ☐Pilot projects only; ✓General authorization	☐NA; ✓1-5; ☐5-10;☐ > 10
DB	☐NA; ☐Pilot projects only; ✓General authorization	☐NA; ☐1-5; ✓5-10;☐ > 10
PPP	☐NA; ☐Pilot projects only; ✓General authorization	☐NA; ☐1-5; ✓5-10;☐ > 10
Other	☐NA; ☐Pilot projects only; ☐General authorization	☐NA; ☐1-5; ☐5-10;☐ > 10

Agency Project Delivery Decision-making Process

State highway agencies have been facing growing pressures for accelerated delivery of highway infrastructure and the constraints of funding and staff resources. Therefore, alternative project delivery methods such as design-build and concession have been utilized more frequently.

Reasons for Selecting Project Delivery Method (most significant reason)

The major reason for selecting the delivery method was the need for a fast-track project delivery.

Case Study Project Risk Analysis Process

Risk Technique used to Draft Contract: A Risk Allocation table was developed during the industry review process. Furthermore, during preparation for the Request for Detailed Proposals (RFDP) draft as much information as possible was collected in order to reduce the risk. Preparation included the following elements:

Developing schematic design and other preliminary engineering

Defining details for evaluating proposals

Preparing RFDP documentation

Case Study Project Procurement Process Summary

Procurement Phase Summary

Table M2: Administrative Project Delivery Method Experience

Designer prequalification program factors	**Administrative**
Prequalification required for all projects	✓
Prequalification required for selected projects only	☐
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	☐
Construction prequalification program factors	**Administrative**
Prequalification required for all projects	✓
Prequalification required for selected projects only	☐
Prequalification standards are the same for all projects	☐
Prequalification standards are different by project class	☐

Table M3: Require Bidding Documents

Requirements of the project advertising/solicitation documents (i.e. IFB, RFQ, RFP, etc.)	Required proposal/ bid package submittal	Evaluated to make the award decision	Required submittal after contract award
Qualifications of the Design Quality Manager	✓	✓	☐
Qualifications of the Construction Quality Manager	✓	✓	☐
Qualifications of other Quality Management Personnel (design reviewers, construction inspectors, technicians, etc.)	✓	✓	☐
Design quality management plan	✓	✓	☐
Design quality assurance plan	☐	☐	✓
Design quality control plan	☐	☐	✓
Construction quality management plan	☐	☐	✓
Construction quality assurance plan	☐	☐	✓
Construction quality control plan	☐	☐	✓
Quality management roles and responsibilities	✓	✓	☐
Design criteria checklists	✓	☐	☐
Construction testing matrix	☐	☐	✓
Quality-based incentive/disincentive features	☐	☐	✓
Warranties	✓	✓	☐
Optional warranties	✓	✓	☐

Design Phase Summary

Table M4: Design Quality Management Roles

Responsibility allocation for design management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's preconstruction staff**	**Agency-hired QA/oversight consultant**
Technical review of design deliverables		✓		✓
Checking of design calculations		✓		✓
Checking of quantities		✓		✓
Acceptance of design deliverables	✓			✓
Review of specifications		✓		
Approval of final construction plans & other design documents	✓			✓
Approval of progress payments for design progress		✓		
Approval of post-award design QM/QA/QC plans	✓			

Construction Phase Summary

Table M5: Construction Quality Management Roles

Responsibility allocation for construction management tasks	**Agency personnel**	**Consultant design staff**	**Constructor's construction staff**	**Agency-hired QA/oversight consultant**
Technical review of construction shop drawings		✓		
Technical review of construction material submittals			✓	
Checking of pay quantities			✓	
Routine construction inspection			✓	✓
Quality control testing				✓
Verification testing			✓	✓
Acceptance testing			✓	
Approval of progress payments for construction progress	✓			
Approval of construction post-award QM/QA/QC plans	✓			✓
Report of nonconforming work or punchlist.				✓

Quality Management Planning

QA/QC Plans

The SH 130 was the first design-build highway infrastructure project in Texas where contractor QC testing was used in the acceptance decision for all project-produced materials. A project specific quality assurance program that addresses the Federal Highway Administration's requirements was developed for the project.

An enhancement to the previous owner verification process was the new three-tiered approach. In this approach Level 1 is applied to the tests which are strong indicators of performance and provides the highest level of confidence in the contractor's QC testing through the running of continuous F- and t- tests. Level 2 is applied to tests that are secondary indicators of performance through running quarterly independent verification on the contractor's QC test results. Level 3 is applied to tests with extremely low test frequencies where independent verification cannot be meaningfully performed or tests on materials whose risk of failure does not affect the long-term performance of the facility past the contractual maintenance obligations.

While the previous DB quality assurance programs served TxDOT well, this new approach was an enhancement that focused verification efforts on tests that were better indicators of material performance.

Use of mandated agency quality management plans

The Quality Control/Quality Assurance Program (QC/QAP) for the SH 130 project was developed with the TxDOT Construction Contract Administration Handbook in mind. Slight deviations from TxDOT practices were embedded into the QC/QAP to accommodate certain EDA requirements. For instance, payment to the Developer was based on percentage complete with scheduled activity items versus aggregation of detailed measurements and calculations for estimates of completion with the traditional TxDOT project and, therefore, the CQAF developed methodologies for tracking the percentage complete with work activities for the purpose of certifying the Developer's draw requests.

In addition to the traditional TxDOT prescriptive specifications, the project adopted several performance-related specifications. For example, the acceptance of the completed embankment and subgrade were subject to pavement design verifications for subgrade resilient modulus and the depths of non-swelling materials (NSMs). Also, bonus and penalty pay adjustments for pavement smoothness were determined by the CQAF based on the measured International Roughness Indices (IRIs). Furthermore, the Developer was obligated to maintain the completed facility to meet the performance criteria over the capital maintenance period. Performance-related specifications and responsibilities of capital maintenance drove the Developer and the CQAF to implement a rigorous CQA program.

Quality staff qualifications

The Independent Construction Quality Manager had to be a registered Professional Engineer in the State of Texas and was required to be employed by the ICQF.

The CQAF testing personnel were required to pass a certification examination for each test method prior to performing such tests on the project. To maintain their qualification for certain test methods specified by the TxDOT IA program, qualified CQAF technicians and inspectors were required to participate in the annual proficiency sample testing program. The CQAF laboratory also participated in CCRL (Cement and Concrete Reference Laboratory) and AMRL (AASHTO Materials Reference Laboratory) laboratory inspection and proficiency sample programs.

Furthermore, the CQAAMs implemented inspector training programs providing instructions on the procedures contained within the QC/QAP, specific inspection techniques, and testing procedures to provide continuing education for the CQAF inspection personnel. Offsite formal training needs were identified for each inspector and arrangements pursued to attain the training.

The Independent Assurance (IA) Program used the system approach for qualifying personnel and equipment qualification. The IA firm evaluated personnel and equipment based on TxDOT's acceptable tolerance limits for split and proficiency samples. All ICQF and Owner Verification

Testing (OVT) personnel were evaluated through a written and performance test to establish their qualifications to perform testing on the project.

Contractor quality assurance test results: Yes.

General Quality Management Procedures

Standard of Care

No different from DBB projects.

Alternate Quality Management Systems

The SH 130 construction QC/QA program was different from previous, conventional TxDOT CQA programs because it involved an independent Construction Quality Assurance Firm (CQAF) who was responsible for the CQA Program and making acceptance decisions.

The CQAF program included the following:

- Inspection of all development work
- Material sampling and testing
- Auditing of records, documentation, and procedures of Developer's QC program
- Reviewing and approving Portland cement and hot mix asphalt concrete mix designs
- Environmental compliance inspections

Though it was considered as part of the Developer's team, the CQAF was technically an independent entity that reported to management from both TxDOT and the Developer.

Such a private-public partnership on quality assurance allowed the Developer and TxDOT to effectively capitalize from the expertise and resources of the private sector and address the critical CQA needs of the fast-track project delivery.

Summary QA Project Approach

The QAO shown in Figure M1 displays the QAO of the PPP SH130 Project in Texas. The project involved an acceptance QAO in which the only formal quality role that the owner has is acceptance.

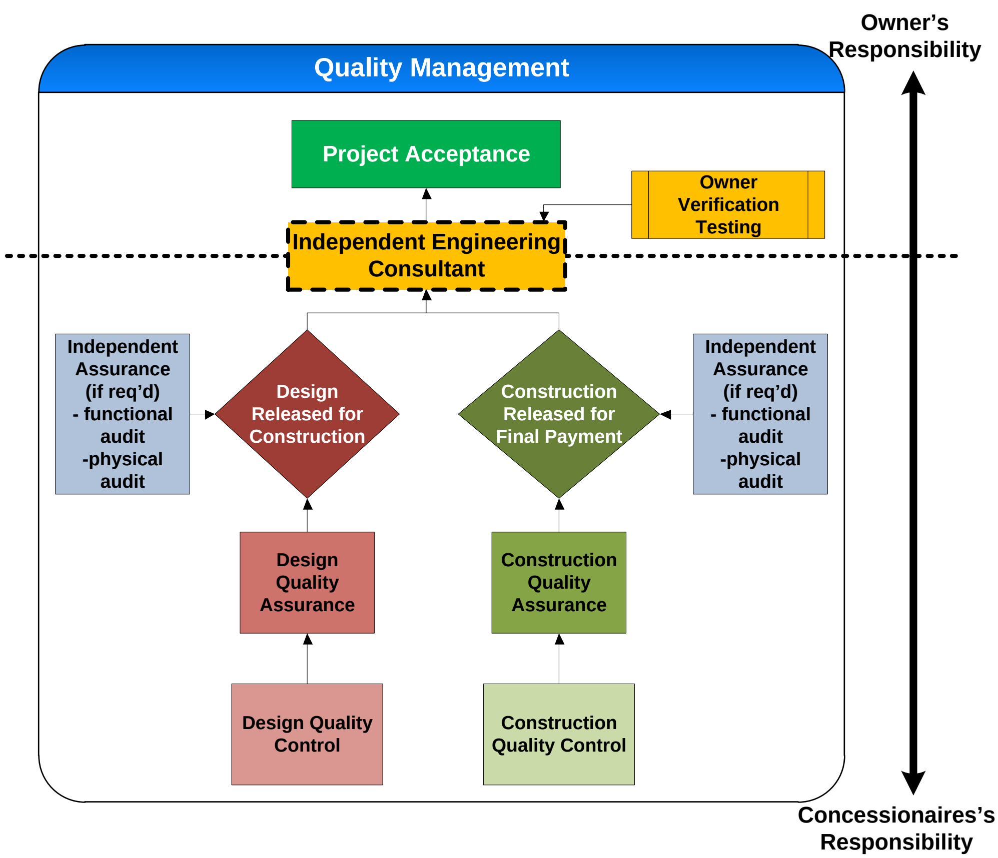


Figure M1: Acceptance QAO Model for SH130 Texas

Example of Alternate QM System Used on This Project

SH130 generated large volumes of data that needed to be processed, stored, and analyzed quickly. As of July 2006, the ICQF had generated and transmitted approximately 65,000 test records and 30,000 inspection reports to TxDOT. The Program Manager had generated approximately 7000 oversight test records and 15,000 inspection oversight reports. This large volume of documentation was anticipated early on in the project and TxDOT tasked the Program Manager with developing and implementing an Electronic Data Management System (EDMS) for TxDOT to meet this demand. TxDOT's EDMS was a web-based tool used on the SH 130 project to enter, receive, search and analyze project testing and inspection records.

The Program Manager's field personnel used PDAs (personal digital assistants) to record test data and write oversight inspection reports on-site. Field sampling and testing results as well as inspection reports were entered into the PDA in the field. At the end of each work day, the oversight technicians and inspectors hot-synced their PDAs to a local network computer and the information was transferred from the PDA into TxDOT's EDMS. Prior to submitting the report for supervisor review, the oversight technicians and inspectors reviewed the information on a regular computer monitor to check for and correct any errors. The respective supervisors received the submitted report via electronic workflow and reviewed it prior to approval. If the supervisors had any concerns regarding the report, they could reject it back to the technician or inspector for correction before approving it at a later time. Laboratory test results were entered directly into TxDOT's EDMS using the local network machines. The ICQF collected the data using hard copy testing and inspection reports and entered them into their EDMS. The ICQF testing reports were transmitted into TxDOT's EDMS for statistical validation. The ICQF inspection reports were transmitted into TxDOT's document management system. TxDOT's EDMS had the capability to search for Owner Verification Testing (OVT) and ICQF test results based on various criteria and run various statistical analyses and data plots. Data could be selected based on the testing laboratory, test method, geographic area, roadway designation, station, feature, structure number, date ranges, sample type (independent versus split samples or random versus fixed locations samples), material code and supplier.

Observations of the Researcher

The SH130 Project progressed with a lot of communication and recording. The amount of communication contributed to the success of the project and provides a good example for future projects. Furthermore, the EDMS seemed to be a valuable tool as long as it is used regularly by those responsible for inputting data.

Effective Quality Management Practices

Effective quality management practices that contributed to the success of the SH130 Project were communication between all parties involved, co-location of team counterparts, partnering early on in the project and the development of an escalation matrix. These practices are described in the following paragraphs.

- Co-location: Due to the magnitude of the project, it was critical for all parties to be co-located on the project. This allowed for the easy access to counterparts within the Program Manager, ICQF, and Developer teams. The full-time on-site FHWA project engineer was also important for understanding potential FHWA concerns and getting FHWA review quickly. In addition, the co-location of FHWA, TxDOT, and the Program

Manager enabled the group to work seamlessly in developing and implementing the QAP.

- Escalation Matrix: Prior to construction, there was a construction partnering session that included nearly every project team member on the construction side of the project. An escalation matrix was developed to provide a clear chain of command for escalating issues that could not be agreed upon, while promoting the resolution of issues at the lowest possible levels. Additional partnering sessions (formal and informal) continued through the life of the project.

- Clarification Requests and Reports: Continuous communication on the project site is critical for keeping all parties up to date on the latest changes in plans, specifications, and schedules. Field clarification requests (FCRs) were used to clarify plans that had disconnects or discrepancies. Construction Deficiency Reports (CDRs) and Non-Conformance Reports (NCRs) were used to track non-conforming materials and workmanship.

- The Web-Based EDMS: The Electronic Laboratory Verification Information System (ELVIS) is a set of web-based data management and engineering analysis tools originally developed to process material testing data and electronically transmit them to TxDOT for statistical validation. To meet the project needs, ELVIS was further expanded to support CQAF construction inspection reporting and manage pavement surface ride quality.

  The system consists of eight key functional components: the integrated database, workflow-driven data management functions, material baseline information management applications, online information delivery system, deficiency management tools, engineering decision tracking functions, statistical analysis tools, and system\administration tools. Data from inspections, sampling and testing, and ride quality measurements are entered into ELVIS by CQAF clerks. CQAF engineers review inspection and testing reports and complete on-line authorization by assigning appropriate stamp codes. The data is then compiled into databases which are electronically transmitted to TxDOT and the Developer simultaneously each day.

  ELVIS also serves as the primary tool used by CQAF engineers to track and monitor construction deficiencies and non-conformances captured through inspections and testing. The system automatically earmarks failing inspections and material tests and pavement sections with unsatisfactory surface roughness. When a quality deficiency has been corrected or reworked and the product has passed re-inspection(s), retest(s), or re-profiling, through secure web pages, CQAF engineers document the non-conformance disposition decisions and corrective actions and close the deficiency by changing the deficiency status from “Pending” to “Closed”.

  Accessed by hundreds of authorized users, ELVIS serves as a secure, real-time, common information-sharing platform among a broad constituency of users, including managers, engineers, QC and CQAF technicians and inspectors, superintendents and designers.

- Industry Review Process: The industry review process included the development of a risk allocation table as a trade-off with the proposers and includes a reiterative cycle of subtasks.

  Initially, the Department released draft sections of Request for Detailed Proposal (RFDP) to the short-listed firms and waited for their written comments. A round of one-on-one meetings was scheduled for discussing these comments. The documentation was reviewed, modified, and edited by the legal consultants and resubmitted to the proposers with other draft sections. Depending on the project complexity, as well as on the procurement schedule pressure, this task requires between two and four rounds of meetings.