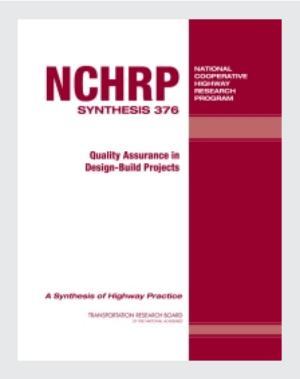

Quality Assurance in Design-Build Projects

DETAILS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP SYNTHESIS 376

Quality Assurance in Design-Build Projects

A Synthesis of Highway Practice

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SUBJECT AREAS
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TRANSPORTATION RESEARCH BOARD

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Staff
Transportation
Research Board

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Jon M. Williams
Program Director
Transportation
Research Board

For transportation design-build projects, the public agency has less control over day-to-day details of the process than with more traditional approaches to project design and construction. Design-build projects, therefore, require a thorough and thoughtful approach to assuring quality in the project by the public agency. This report examines how state transportation agencies have successfully approached quality assurance for design-build, including in procurement, design, construction, and post-construction operations and maintenance.

Information for this study was gathered through a survey of all state DOTs, literature review, content analysis of solicitation documents from 26 DOTs, and review of policy documents from 17 DOTs.

Douglas Gransberg and Joseph Datin of the University of Oklahoma, Norman, and Keith Molenaar of the University of Colorado, Boulder, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

QUALITY ASSURANCE IN DESIGN-BUILD PROJECTS

SUMMARY

The quality of transportation projects affects nearly everyone in the United States daily. This report focuses on the mechanics of how departments of transportation (DOTs) achieve quality projects. Specifically, this reports looks at quality in design-build (DB) projects. DB has been advancing rapidly in popularity and many states now have some experience using DB in their transportation projects. In traditional design-bid-build (DBB) construction, the design and construction are done under two separate contracts. In many cases, the DOT performs the design itself and then advertises for construction contractors to bid on the finished design. In DB, the design and construction are done under one contract by the same entity. As a result, the DOT has less control over the day-to-day details of design development in the DB project.

An understanding of how to ensure that DB projects achieve at least the same level of quality as DBB projects is of interest to all involved in the process. Two definitions are relevant for further discussion. First, *quality* is the degree of excellence of a product or service, the degree to which a product or service satisfies the needs of a specific customer, or the degree to which a product or service conforms to a given requirement. Second, *quality management* is the system used to manage the ultimate quality of a product. Managing quality has traditionally been the responsibility of the DOT. DOTs developed the designs, specified the materials to be used, and watched over the construction for DBB projects. In DB, however, many of the quality management responsibilities have been shifted to the design-builder. This report discusses how these responsibilities were distributed and communicated in DB projects across the nation. Also identified are the trends or practices that have become common.

The objective of this synthesis is to capture the various ways in which quality assurance (QA) is handled in DB projects. The synthesis identifies different approaches, models, and commonly used practices, recognizing the differences in each of the different delivery methods. The synthesis also addresses how the core principles of QA can be satisfactorily addressed in DB projects. It applies these principles from the procurement phase to both the design and construction phases and, in the cases of projects with post-construction options for operations and/or maintenance, to the operational phase to cover the entire life cycle of a DB project. In addition to a rigorous literature review, the synthesis is based on new data from two sets of surveys and two content analyses. A general survey on DB quality management provided 76 responses from 47 states. A content analysis of DB solicitation documents from projects with a total contract value of more than $11.5 billion from 26 transportation agencies across the country was also conducted. For further verification, an additional content analysis of DB policy documents from 17 states was conducted and the data were collected from a brief survey on DB quality perceptions from 17 states.

This synthesis report is timely because it follows a report published in 2006 by the FHWA to the U.S. Congress detailing the effectiveness of DB on a sample of the first 300-plus transportation projects authorized under Special Experimental Project No. 14 (SEP-14). The FHWA study's findings are best summarized by the following excerpt:

> 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.* (italics added)

The synthesis has generally confirmed that quality issues pervade the procurement, design, construction, and operations and maintenance phases of a DB project. The issues range from the quality of the design-builder's personnel, to the quality of the past experience of the various firms that make up the design-builder's team, to the quality of the plans that will be used to implement quality management practices after the DB contract is awarded, not to mention the classic design and construction quality issues present in traditional projects. Therefore, the management of quality in the DB project is of utmost importance, and a DOT that is considering using DB project delivery must prepare a thorough and thoughtful approach to communicating the DB project's quality requirements as well as the administrative and technical mechanisms that the DOT intends to use to manage both design and construction quality.

The synthesis' conclusions cover the life cycle of the DB project and are as follows:

- An examination of DB policy documents found that they were either silent or overly general on the subject of quality. Additionally, approximately half of DB procurement documents did not clearly articulate the owner's approach to quality management and appeared to rely on the qualifications evaluation portion of the award process using an approach called "quality by qualifications." As a result, the study concluded that DOT DB policy documents, such as guidelines and model requests for proposals (RFPs), would benefit from specific guidance with regard to the agency's quality management approach to set the stage for ensuring that quality is properly emphasized throughout the project's life cycle.
- The DB solicitation document content analysis, the survey responses, and the literature review identified a new set of quality management activities. These are the activities that the DOT undertakes with its own forces or with the assistance of a third-party consultant to ensure a quality project when it has assigned QA responsibilities to the design-builder. This set of activities was termed "project quality assurance" (PQA) and includes oversight, independent assurance, verification, and acceptance found in DBB projects as well as DB-specific activities such as "over-the-shoulder" design reviews and "witness and hold points" during construction. A model for DB PQA is presented in chapter one.
- Convergence was also found between the literature and the DB solicitation content analysis regarding the value of using the two-step selection process for emphasizing quality in DB projects. One author called the two-step selection process "essential for success," and the RFP content analysis agreed when it found that 89% of the projects analyzed used the two-step request for qualifications/request for proposals (RFQs/RFPs) process. DOTs can leverage the two-step process to promote quality by requiring competing design-builders to include a quality-focused submittal in both steps.
- Continuing in the procurement phase analysis, the study found that DOTs are using a "best value" rather than a low-bid award process. This finding was indicated by the literature and the DB solicitation document analysis. Most of the RFPs analyzed (90%) used some form of best value award. Qaasim stated that "best value award is a good way to add extra weight to quality components," and one DOT indicated that "placing a quality component in the RFQ or RFP brings extra attention to the design-builder that quality is an important issue for the DOT and that a proposal emphasizing quality will be evaluated more favorably."
- The synthesis finds that design quality management is not receiving sufficient emphasis by DOTs in their DB quality management programs. The RFP content analysis showed that only about one-third of the documents contained specific references to design quality, whereas two-thirds of the survey respondents indicated that they rated detailed design criteria as having a high or very high impact on the project's ultimate quality. The literature clearly shows that the design phase is the time when the quality of the constructed product is defined.
- The issue of how to incorporate the DOT's standard specifications was explored in both the survey and the content analysis. It was resolved by reviewing both the RFP content

analysis output and survey responses from states that have completed more than five DB projects. Most of these agencies chose to incorporate their standard specifications by reference in their DB contracts and to allow the design-builder to optimize specific construction means and methods with its design approach. The agencies are comfortable with this because, as previously stated, they remain involved in the design process by retaining the responsibility for design QA.

- Finally, the survey of the perception of DB's impact on project quality was analyzed. More than 80% of the industry practitioners responded by rating DB project quality as either the same or better than DBB project quality. This was not the case, however, for the public agency respondents to the same survey who were evenly split among the possible answers of better, the same, or worse than DBB project quality. Thus, perceptions that teaming the engineer of record with the construction contractor might degrade the quality of the project remain a barrier to implementation in spite of the FHWA DB effectiveness study that found that quality was comparable. DOTs need to remain sensitive to this issue in developing their DB quality management programs. Retaining design QA responsibilities, as cited in the previous conclusion, may furnish an effective response to this perception if this perception exists within a given DOT.

The analyses also led to the identification of 10 commonly used practices, which were found in the literature and then confirmed in practice by either the survey or content analysis. These practices cover the entire life cycle of the DB project and are listed here without the supporting information, which can be found in the appropriate chapters of the text.

- Use of the best value, two-step DB procurement process.
- Clear identification of the quality management organizational approach that will be used on the DB project in the solicitation documents and clear assignment of the responsibility for all levels of quality management in both design and construction, ensuring that those roles that are reserved for the DOT or its third-party quality consultant are also clearly indicated.
- Having the design-builder furnish highly qualified and experienced personnel on its DB projects and list required quality-specific qualifications for both the design and construction members of the DB team in the DB RFQ/RFP.
- To ensure that the competitors understand the requisite level of design and construction quality, preliminary design documents in the RFP must clearly state the specifications, design criteria, and standards that will be used in the final design and construction of the project.
- Determining the number of design reviews that will be conducted during the DB project design phase and clearly assigning the responsibility for conducting those reviews in a manner consistent with the selected QA organizational plan, publishing them in the project's solicitation documents to create the necessary contractual requirements for both parties to the DB contract. If the project is not schedule-constrained, the DOT can afford to inject more design review points, whereas design reviews are minimized on a fast-track project.
- Unless the DB project has a follow-on maintenance or operations option, the DOT can satisfy its federally mandated oversight requirements by remaining involved in design QA, using either its own forces or through the employment of a third-party quality consultant.
- The design-builder's engineer of record is usually assigned some responsibility for conducting construction QA.
- The design-builder's construction quality manager is usually assigned some responsibility for conducting construction quality control.
- The DOT normally conducts PQA activities to satisfy its federally mandated oversight responsibilities, using either its own forces or through the employment of a third-party consultant.
- Incorporating standard state specifications by reference in the DB contract and allowing the design-builder to optimize construction means and methods with its proposed design approach.

CHAPTER ONE

INTRODUCTION

SYNTHESIS OBJECTIVE

The objective of this synthesis is to capture the various ways in which quality assurance (QA) is handled in design-build (DB) projects. The synthesis identifies different approaches, models, and commonly used practices, recognizing the differences in each of the different delivery methods. The synthesis also addresses how the core principles of QA can be satisfactorily addressed in DB projects. It applies these principles from the procurement phase to both the design and construction phases to cover the entire life cycle of a DB project. In addition to a rigorous literature review, the synthesis is based on new data from two sets of surveys and two content analyses. A general survey on DB quality management provided 76 responses from 47 states. A content analysis of DB solicitation documents from projects with a total contract value of more than $11.5 billion from 26 transportation agencies across the country was also conducted. For further verification, an additional content analysis of DB policy documents from 17 states was conducted and the data were collected from a brief survey on DB quality perceptions from 17 states.

DESIGN-BUILD BACKGROUND

The Design-Build Institute of America (DBIA) predicts that 50% of nonresidential construction projects will be delivered using DB in 2010 (Eby 2005). This tracks well with a 2004 survey that found that construction companies expect 50% of their revenues to come from DB projects in 2006 (Zweig-White Research 2004). This same study reported that 80% of all design and construction firms surveyed in the United States expect the percentage of their business derived from DB projects to increase over the next 5 years. Figure 1 shows that the percentage of nonresidential construction projects being delivered by DB has increased steadily over the past 20 years from an estimated $18 billion in 1986 to more than $250 billion in 2006 (Design-Build Institute of America 2005). This shift in project delivery culture first began in the 1960s in the private sector on commercial construction projects with strong revenue streams where the financial benefit of compressing the project delivery period outweighed the risk of starting construction before the design was totally complete (Gransberg et al. 2006). In the 1980s, it spread to the public sector as a method for delivering revenue-producing projects, such as toll roads and bridges, as well as an effective means to expedite the procurement of emergency reconstruction after natural disasters, such as the Interstate bridges demolished by hurricanes in Florida. In 1996, the Federal Acquisition Reform Act was passed and specifically provided both regulation for the use of DB on federal projects and the authority to utilize the delivery method without seeking special permission (Gransberg et al. 2006).

Since its inception in 1993, DBIA has tracked state and federal capital project and infrastructure procurement laws regarding DB. It has documented the trend of expanded legislative authority to public-sector engineering and construction agencies to legally use DB in all types of construction procurements. The building sector has led the infrastructure sector in terms of embracing the use of DB. States such as California and Oklahoma have authorized its use on public buildings without extending broad DB authority to their departments of transportation (DOTs). Nevertheless, in the past decade, DB transportation projects have been constructed in more than 35 states. Some are restricted to toll projects or mass transit projects in which the revenue generation potential forms a convincing argument for achieving an early opening by compressing the traditional delivery period to its shortest state. Thus, the use of DB project delivery in the transportation sector is growing across the country.

DESIGN-BUILD IN TRANSPORTATION

By 2004, the FHWA had approved more than 300 DB transportation projects worth nearly $14 billion in 32 states under the FHWA Special Experimental Projects program (SEP-14) (*SEP-15 Program* 2006). Figure 2 shows the status of SEP-14 project approvals as of 2002. By 2002, the Florida DOT alone had awarded 49 DB projects for nearly $500 million worth of work and estimated that DB cut the traditional project delivery period by 30% (Peters 2003). When one adds the uncounted number of public building, utility, and other infrastructure DB projects completed by county and municipal public agencies as well as the public-private partnerships (PPPs) that deliver critical infrastructure such as toll roads, toll bridges, and water and wastewater projects, the nationwide market for DB project delivery is truly staggering. To generate such meteoric growth in such a short period vividly confirms that DB must accrue tangible benefits to the public agencies that implement it. FHWA eloquently

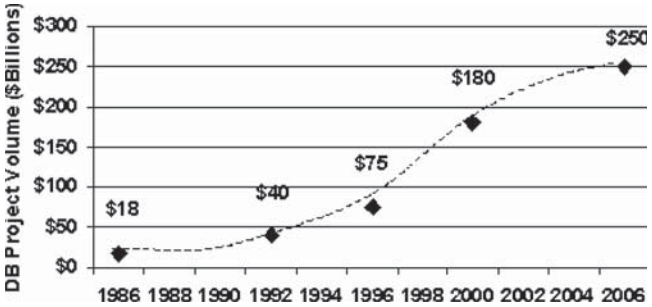

FIGURE 1 Design-build growth in the United States (Design-Build Institute of America 2005).

articulates the motivation for implementing DB when it states that:

> The greatest motivation and realized benefit to a contracting agency of using design-build . . . is the ability to *reduce the overall duration of the project development process* by eliminating a second procurement process for the construction contract, reducing the potential for design errors and omissions, and allowing for more concurrent processing of design and construction activities . . . (*Design-Build Effectiveness Study* . . . 2006).

Design-Build Controversy

The emergence of DB contracting on the national transportation scene has certainly been controversial. The emotions associated with the paradigm shift required to implement it have run high. When it emerged in the late 1980s, its detractors consisted primarily of the professional societies associated with the design industry who argued that the use of DB would inevitably degrade the ultimate quality of the constructed product by compromising the integrity of the design process. This fear was expressed in the National Society of Professional Engineers Position Statement #1726 that stated:

> Design decisions may be determined or inappropriately influenced by team members other than the designer. This is more likely to occur when a non-designer is the lead on the design-build team. The leader may pressure designers to reduce self-imposed quality criteria or design standards to minimum levels in order to maximize profit ("Design/Build in the Public Sector" 1995).

This confirms the need for a study like this synthesis to assist public transportation agencies in determining an appropriate distribution of responsibility for quality management in a DB transportation project and how to communicate this distribution effectively in DB solicitation documents. Many factors will independently influence the outcome of any construction project; "however, performance can be significantly influenced by the system employed to ensure quality" (*NCHRP Synthesis of Highway Practice 65* . . . 1979). To transfer design liability effectively to the design-builder, a DOT must also transfer many of the traditional QA responsibilities as well. This leads to a concern that the "fox may be guarding the hen house," as captured by the preceding statement. A study by Ernzen and Feeney of the Arizona DOT's DB program (appropriately titled "Contractor-Led Quality Control and Quality Assurance Plus Design-Build: Who Is Watching the Quality?" 2002) addressed this concern directly by comparing project

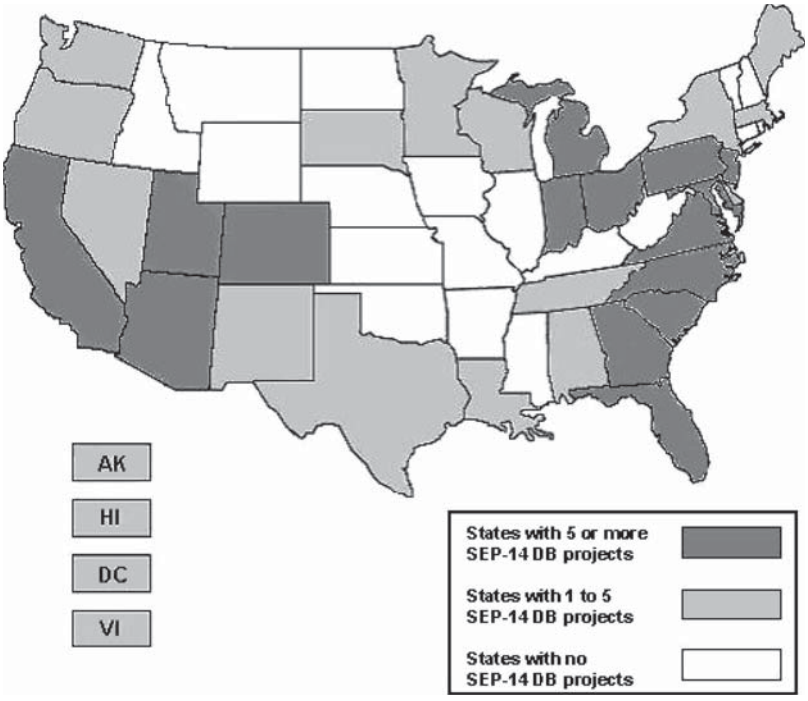

FIGURE 2 SEP-14 DB project approvals as of December 2002 across the United States (*Design-Build Effectiveness Study* . . . 2006).

QA test data on a DB project in which the design-builder had been assigned the responsibility for QA with data from a similar project delivered by traditional means. The study found the following:

> Analysis of the data shows that despite a highly compressed schedule, the quality of the material on the project exceeded the project specifications and was similar to the quality of work completed for the state under traditional contracting methods with an Arizona DOT-operated quality assurance program (Ernzen and Feeney 2002).

The Arizona DOT study and the numbers for DB growth previously cited regarding the growth in DB across the nation effectively belie the theory that implementing DB project delivery will inherently result in decreased construction quality. It would be difficult to believe that sophisticated public owners, such as state DOTs, would propagate the spread of a delivery method that consistently resulted in substandard or poor-quality product regardless of its ability to expedite project delivery.

There have, however, also been recent studies done by Turochy and associates that show a statistically significant difference in test results for hot-mix asphalt mat compaction between contractors and the state DOT (Turochy et al. 2006; Turochy and Parker 2007). In the first study, done using Georgia DOT data comparing DOT QA tests with contractor quality control (QC) tests, the differences in the variances in the majority of cases were statistically significant, although the differences in means were not (Turochy et al. 2006). In a later study analyzing data from Alabama, Florida, Kansas, and North Carolina, the authors found that "standard deviations for the contractor test results are always smaller than agency counterparts, and usually significantly so from a statistical perspective" and that "contractor test results are always more favorable (i.e., larger) than agency test results" when examining the differences in means (Turochy and Parker 2007). These authors concluded that "the consistent indications of less variable and more favorable contractor test results, relative to specification limits, are compelling reasons to consider limiting the use of contractor-performed tests to quality control," while recognizing benefits to having contractors perform QA on their products (Turochy and Parker 2007).

Even though these studies have conflicting conclusions, DB project quality was approximately equal to the quality found on the design-bid-build (DBB) projects in both cases. The FHWA Design-Build Effectiveness Study reports actual results that conclusively confirm this belief, as summarized in the following quotation:

> 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* (*Design-Build Effectiveness Study* . . . 2006, italics added).

Culture Shift for Quality Assurance in Design-Build

The need for this synthesis is a consequence of both continued growth and the need for a better definition of QA in the DB context. All DB projects must be delivered with at least the same level of quality that occurs in DBB. In traditional DBB contracting in the transportation industry, decades of QA and QC experience provide a wealth of knowledge and standard practices that are readily accessible and widely accepted for assuring quality on infrastructure projects. In DB, however, there exists a limited but rapidly expanding body of experience associated with assuring quality. The purpose of this synthesis is to bring together this relatively new body of experience and summarize it in one easily accessible reference on QA in DB projects. The authors realize that not all topics are fully developed and recognize the limitations placed on a summary report.

One of the major challenges facing DOTs and design-builders in implementing DB is the change that must take place in the culture of both parties. This is well described in an evaluation report given on the I-15 DB project in Utah.

> The Owner felt that one of the biggest challenges to the QC and QA program was "breaking the mold" of the traditional roles of the contractor and Owner. The Owner's personnel had all come from the "catch and punish" culture. Likewise the Contractor personnel came from a similar background. To change philosophies to a more proactive quality role by the Contractor and a less controlling oversight role of the Owner was a significant challenge. Most personnel assigned to the project by either party had worked under traditional systems for many years and this was the first experience with this type of project (Postma et al. 2002).

As both DOTs and design-builders become more familiar with DB, the culture change will be less of an issue.

Another issue that has confronted DB projects since their implementation has been the idea that contractors, who take the lead in many DB projects, would pressure the designers, who are often a subcontractor, into sacrificing quality for higher profits. According to the Design-Build Effectiveness Study mentioned earlier (*Design-Build Effectiveness Study* . . . 2006) this has not been the case. However, having a well-defined quality management system is one way to address some of these fears. This is even more important on high-profile projects that are delivered using DB. A quality management system adds credibility and assurance for all involved—from the contractors, to the DOT, to the public users (Pantazides 2005).

KEY DEFINITIONS

In reading this synthesis, it is important that the vocabulary associated with the assurance of quality is clearly understood. Throughout the construction industry, there are certain terms that are used to define aspects of quality programs. The

literature review revealed what is best described as "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 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" ("Quality Glossary" 1998).

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 the DB project request for proposal (RFP). One way to do that is by requesting specific quality-related submittals as a part of the DB proposal. The other way is to include the requirements for design and construction quality management as submittals required after contract award. The American Society for Quality goes on to define five varying types of quality as follows ("Quality Glossary" 1998):

- 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.

Thus, it can be seen 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), a topic that is addressed in chapter three.

Standard Definitions

For the purposes of this report, the *Transportation Research Circular E-C074: Glossary of Highway Quality Assurance Terms* (2006) is used to define the QA terms. The major definitions are cited here.

- 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—All of 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—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 the purpose of evaluating the acceptability of a lot of material or construction.

New Definitions for Design-Build Environment

To these definitions the report adds two that are not contained in *Transportation Research Circular E-C074*: "quality management" and "project quality assurance." *Transportation Research Circular E-C090* recognized the need for new definitions for quality in DB projects and noted that:

> 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 et al. 2006, italics added).

Quality management is defined as follows: The totality of the system used to manage the ultimate quality of the design as well as the construction encompassing the quality functions described previously as QA, QC, IA, and verification.

Defining a quality management system was simplified in a previous report to the following four basic questions that provide a concise reference to ensure that a quality management system is fulfilling its needs (*NCHRP Synthesis of Highway Practice 65* . . . 1979):

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 don't get what we ordered?

Project quality assurance (PQA) is defined as 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 IA 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 (*Use of Contractor Test Results in the Acceptance Decision . . .* 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.

Project Quality Assurance Model

Figure 3 is a graphical representation of the DB PQA model. The shaded area represents the universe of QA requirements that exist during both the design and construction phases of a DB project. In this form, it makes no specific assignment of QA/QC roles and responsibilities between the owner and the design-builder. The owner is free to make those assignments to whichever entity is best suited to carry them out in a satisfactory manner. The model shows that no matter who actually performs the classic design and construction QA/QC tasks, at some point the owner must make a business decision as to whether or not to 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 decisions have been made, the DB project is accepted. The details associated with the making of these two decisions contribute to the DB project's acceptance plan as defined in *Transportation Research Circular E-C074*. For purposes of this report, the acceptance plan uses the definition proffered by Burati in a FHWA report on QA specifications. The acceptance plan will "be considered to represent only those functions associated with acceptance" (Burati et al. 2003).

Along the way, the owner may use some form of IA to provide information that will assist him or her in making the design and construction acceptance decisions. In design, IA could take the form of sending portions of the design to another design professional for peer review before releasing it for construction, and in construction, IA could involve sampling and testing to statistically validate the design-builder's QA and QC testing programs. Finally, PQA also encompasses the less formal activities in which the owner engages to facilitate the design-builder's progress. DB project delivery demands a rich flow of technical information between the owner and the design-builder (Beard et al. 2001) and, as a result, owners have developed mechanisms to satisfy this requirement. One such activity has become known as "over-the-shoulder" design reviews (these are discussed in detail in chapter four). The Minnesota DOT (MnDOT) defines these as follows:

> The over-the-shoulder reviews are not hold points that restrict the progress of design. They are simply reviews of the design as it progresses and opportunities for MnDOT to provide comments and feedback on the design (*Addendum 5 Project Management Book 2B . . .* 2005).

Another example of the types of activities that fall into the PQA universe was found in the Virginia DOT's DB guide (*Quality Control, Quality Assurance . . .* 2007), which defines two new quality management roles beyond QA and QC and calls them "owner independent assessment" and "owner independent validation." They are defined as follows:

- Owner independent assessment—Oversight performed by the department (or agent) to satisfy Virginia DOT and FHWA requirements for documenting that proper QC and QA are being performed. This oversight provides an independent assessment of design-builder's

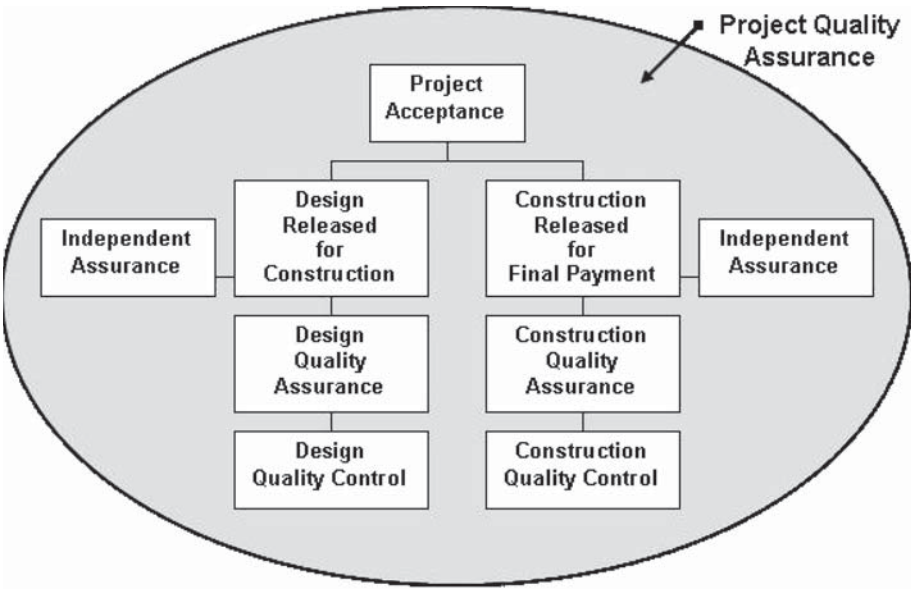

FIGURE 3 Design-build project quality assurance model.

implementation of and compliance with the approved QC and QA plan.
- Owner independent validation—Oversight performed by the department (or agent). The focus of owner independent validation is to verify design-builder's QC and QA compliance and confirm that the quality characteristics of the products incorporated in the project are valid for acceptance and payment.

QA in DB is currently developing. The same universe of responsibilities exists in DB as in DBB. The difference lies with who holds the responsibility. This report looks at this question and presents generic quality management organizations found in the content analysis. Although there is no consensus among the various entities that use DB as to a recommended or preferred QA organization, all DOTs have shifted more of the quality responsibility to the design-builder than is typically seen in DBB.

SYNTHESIS METHODOLOGY

This report is the result of an intersection between a comprehensive literature review, a national survey of both public and private organizations with DB experience, and a content analysis of a large sample of DB RFPs. This methodology allowed for the collection of information on DB QA policies and procedures across the nation by means of the standard survey, as well as the confirmation of those findings through a rigorous analysis of DB solicitation documents. The literature allows the findings from the other research instruments to be put in a global context to identify trends and similarities and capture the state of the art in the more general topic of alternative project delivery method quality management. The triangulation of these three methods allows for the development of emerging commonly used practices in this area to be identified.

Before a description of the details of the report methodology is presented, the relative importance of the various research instruments should be understood. Because DB project delivery is still relatively new to the U.S. transportation industry and only a handful of states have more than 5 or 6 years' worth of experience, the importance of the general survey responses is less than would normally be expected in a typical NCHRP synthesis report. Because most of the survey responses can best be characterized as anecdotal, the study went beyond the typical synthesis literature review and survey to conduct two content analyses of DB solicitation documents and DB policy documents. These analyses helped develop lines of converging information with the literature review and the survey responses by furnishing a quantitative analysis of how DOTs are actually applying QA to the DB project delivery process. The analyses provided a valuable insight into the best value procurement process as well as into various ways in which quality management organizations are being fielded on various types of DB projects. Thus, the study gives the greatest weight to the output from the content analyses as it intersects with the literature review and uses the survey responses to validate conclusions drawn by those intersections.

Study Instruments

Two of the study instruments used in this synthesis consisted of content analyses of DB solicitation documents and state DOT DB policy documents. These content analyses involved gathering and reviewing solicitation documents and searching for the requirements of QA and QC programs that were outlined in the documents. The first formal content analysis furnishes quantitative measurements of DB RFP requirements for QA and QC elements. These measurements are found by counting the number of times that QA and QC terms are either expressed by the owner in the RFP or required to be submitted in the design-builders' proposals. This type of analysis can be used to develop "valid inferences from a message, written or visual, using a set of procedures" (Neuendorf 2002). The primary approach is to develop a set of standard categories into which words that appear in the text of a written document (in this case a DB RFP) can be placed and then the method utilizes the frequency of their appearance as a means to infer the content of the document (Weber 1985). Therefore, in this study, the content analysis consisted of two stages. First, all instances of the word quality were found in each document and the context was recorded. Second, that context was used to determine, if possible, to which party in the contract the responsibility for quality in a given context was assigned. This allowed an inference to be made regarding the given owner's approach to quality management for a particular project. When the results are accumulated for the entire population, trends can be identified and reported. This method was then repeated with other terms that were common to quality management, such as verification and assurance, and the context was recorded and then analyzed.

This process was repeated for the formal content analysis of the DB policy documents. The output from the two content analyses can then be compared with each other to determine how DB policy is being implemented in the DB solicitation documents. The output can also be compared with the responses from the two surveys that are discussed in detail later in this chapter to map respondents' output against their respective state DB policy and DB solicitation documents. The use of these instruments in conjunction with the comprehensive review of the literature allows the team not only to maintain a high level of technical rigor in the study but also to follow Yin's three principles in the process of data collection (Yin 2004):

1. Use of multiple sources,
2. Creation of a database, and
3. Maintaining a chain of evidence.

During the effort, the team was careful to remember that single sources provide limited data based on "one specific source" and can create difficulty when drawing results, in addition to a lack of "trustworthiness and accuracy" (Yin 2004).

Multiple sources help alleviate lack of trust, increase viability, and frequently provide supplementary realms of thought and research that strengthen results.

Design-Build Solicitation Content Analysis

Sixty-six different projects were reviewed from 26 transportation agencies comprising 23 states, the District of Columbia, the U.S.DOT Eastern Federal Lands Highway Division, and one Canadian Province (Alberta), with a total contract value of more than $11.5 billion (see Figure 4). This sample included 59 RFPs and 15 requests for qualifications (RFQs), with 8 of the projects having both documents. The majority came from state DOTs, with a handful from special agencies or authorities that were set up for specific projects. The distribution of project type is displayed in Table 1.

A matrix was developed from the content analysis output containing key quality concepts and practices. As the project literature review and survey progressed, further review was necessary for topics that had not been identified in the original content analysis. The information gathered was reduced to general categories that are detailed in chapter three of this report. The content analysis output was further combined with the results of the survey for this project and the literature that was reviewed to create the synthesis.

Design-Build Policy Document Content Analysis

In addition to the analysis of DB solicitation documents, the study also sought to identify state DOT DB policies and guidelines that were currently available. Consequently, 17 sets of DB policies and guidelines from the 17 states shown in Figure 5 were assembled and the process described for the DB solicitation document content analysis was used to derive the quality content of each of those documents.

TABLE 1
DESIGN-BUILD REQUEST FOR PROPOSAL CONTENT ANALYSIS SAMPLE

Major Project Types		Minor Project Types	
Road	14	Mass Transit/Light Rail	4
Bridge	14	Rest Area	2
Road and Bridge	27	Tunnel	2
		Toll Collection	1
		Signage	1
		Fiber Optic (ITS)	1
Total	55	Total	11

General Nationwide Survey

In addition to the content analysis, a survey was issued to state DOTs, other public transportation agencies, design-builders, and DB design and construction consultants (see Appendix C for details). A total of 63 complete and 13 partial responses were received. The survey respondents were from 47 states (see Figure 6). DOT responses from 27 of the 31 state DOTs that have performed DB are included. Additionally, three state DOTs that have not yet awarded a DB contract, but either are in the process of awarding their first contract or intend to implement DB in the future also responded. Responses from five non-DOT transportation agencies (four transit agencies and one toll road authority) with DB experience are also included as are the four responses received from

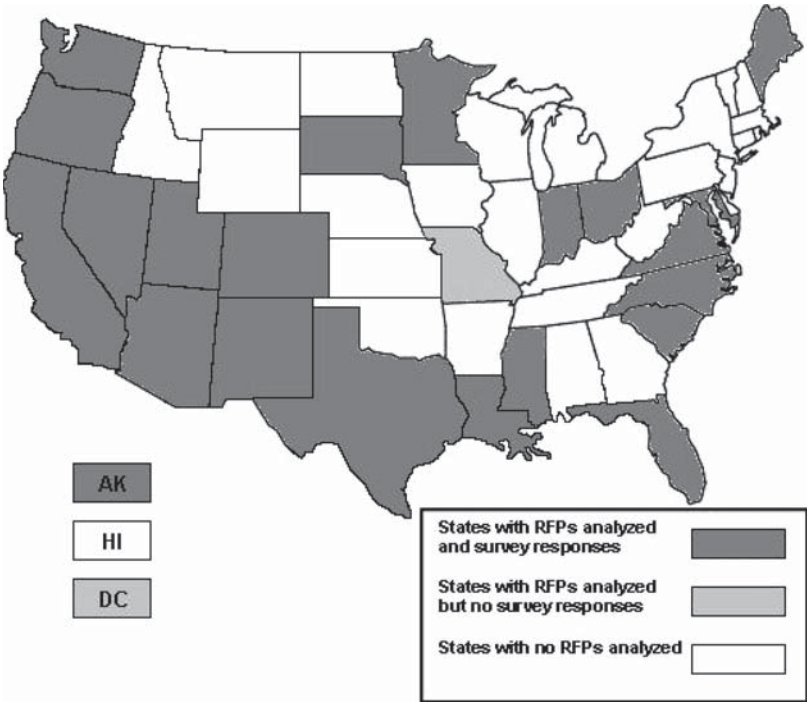

FIGURE 4 Geographic distribution of design-build requests for proposals analyzed in this study.

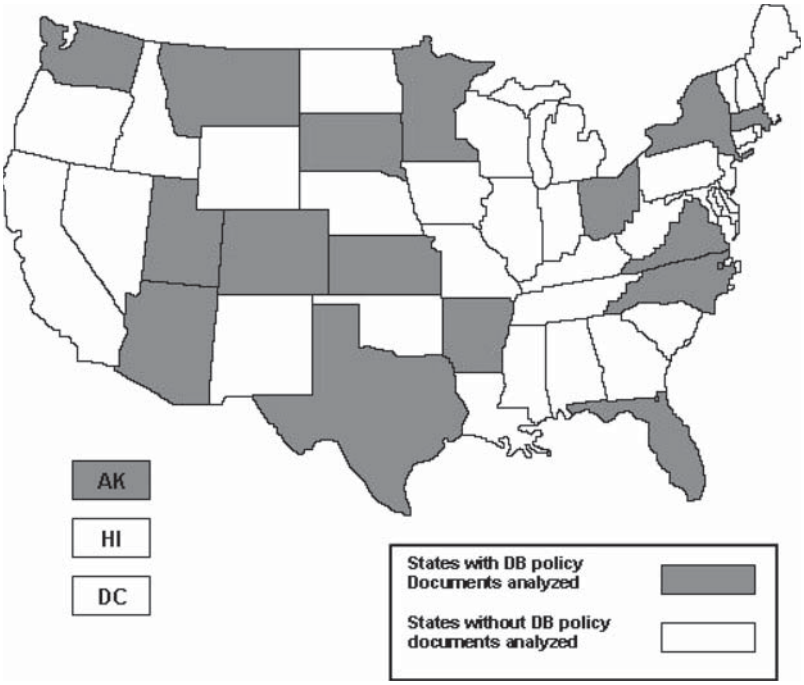

FIGURE 5 Geographic distribution of design-build policy documents analyzed in this study.

the engineering and construction industry. Survey respondents' DB experience ranges from as early as 1988 to as recently as 2007, and from one completed project to more than 10. As can be seen, the survey also captured a wide range of states with DB experience.

Design-Build Quality Perception Survey

In public policy, perceptions are often of equal importance to facts. Legislative action is heavily influenced by perceptions and, as previously discussed, implementation of DB for public infrastructure projects has had to overcome the perceptions that DB project delivery would result in an inherently poor quality and possibly unsafe final product because the designer's fiduciary loyalty has been moved to the builder's team. One report on DB implementation classifies perceptions as "barriers to broad acceptance" (Byrd and Grant 1993). An interesting discussion of the issue of perceptions creating a barrier to implementing DB was published in 2005. Although it is specifically directed at architectural projects, its content applies directly to transportation. The article states that "architects have groomed a cultural perception that builders can't be trusted" and, as a result, participating in a DB project must be unethical. The author goes on to state: "That perception [that DB is unethical] subsequently contributed to many bidding and contracting laws that made design-build cumbersome or impossible in the U.S." (Nicholson 2005). This perception is contradicted by the legislation that specifically authorizes the use of DB on all types of projects across the country. Nevertheless, the perception is stubbornly persistent. Thus, this study has measured the perception of DB's impact on project quality and compared it with the data obtained in the general survey. In this manner, the potential divisive influence of persistent anti-DB perceptions can be potentially identified.

To accomplish this purpose, a short survey (see Appendix F for details) was distributed to TTB's Design-Build Task Force

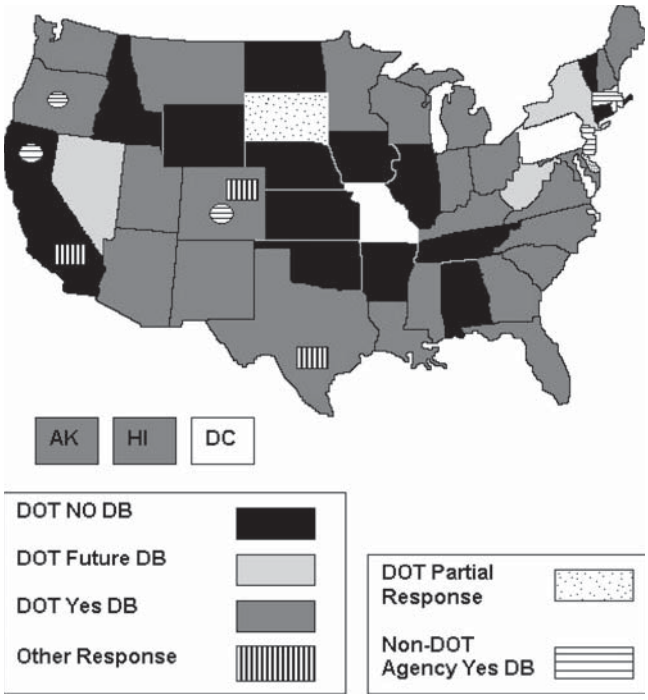

FIGURE 6 Geographic distribution of general nationwide survey responses.

at its 2007 meeting in Washington, D.C. The task force is made up of both public agency and private industry professionals with an interest in the subject. Not all have DB experience. Many choose to join the task force for its value as a training and informational resource for DOT members who anticipate using DB in the future. Additionally, the meetings are open to the public and are well attended by nonmembers with similar interests. The meetings are lively and decidedly open to opinions from all sides of the DB issue. Thus, it is an excellent forum to capture the perceptional input that this study requires. Thirty-two surveys were issued and 23 responses were received, for a 72% response rate. The responses came from individuals working for both private and public organizations in 17 states. Figure 7 shows the distribution of those responses and highlights those that are from states that also returned general surveys. When one correlates these responses with the SEP-14 data, it is found that only three responses are from states with no DB transportation experience: Illinois, Iowa, and Oklahoma.

The first series of questions sought to measure the potential threat to the DBB status quo by DB regarding the potential for public engineer job loss and DOT role changes. Half the DOT respondents believed that implementing DB would decrease the need for professional engineers in state service. Additionally, half the DOT respondents expected their role to change in a DB project. These results can be compared with a recent study of DB impact on the public workforce (Gransberg and Molenaar 2007), which found that 86% of the DOT respondents reported that their professional workforce either remained the same or increased in size after implementing DB project delivery.

The final two questions were designed to assess the perception that the change in the designer's role from working for the owner to working for the builder would degrade the ultimate quality of the constructed project. The survey asked the respondents to reveal their impression of the impact of DB project delivery on project quality. Interestingly, 78% indicated that DB quality was either better or equal to the quality of traditionally delivered projects. Only one respondent indicated that the quality would be worse, and four had no opinion. Breaking out the responses by group, the public employees were evenly divided between "better," "no change," and "don't know." Eighty-five percent of private practitioners indicated that DB quality was better or equal. Again, there is a disparity between the two groups with the public employees showing no trend and the private practitioners indicating substantial confidence in the delivery method.

The final question asked who might be assigned the majority of the responsibility for QA in a DB project. The results showed that nearly half the respondents believed that this essential task should be shared between the agency and its design-builder. The trend remained the same when the results were split out between the two groups.

The perceptions survey showed that public agency engineers believe that their roles will change and are unsure of the impact on the quality of their most important deliverable: the constructed transportation project. Some see implementing DB as potentially reducing the need for public agency professional engineers. Given this discussion, it can be concluded that perceptions will probably remain a barrier to DB implementation

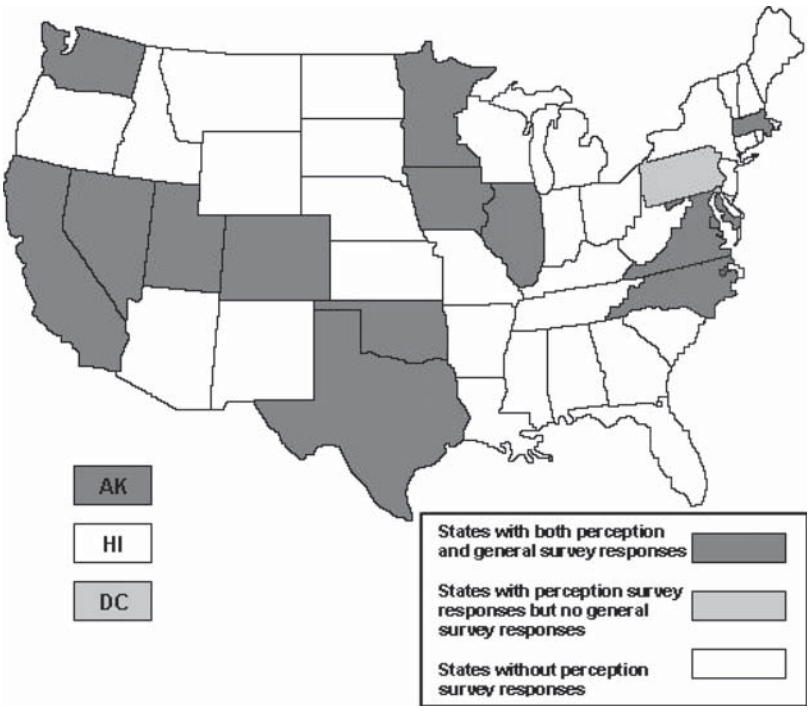

FIGURE 7 Geographic distribution of design-build quality perception survey responses.

and that DOTs must be sensitive to this issue when developing their DB quality management policy and programs.

COMMONLY USED PRACTICES

Although developing commonly used practices was not the primary purpose of this synthesis, a number have been identified and are organized in logical groups. The definition of a commonly used practice for this synthesis is a method or procedure that was found in the literature and confirmed as applicable through survey responses. The DB RFPs whose content was analyzed are considered part of the application for purposes of identifying commonly used practices and the DB policy documents reviewed were included as part of the literature.

CHAPTER TWO

DESIGN-BUILD QUALITY ASSURANCE ORGANIZATIONAL STRUCTURES

INTRODUCTION

One of the benefits of DB is the opportunity for the owner to shift some of the risks associated with the design and construction of a project (Beard et al. 2001). The shifting of risk, however, parallels the shift in authority. A public owner can delegate as little or as much authority for quality management tasks as it wishes; however, it must remember that the agency itself will always ultimately be responsible for the satisfactory completion of the project. Thus, the determination of which party to the DB contract is assigned the authority to perform both design and construction QA and QC essentially drives the final form of the organization that will be fielded to accomplish those critical tasks.

ORGANIZING FOR QUALITY MANAGEMENT

DB project quality must be reviewed within the context of the DB contract itself. Project delivery can be modeled as a three-legged stool whose legs are cost, schedule, and quality (as defined by the details of design). The quality is established in the traditional DBB delivery method by developing a completed design on which construction contractors can bid (Ellis et al. 1991). Then, as the time is fixed by a specified contract completion date, the only leg of the stool left to ensure a level platform is the bid price (Ellicott 1994). As a result, DBB can be defined as a "system where the constructor tells the owner how much it will cost to deliver the quality defined in the design within the specified period of performance" (Gransberg et al. 2006). DB, as currently being used in the transportation sector, usually requires the design-builder to offer a firm fixed price for a project whose scope is defined by a set of performance criteria within a specified period of time (Molenaar and Gransberg 2001). This leaves the details of design as the variable leg in the DB stool, placing the design-builder in a position where the details of design, and hence the resultant level of quality, are constrained by both the budget and the schedule. Therefore, to be successful, the design-builder must complete the final design to match both the DB contract's cost and schedule. *This makes it particularly important to both the owner and the design-builder that the requirements for quality be clearly articulated in the DB project's RFP to ensure that the resultant proposals are as responsive to the owner's needs and desires as the budgetary, technical, and schedule constraints of the project allow*. To achieve this state, the owner must have determined in the solicitation documents how it will distribute the authority for the management of quality during design and construction, and that plan is essentially encapsulated in the quality management organization.

Quality Management Spectrum

In DB, the RFP must make the distribution of quality management responsibilities totally clear. The owner can choose to assign specific responsibilities to the design-builder and retain the rest for itself. Additionally, it is also possible to retain a third party to conduct quality management activities. This firm could be under contract to either the design-builder or the owner. The survey responses and content analysis indicated that this third party was given many different titles. Some of the more common were general engineering consultant, design oversight consultant, and independent quality consultant. It is not that the processes or activities for ensuring quality are different in DB. The vast majority of activities will remain the same. The difference lies with whom will be responsible for performing the activities (Tam et al. 2003). In 74% of the projects reviewed, quality management responsibilities were at least generally assigned in the solicitation documents. The other 26% may have had quality management responsibilities defined in other solicitation documents, such as incorporated references and policies that the authors were not able to access. This is almost identical to the survey response where 72% of respondents answered affirmatively to the question, "Do either your RFQ or your RFP contain quality management roles and responsibilities?" Once the quality management distribution decision is made, both the design-builder and the owner must assemble organizations to carry out those functions. Table 2 lists typical design and construction quality management tasks that must be assigned to one party or another to ensure quality on any transportation construction project.

Figure 8 is the theoretical spectrum of quality management extending from one end, where the owner conducts all quality management functions, to the other, where the owner assigns the total quality management program to the design-builder and satisfies its FHWA-mandated oversight responsibilities (Stefani 2004) using some form of PQA. Table 3 expands on the Figure 8 concept by showing the details of the possible combinations of quality management functions in tabular form. It moves from assigning all the quality management

TABLE 2
TYPICAL QUALITY MANAGEMENT TASKS ON TRANSPORTATION PROJECTS

	Design	Construction
Quality Control (QC)	Technical review of design deliverables Checking of calculations Checking of quantities Review of specifications	Technical review of shop drawings Technical review of material submittals Checking of pay quantities Routine construction inspection; QC testing Establishment of horizontal and vertical controls on site
Quality Assurance (QA)	Acceptance of design deliverables Approval of final construction documents Approval of design progress payments Approval of post-award QC plan	QA inspection QA testing Verification/acceptance testing Approval of construction progress payments Approval of post-award QC plan
Project Quality Assurance (PQA)	Approval of post-award QM/QA plans Audit of design QA activities Over-the-shoulder design review	Approval of post-award QM/QA plans Independent verification/acceptance testing Oversight

Note: These lists are not meant to be all inclusive.
After *Transportation Research Circular E-C074* (2006).

functions to the design-builder, as happens in many PPP projects overseas (Tyborowski et al. 1997), to the other end of the spectrum where the owner holds all the quality management functions. It also includes third-party QA participation as found in the DB RFP content analysis. This results in 14 different types of QA organizations.

Not all of these types of DB quality management organizations were found in the content analysis. Table 4 is an extract from Table 3 showing only the quality management organizations that were found in the solicitation document content analysis. The states that used each type of quality management organization are also listed. Additionally, a 2006 study completed for the Maryland State Highway Administration (SHA) on QA and QC organizations for DB mega-projects (Potter and McMahon 2006) substantiated the spectrum shown in Figure 8.

Classifying Quality Management Organizations

Table 4 illustrates two things. First, a large group of DOTs is comfortable assigning the majority of the quality management functions to the design-builder based on the number of times the Type 1 organization was observed in the RFP

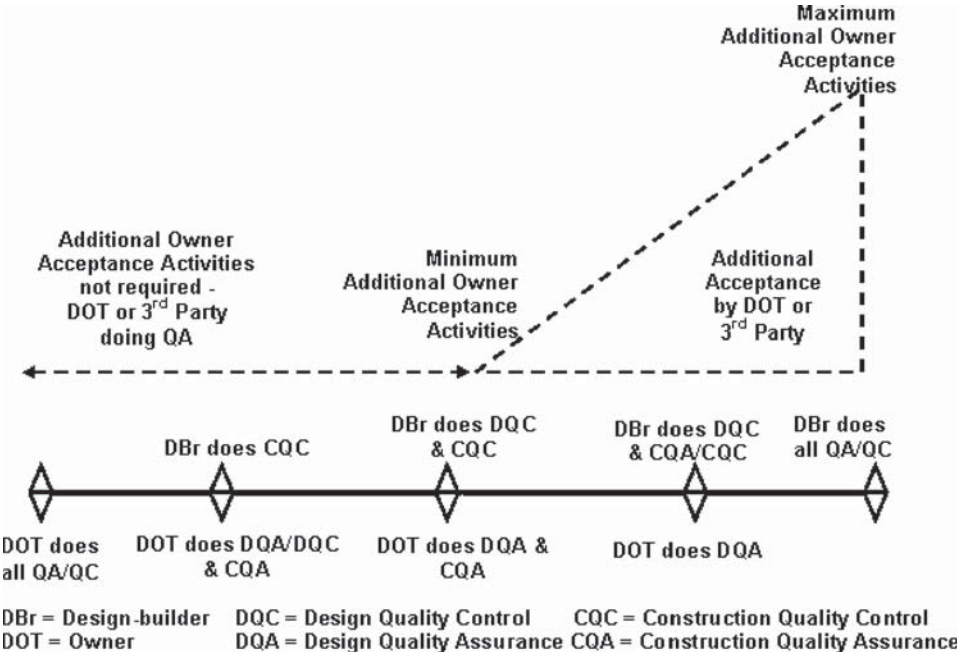

FIGURE 8 Quality management spectrum.

TABLE 3
POSSIBLE QUALITY MANAGEMENT ORGANIZATIONS

	Design QA	Design QC	Construction QA	Construction QC	Comments
Type 1	DBr	DBr	DBr	DBr	DOT oversight of design and construction
Type 2	DBr	DBr	DOT or 3rd	DBr	DOT and 3rd party share construction QA
Type 3	DBr	DBr	DBr and DOT	DBr	DOT and DBr share construction QA
Type 4	3rd	DBr	3rd	DBr	3rd party QA; DBr QC
Type 5	3rd and DBr and DOT	DBr	3rd and DBr and DOT	DBr	QA is shared; DBr QC
Type 6	DOT	DBr	DBr	DBr or 3rd	DOT design QA only
Type 7	DBr	DBr	DOT	DBr or 3rd	DOT oversight of design
Type 8	DOT	DBr	DOT	DBr	DOT QA; DBr QC
Type 9	DOT	DBr	DOT or 3rd	DBr or 3rd	3rd party is involved in construction QA or QC
Type 10	DBr and DOT	DBr	DOT	DBr	DOT and DBr share design QA only
Type 11	DBr and DOT	DBr	DBr and DOT	DBr	DOT and DBr share QA
Type 12	DOT	DOT	DBr	DBr	DOT oversight of construction
Type 13	DOT	DOT	DOT	DBr	DBr construction QC only; traditional DBB QM
Type 14	DOT	DOT	DOT	DOT	Force account project done with DOT forces

Note: DBr = design-builder; DOT = department of transportation (i.e., the projects owner); 3rd = third party (independent firm retained to conduct QA and QC or independent assurance responsibilities); QM = quality management.

content analysis. Second, some DOTs have chosen to vary the type of quality management organization that they employ from project to project. This can be seen for the states of Florida, North Carolina, Utah, and Virginia, which used more than one organizational type. All four of these states reported multiple DB project experiences and therefore have evolved their DB quality management approach based on their actual project experiences. This analysis leads to the conclusion that a DOT can add clarity to its RFP by classifying the type of quality management organization that it believes best suits the quality needs of a given project and publishing that organizational structure in its DB RFP.

To assist the readers of this document in applying the findings of this portion of the study to their own projects, examples of each type of quality management organization in Table 4 are now provided. Excerpts from actual RFPs explain exactly how each type of quality management organization is defined and how they were classified in the content analysis.

Type 1 Organization

Design-builder does all QA and QC, and DOT furnishes PQA—In the Type 1 organization, the design-builder is responsible for design QA and QC and construction QA and QC. The DOT retains responsibility for oversight of the design-builder's QA and QC activities through some form of PQA. This is referred to by various terms such as independent assurance, owner verification, or due diligence. In some

TABLE 4
QUALITY MANAGEMENT ORGANIZATIONS FOUND IN THE REQUEST FOR PROPOSAL CONTENT ANALYSIS

	Design QA	Design QC	Construction QA	Construction QC	States
Type 1	DBr	DBr	DBr	DBr	CA (Alameda Corridor), CO, MN, MO, NV, OR, TX, UT, VA, WA, Wash DC, EFLHD, Alberta
Type 2	DBr	DBr	DOT or 3rd	DBr	CA (San Joaquin Hills), FL, MN, UT, VA
Type 3	DBr	DBr	DBr and DOT	DBr	ME
Type 7	DBr	DBr	DOT	DBr or 3rd	NC, UT
Type 8	DOT	DBr	DOT	DBr	AK, FL, NC
Type 9	DOT	DBr	DOT or 3rd	DBr or 3rd	LA, MS, NC
Type 11	DBr and DOT	DBr	DBr and DOT	DBr	NM, SD

Note: DBr = design-builder; DOT = department of transportation (i.e., the project's owner); 3rd = third party (independent firm retained to conduct QA and QC or independent assurance responsibilities); EFLHD = Eastern Federal Lands Highway Division.

cases, a third-party independent quality firm is retained to conduct IA, oversight, and/or verification of the design-builder's QA and QC activities during both design and construction. This case corresponds to the maximum level of PQA activities in that the DOT is not involved in any of the QA activities that it usually conducts in a DBB project. An example from Missouri illustrates the RFP verbiage that would be associated with a Type 1 quality management organization.

> The Contractor shall perform the quality management necessary for the Contractor to comply with its obligations under the Contract Documents. . . . All materials and each part or detail of the Work shall also be subject to oversight, audit and testing by the Commission [DOT] and other Persons [third party] designated by the commission. (*Final Request for Proposals for The New I-64 Design-Build Project* 2006)

Type 2 Organization

Design-builder does design QA and QC and construction QC and DOT performs construction QA and design PQA—In the Type 2 organization, the design-builder is responsible for design QA and QC and construction QC. Because the DOT is not involved in design QA, it must perform design PQA, which is referred to as auditing, oversight, or review. The DOT is responsible for construction QA; therefore, there is no need for construction PQA. In certain cases, the DOT assigns the construction QA to an independent quality firm and does not perform the QA functions with the DOT's own forces. The following example from a MnDOT RFP indicates this type of organization.

> [Design] Design-Builder Responsibility. The objective of the DQMP [design quality management plan] is to place the *responsibility for conducting DQC [design quality control] reviews and performance of DQA [design quality assurance] duties solely with the Design-Builder,* yet allow the Department to fulfill its responsibilities of exercising due diligence in overseeing the design process and design products. The Department reserves the right to audit the DQMP.
>
> [Construction] Design-Builder Responsibility. The objective of the CQMP [construction quality management plan] is to place the *responsibility for conducting CQC* [*construction quality control*] *reviews and inspection duties solely with the Design-Builder*, yet enable the Department to perform its CQA [construction quality assurance] audits, IA, and acceptance testing [*T.H. 52* (*Rochester*) *Design-Build Request* . . . 2002, italics added].

Type 3 Organization

Design-builder is completely responsible for design QA and QC and construction QC, and construction QA is shared between design-builder and DOT. DOT performs design PQA—The Type 3 organization is similar to Type 2 in that the design-builder is responsible for the design QA and QC and the construction QC. The DOT must still perform design PQA either with its own forces or with an independent quality firm. The difference, however, lies with who performs the construction QA. In Type 3, both the design-builder and the DOT share responsibilities for construction QA. Because the DOT is involved in this, Type 3 does not require construction PQA. The Maine DOT used this approach as shown in the following RFP excerpt.

> [Design] [To be included in the proposal] . . . Describe the QC/QA procedures for preparing and checking all plans, specifications, calculations, reports, and all other documents that designers will prepare for use by the Design-Builder. Independent checking and back checking of these documents shall be in accordance with industry accepted practices. . . . [Construction] *The Design-Builder is responsible for all aspects of the quality of construction, including* labor, equipment, materials, incidentals, processes, construction methods, and *QC*. . . . The *Department is responsible for* approving the QCP [quality control plan], and *assuring that the Design-Builder is following the QCP*. . . . The Department may conduct Quality Assurance by review of QC Reports; random inspection of work; randomly accompanying the inspector during QC Inspections/Testing; sampling and testing (*Request for Proposals, I-295* . . . 2003, italics added).

Type 7 Organization

Design-builder is solely responsible for design QA and QC and may share responsibility for construction QC with an independent quality firm—DOT must perform design PQA and is responsible for construction QA. In the Type 7 organization, the design-builder is completely responsible for the design QA and QC of the project. Once again, the DOT must perform design PQA. Construction QC is shared between the design-builder and an independent quality firm or performed solely by the design-builder. The DOT performs construction QA. The following example from Utah indicates that the design-builder will be responsible for the construction QC.

> Perform [meaning the design-builder] all of the Quality Assurance (QA) tasks required to ensure that the design of the project complies with all of the terms of the Contract. *The Department will perform all of the Quality Assurance tasks required to ensure that construction meets all of the requirements of the Contract*. . . . Perform [referring to the design-builder] all of the Design Quality Control checks outlined . . . Perform [referring to the design-builder] all of the Quality Control (QC) inspection, sampling, and testing needed to ensure that the final installed product meets or exceeds the specifications outlined in the contract documents (*Request for Proposals SR-201* . . . 2004, italics added).

Type 8 Organization

Design-builder is responsible for all QC. DOT is responsible for all QA. PQA is not required—In the Type 8 organization, the design-builder is responsible only for the QC portion of the design and construction. The DOT performs the design and construction QA. PQA is not required because the DOT already is involved through QA in both design and construction. The MnDOT used this organization as outlined in the following RFP excerpt.

> To ensure the quality of the Design-Build project, *Mn/DOT 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 (*Part I: Scope of Work T.H. 100* . . . 2001, italics added).

Type 9 Organization

Design-builder is responsible for design and construction QC. DOT is responsible for design QA and shares construction QA with an independent quality firm—The Type 9 organization is similar to Type 8 in that the design-builder is responsible for the QC of the project and the DOT is responsible for the QA of the project. Also, PQA is not required for either design or construction because the DOT is involved in the QA. The difference from Type 8 is that an independent quality firm is involved in the construction QA for the project. The Mississippi DOT indicated the use of this organization in the following RFP.

> Project services shall include but are not limited to . . . *Quality Control for both design and construction services*. . . . Following the incorporation of [Mississippi DOT's] MDOT's comments from the Final Design Review Phase, the CONTRACTOR shall prepare and submit a Release for Construction submittal to MDOT for *MDOT's final review and Released for Construction stamp*. . . . The CONTRACTOR may proceed with Work in compliance with an approved Quality Control Plan including any associated sampling and testing requirements prior to receipt of a drawing depicting the Work as issue stamped "Released for Construction" and prior to the receipt of all required Governmental approvals; however, all such Work shall be at the CONTRACTOR'S sole risk. . . . *COMMISSION 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* (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Biloxi to Ocean Springs Bridge*. . . 2005, italics added).

Type 11 Organization

Design-builder is responsible for all design and construction QC, whereas design and construction QA is shared between the design-builder and the DOT—The Type 11 organization involves the design-builder in all aspects of quality management. The design-builder is completely responsible for the design and construction QC. The design and construction QA responsibilities are shared between the design-builder and the DOT. Thus, there is no need for PQA. The DOT is already involved in the QA. This is the organization used by New Mexico in a DB project as the following RFP excerpts indicate.

> ROLE OF THE DEPARTMENT . . . Oversight and audit of Contractor design and construction, including Verification Sampling and Testing . . . Independent Assurance. . . . The *Contractor will be required to plan, implement, and provide a Quality Assurance/Quality Control* (*QA and QC*) *Program for its design and construction operations*. . . . The Department will review the Contractor's program to assure that it meets guidelines and minimum requirements established by the Department. Department approval of the program will constitute Department agreement that it meets these criteria, but the Contractor shall maintain ownership of the program and shall be fully responsible for its execution. . . . *The Department may establish and maintain its own quality assurance* and/or an independent quality assurance organization to oversee and/or perform quality audits of the Contractor's management, design, construction and maintenance activities, the Contractor's Quality Assurance procedures, Verification Sampling and Testing and the quality of the final product (*Request for Proposals, US 70 Hondo Valley* . . . 2001, italics added).

Quality Management Organization Survey Responses

As seen in Table 4 and in the DB RFP citations that follow, there is no consensus on the best way for quality management responsibilities to be distributed in a DB project. In some cases, the DOT has chosen to make the design-builder responsible for all quality management functions and, in other cases, just for the QC functions. Often, there is a sharing of responsibility between the design-builder, the DOT, and/or a third-party independent quality firm. The survey results also offer no consensus on DB quality management responsibilities. When asked to indicate "Which of the below best describes your agency's approach to DB QA," the responses were mixed. Figure 9 shows the results for this question. As can be seen, "agency uses two or more of approaches" was the most popular answer (45%); however, it was closely followed at 35% by DOTs that place the primary QA responsibility on the design-builder while the DOT only audits or oversees the program—in other words, Type 1 as defined in Table 3.

The use of multiple approaches supports the findings in the content analysis of solicitation documents in which some state DOTs or agencies—such as Florida, North Carolina, and Utah—employed different quality management organizations

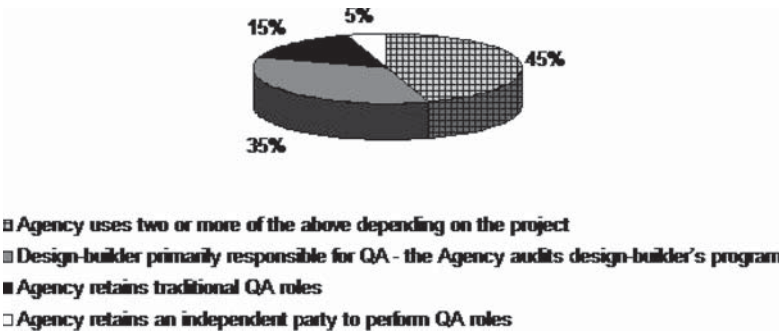

FIGURE 9 Survey responses for DOT approach for quality assurance.

for different projects. This may also indicate that not all quality management organizations neatly fit within the categories listed on the survey, and some respondents believed that there was no adequate answer. Respondents who answered in this manner could have had one of two possible meanings:

1. The agency makes the design-builder primarily responsible for QA and retains an independent consultant to perform what this report is now calling PQA, or
2. The agency retains its traditional QA roles and retains a consultant to assist it.

Unfortunately, the wording of this question does not allow one to differentiate between the two possible meanings. However, if one then looks at the question that asked the respondent to identify the primary responsibility for various traditional design and construction tasks, one can see that for most design and construction QA tasks, the majority response indicated that these responsibilities were assigned to the design-builders' team members with a relatively large share also being assigned to an agency-hired consultant, as shown in Figures 10 through 14.

It is interesting that the respondents who had more experience tended to shift more responsibility back to the agency. In every case shown in Figures 10 through 14 for the respondents with five or fewer projects of DB experience, the design-builder's staff had a higher percentage than the agency personnel. With the more experienced respondents, this only occurred in two of the categories: "checking of design calculations" and "technical review of construction shop drawings." This infers that the first possible meaning was probably indicated by more of the respondents than the second possible meaning.

It is also interesting that 15% of the agencies in Figure 9 retain the traditional QA roles in DB projects. This group may also be the one that had the least experience and as a result is still evolving its DB quality management policies and procedures on the DBB basis where the contractor has QC and the DOT has QA. Finally, Figure 9 shows that the approach involving an independent third-party firm conducting QA registered only 5% of the respondents. This does not mean that other approaches did not involve an independent firm in QA activities. This analysis furnishes no clear-cut consensus for how to best organize quality management roles and responsibilities in DB and probably serves best to reinforce the previous conclusion that quality management organizations need to be tailored on a project-specific basis. Specific examples can, however, be instructive in understanding the different options available to DOTs when performing a DB project.

When specifically analyzing construction QA activities, in some RFPs, the design-builder is responsible for the QA activities in construction, but is required to hire an independent third party to do the work, as shown in the following RFP excerpts from Virginia and Utah.

> [Virginia] The Offeror shall be responsible for 100% QA work and QA sampling and testing for all materials. These functions shall be performed by an independent firm that has no involvement in the construction QC program/activities [*Request for Proposals, A Design-Build Project Approaches and Bridge over Garden Creek Canal* (*Route 609*) . . . 2006].

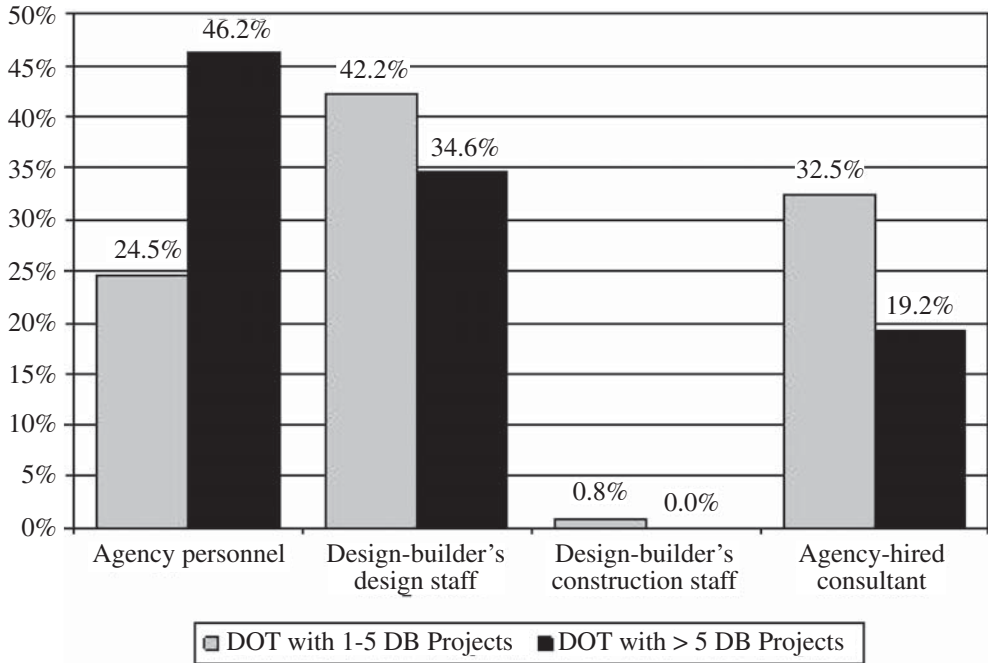

FIGURE 10 Comparison of experienced DOT assignment of responsibility for review of design deliverables with DOTs having 1 to 5 design-build projects' worth of experience.

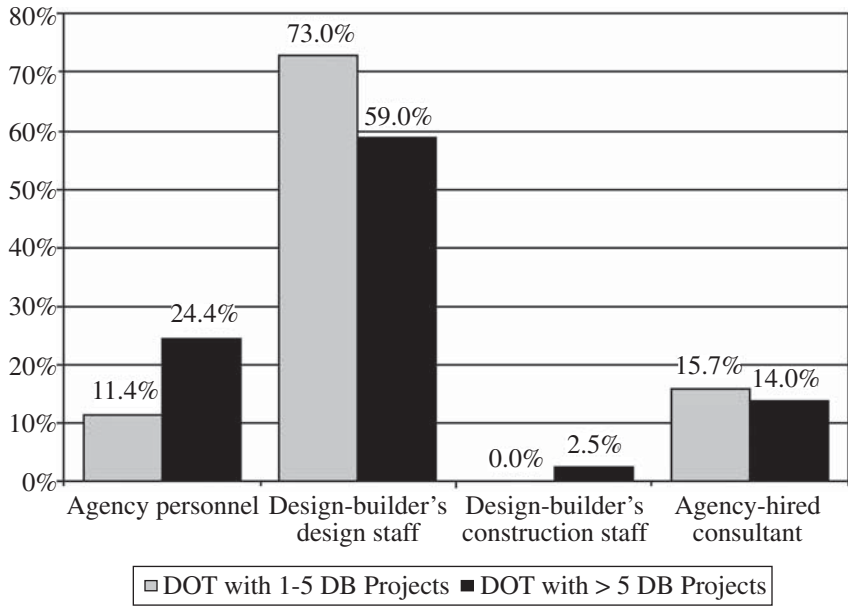

FIGURE 11 Comparison of experienced DOT assignment of responsibility for checking design calculations with DOTs having 1 to 5 design-build projects' worth of experience.

> [Utah] Members of the CQO [construction quality organization] who have TPOC [testing proof of compliance; i.e., QA] responsibilities (this includes the CPOC [construction proof of compliance] Manager) shall not be employees of constructors or suppliers working on or providing materials to the project (*Request for Proposals SR-265* . . . 2004).

In other cases, the design-builders are allowed to perform construction QA with their own employees who have no construction production responsibilities. The following example is from the Washington State DOT:

> Persons performing Quality Control and/or Quality Assurance functions shall be at an organizational level that reports directly to upper level management of the Design-Build firm to assure independence from the influences of the project production staff. All key personnel performing Quality Control and/or Quality Assurance functions shall be designated as such and shall not be assigned to perform any conflicting duties (*Request for Proposals, Thurston Way Interchange* . . . 2000).

However, one survey respondent believes that "ensuring independent QA Management from [the] contractor" is a

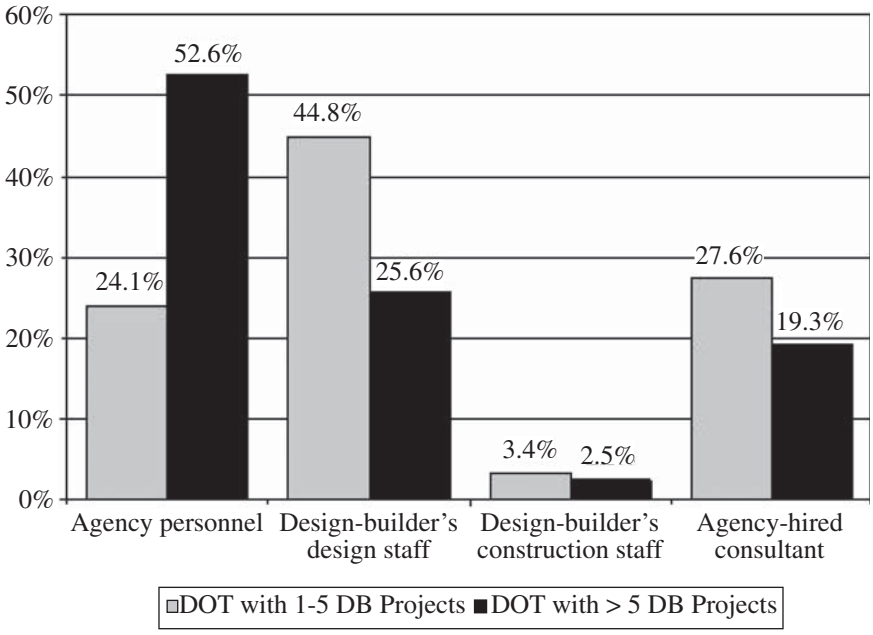

FIGURE 12 Comparison of experienced DOT assignment of responsibility for review of specifications with DOTs having 1 to 5 design-build projects' worth of experience.

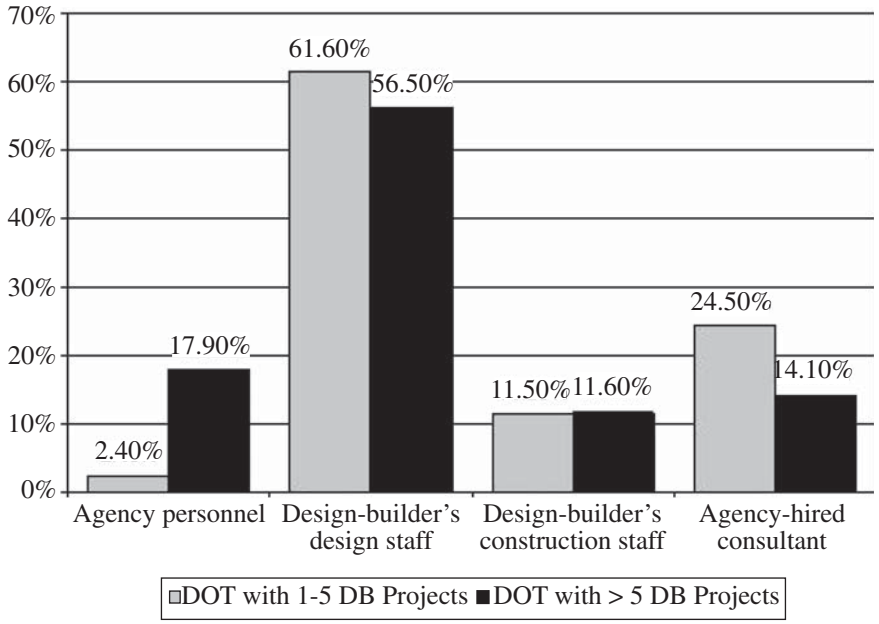

FIGURE 13 Comparison of experienced DOT assignment of responsibility for review of construction shop drawings with DOTs having 1 to 5 design-build projects' worth of experience.

challenge. On the other side of the contract, there are some DOTs that retain responsibility for construction QA, but may not perform it themselves. They state in the RFP that an independent third party may perform it. An example comes from the MnDOT.

> The Department's role in construction is to provide . . . quality assurance (QA) and independent assurance (IA) of all construction activities, inspection, and material testing. . . . *The Department will do this with either its staff or a consultant acting as its representative* (*Request for Qualifications T.H. 52* . . . 2001, italics added).

An interesting note is that none of the projects retained the traditional roles of QA and QC that are found in DBB where the contractor is only responsible for construction QC and the DOT performs design QA and QC and construction QA (Type 13 organization). All the DOTs have written RFPs that put more responsibility for quality on the design-builder. Another interesting finding is that in a few cases the DB RFP placed the responsibility for design QA and at times construction QA and QC on a third-party IA firm under contract with the design-builder. This was the case with Utah's I-15 project and Texas' Central Texas Turnpike

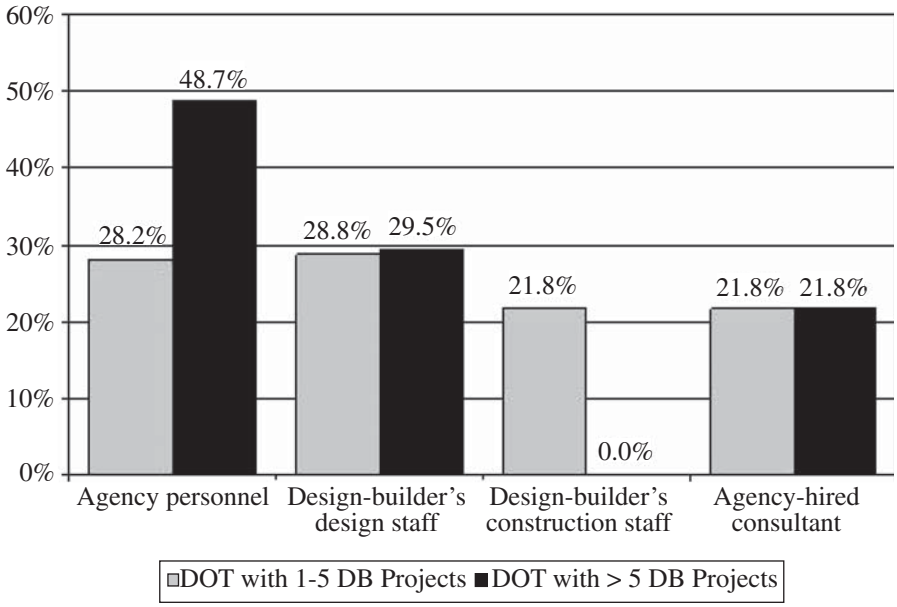

FIGURE 14 Comparison of experienced DOT assignment of responsibility for review of construction material submittals with DOTs having 1 to 5 design-build projects' worth of experience.

(SH 130), as well as in Florida, North Carolina, and Virginia on smaller projects.

For the projects that allocate all QA and QC responsibility to the design-builder, the DOT still has quality responsibilities. Ultimately, the DOT is the entity responsible to the public for getting the project finished at an acceptable quality level. A third layer of quality management, PQA, has been introduced for the purpose of the DOT ensuring that the design-builder has produced a product that meets the contract requirements and to satisfy the FHWA-mandated oversight requirements on federally funded projects. Often, this new layer is called verification testing, IA, audit, or oversight in the literature and the solicitation documents. One DOT respondent to the survey expressed this exact idea, in relation to design first and then construction, as follows:

> If a consultant designed the project for us (owner) on a traditional DBB project, we wouldn't require as extensive of QA and QC practice nor would we audit the process like we do on our Design-Build projects. We have placed more QA, QC, and inspection requirements on the design-build team. *We also added an additional layer of testing* (verification testing) that the department must do. However, we plan on changing back and reducing the number of layers (combining QA and QC) and having the department play a more active role in testing and inspection (italics added).

Two other respondents to the survey also expressed a similar observation in relation to construction:

- "A significantly greater [construction quality] responsibility is given to the contractor . . . [the] Department primarily does only verification testing."
- "Quality activities are performed by Design/Build personnel and [are] clearly described in the approved QA and QC program. Oversight of [the] quality program [is performed] by [the] agency and/or [a] consultant."

Applying the Project Quality Assurance Model to Organizations

By definition, PQA cannot be performed by the design-builder. It must be performed by the DOT or by an independent third-party firm. This prevents the design-builder from being responsible for all the QA and QC. Table 5 is a revision of Table 4 with the added PQA category in quality management organizations in which PQA is necessary. It should be noted that QA organization Types 8, 9, and 11 shown in Table 3 do not require PQA and therefore are not included in Table 4. The 2006 Maryland SHA study of DB mega-project QA and QC found that 8 of the 11 case study projects surveyed used what the Maryland report called "quality oversight," which is essentially the same as the activities that this synthesis calls PQA (Potter and McMahon 2006), validating the above findings. The report also stated that the Maryland SHA "do[es] not have a separate Quality Oversight (QO) program developed . . . so [will] need to develop the program and train their staff" (Potter and McMahon 2006).

When the DOT or a third-party firm is involved in QA activities there is no need for the PQA activities. This is shown in Types 2, 3, and 7. PQA is needed only for the design portion of the work because the DOT is involved in construction QA. Some examples are given here to illustrate how this has been defined in RFPs. Keep in mind that each of these RFPs first assigned the QA responsibility to the design-builder. For Type 1, this includes both design and construction QA; for Types 2, 3, and 7, only design QA was assigned to the design-builder.

PQA Model Type 1 Organization

DOT or independent quality firm provides PQA for design and construction—In the revised Type 1 organization, either the DOT or an independent quality firm must provide PQA for both the design and the construction of the project. This is required because the design-builder carries the responsibility for both the design and construction QA and QC. The only possible way for the DOT to ensure that the design-builder's quality management plan is effective is to review it in some manner. The RFPs in the content analysis referred to this as due diligence, oversight, validate, verify, or audit. This organization is shown in Figure 15.

The following RFP excerpts show how this has been written into the solicitation documents.

> [Colorado] [The design quality management process] Allows the SEC [Southeast Corridor] Representative to fulfill its responsibilities of exercising *due diligence in overseeing the design process* and design products by the Contractor demonstrating, through its quality assurance process, that the DQMP is understood and followed by the Contractor's organization. . . .

TABLE 5
QUALITY MANAGEMENT ORGANIZATIONS WITH PQA

Type	Design QA	Design QC	Design PQA	Construction QA	Construction QC	Construction PQA
1	DBr	DBr	DOT or 3rd	DBr	DBr	DOT or 3rd
2	DBr	DBr	DOT or 3rd	DOT or 3rd	DBr	none
3	DBr	DBr	DOT or 3rd	DBr and DOT	DBr	none
7	DBr	DBr	DOT or 3rd	DOT	DBr or 3rd	none

Note: DBr = design-builder; DOT = department of transportation (i.e., the project's owner); 3rd = third party (independent firm retained to conduct QA and QC or independent assurance responsibilities).

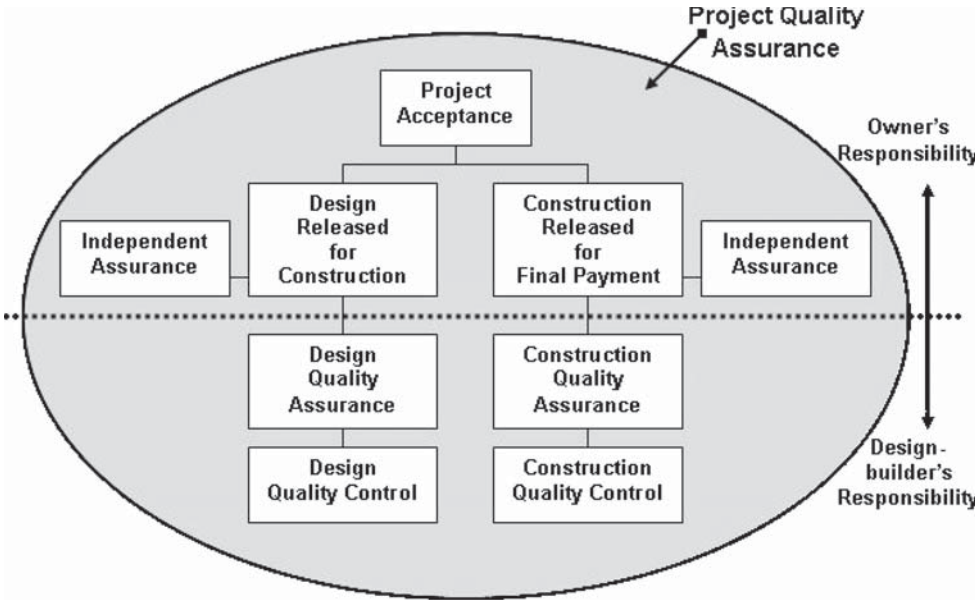

FIGURE 15 Design-build project quality assurance model for a Type 1 quality management organization.

[The construction quality management process] Allows the SEC Representative to fulfill its responsibilities of exercising *due diligence in overseeing the construction process* by the Contractor demonstrating through the quality assurance process that the CQMP is understood and followed by the Contractor's organization (*Request for Proposal, Book 1* . . . 2000, italics added).

[Utah] [After assigning QA to the design-builder] The Department will perform *Independent Assurance* (*IA*) *testing and inspection* to validate the accuracy and reliability of the CPOC [construction proof of compliance] testing and inspection. The Department will also perform *Verification inspection and testing* to confirm that the work and materials meet contract requirements. . . . The *Department will audit*, as needed, the DPOC [design proof of compliance] processes and Design Documents to *verify compliance* with the Contract Documents. The Department will be invited to attend all reviews (*Request for Proposals Parley's Crossing Tunnel* . . . 2004, italics added).

[Virginia] . . . the VDOT will limit their *design oversight* to spot checks to insure that the design work complies with the RFP requirements. . . . The VDOT's construction role will be limited to *oversight* of the QA firm activities, *verification* sampling and testing, *independent assurance* sampling and testing, review of progress payments, and *oversight* of the contractor's construction management scheduling, document control, etc. (*Request for Proposals, A Design-Build Project Design and Construction* . . . 2002, italics added).

[Washington State] WSDOT . . . will *comment* on Design Work, but *will not require comment responses* unless work is deemed to be outside the provisions of the contract. . . . [After assigning QA to the design-builder] Department Responsibilities Verification sampling and testing will be performed by WSDOT to *validate* Design-Builder sampling and testing as well as the quality of the material produced. An *Independent Assurance* Program will also be conducted by WSDOT to evaluate all sampling and testing used in the acceptance of material (*Request for Proposals, Thurston Way Interchange* . . . 2000, italics added).

PQA Model Type 2 Organization

DOT or independent quality firm provides PQA for design and construction QA—In the Type 2 organization shown in Figure 16, PQA is necessary only for the design of the project. The construction quality is already ensured by the DOT participation in construction QA. Oversight of design is necessary to ensure that the design-builder's quality program fulfills its intended function. The following example from Minnesota expresses the required design PQA function of the DOT.

> The objective of the DQMP is to place the responsibility for conducting DQC reviews and performance of DQA duties solely with the Design-Builder*, yet allow the Department to fulfill its responsibilities of exercising due diligence in overseeing the design process and design products*. The Department reserves the right to audit the DQMP [*T.H. 52* (*Rochester*) *Design-Build Request for Proposals* . . . 2002, italics added].

PQA Model Type 3 Organization

DOT or independent quality firm provides PQA for design and DOT shares construction QA with design-builder—In the Type 3 organization (see Figure 17), as in the Type 2 organization, PQA is necessary only for the design of the project. The construction quality is already ensured by the DOT participation in construction QA. Oversight of design is necessary to ensure that the design-builder's quality program fulfills its intended function. The following example from Maine expresses the required design PQA function of the DOT.

> The DQMP objective is intended to place the responsibility for the quality of the design on the Design-Builder, facilitate construction by the Design-Builder, and allow the *Department to*

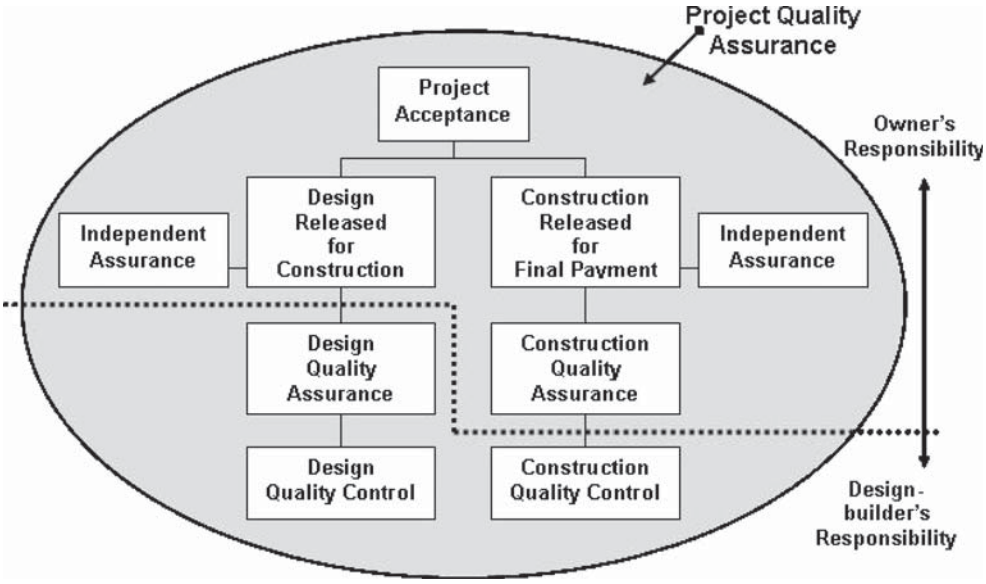

FIGURE 16 Design-build project quality assurance model for a Type 2 quality management organization.

fulfill its responsibilities of exercising due diligence in overseeing the design process and products (*Request for Proposals, I-295 Commercial Street Connector* . . . 2003, italics added).

PQA Model Type 7 Organization

DOT or independent quality firm provides design PQA and construction QA; independent quality firm shares construction QC with design-builder—In the Type 7 organization (see Figure 18), as in the Type 2 and Type 3 organizations, PQA is necessary only for the design of the project. The construction quality is already ensured by the DOT participation in construction QA. Oversight of design is necessary to ensure that the design-builder's quality program fulfills its intended function. The following example from Utah expresses the required design PQA function of the DOT.

> The DESIGN-BUILDER will review all designs to ensure the development of the plans and specifications are in accordance with the requirements of the Contract. . . . *The Department will audit, as needed*, the DESIGN-BUILDER processes and Design Documents to verify compliance with the Contract Documents. The Department will be invited to attend all reviews (*Request for Proposals Parley's Crossing Tunnel* . . . 2004, italics added).

There were several instances in which the entire quality management structure was not clearly defined in the solicitation documents reviewed by the authors. Because any change in the traditional quality management structure would have to

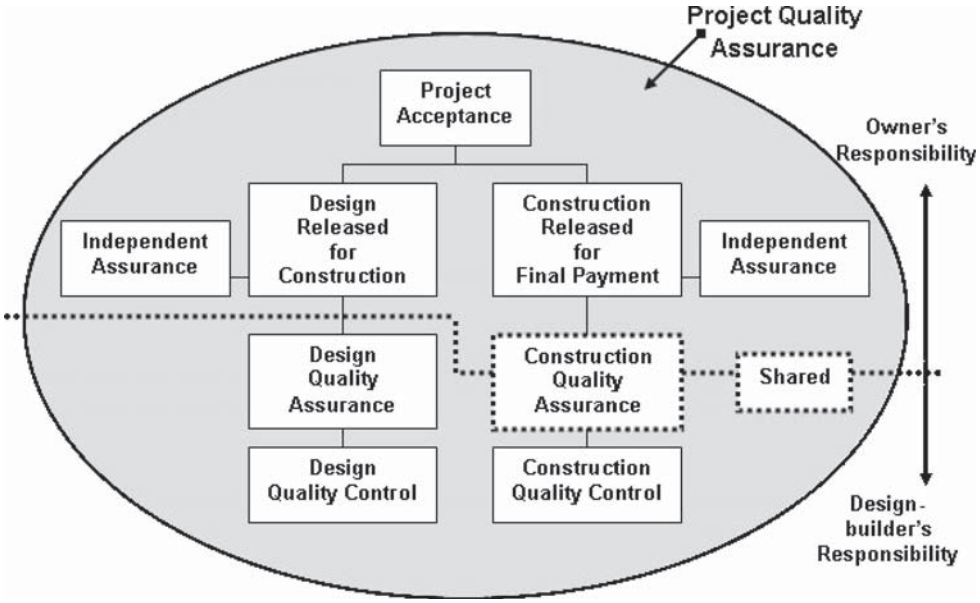

FIGURE 17 Design-build project quality assurance model for a Type 3 quality management organization.

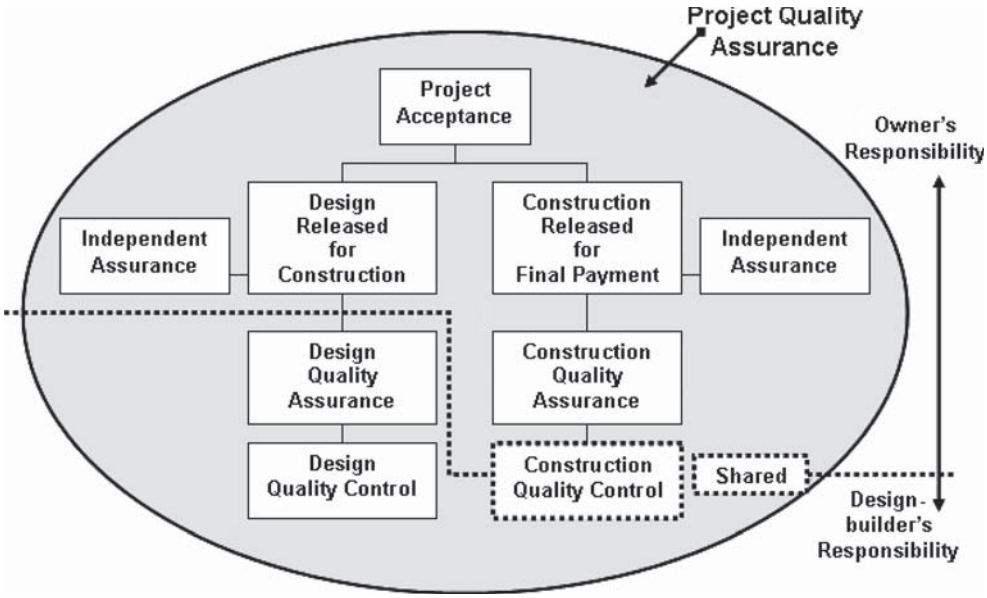

FIGURE 18 Design-build project quality assurance model for a Type 7 quality management organization.

be outlined in the contract documents, it was assumed, for the purposes of design QA, that the DOT would perform design QA activities unless specifically stated in the RFP. In regard to the other projects in which not enough information was obtained, there were no more assumptions made; however, with the information obtained from the content analysis, it was determined that all projects have quality management structures that will most likely correspond to the ones outlined in Table 4.

QUALITY RESPONSIBILITIES IN DESIGN-BUILD

One of the most challenging aspects of DB is having all parties clearly understand their roles in regard to design and construction quality. It is very important that the DOT ensure that it writes its RFP with a clear definition of how the quality management responsibilities will be assigned between the owner and the design-builder. The solicitation document content analysis found that no DOT used the same quality management organization on DB that is traditionally used on DBB projects. The DB PQA model as applied to the different quality management organizations makes the DOT and the design-builder responsible for different aspects of quality. As stated by the Arizona DOT in the *Design-Build Procurement and Administration Guide* (2001),

> Both the Design-Builder and the Department are jointly responsible for quality management. The Design-Builder is responsible for quality as the producer and constructor, while the Department is responsible for quality as a specifier and buyer.

DB requires that all of the traditional quality management tasks that were performed for DBB also be completed in execution of the DB project. The difference is merely the assignment of the responsibility for each task to the owner, a third-party independent quality firm, or the design-builder. This "shifting of responsibility for QA and QC . . . requires clear definition of roles for both the owner and contractor. The owner and contractor must carefully define the QA and QC program, including roles and responsibilities, within the bid documents so those participants are clear as to their requirements" (Carter et al. 2002). This places the quality roles in the contract documents where all parties are legally bound to follow them. The need for clearly defining quality responsibilities has been documented by other studies (Strong 2005). Indeed, even the FTA *Quality Assurance and Quality Control Guidelines* state, "QA/QC program effectiveness hinges on clear allocation of roles and responsibilities to the involved parties" (Carter et al. 2002). This is also an issue that was brought up by survey respondents when asked for the three biggest challenges to implementing QA on DB. One respondent listed "communicating QA/QC roles" as the number one challenge, whereas another respondent listed "recognize the difference between QC and QA."

Several state DOTs have written guidelines to help their employees better understand and implement DB in an organized manner. These guidelines provide general and/or detailed state accepted and required procedures for implementing DB projects. The authors analyzed 17 of these guidelines, searching for how quality responsibilities were communicated within DOT policy documents. Two different types of quality definitions exist in the state DB guidelines: explicit and open-ended. In addition, some guidelines do not specifically mention the roles for quality management. In seven of the guidelines, the quality management responsibilities are left open-ended, whereas explicit quality management responsibilities are used four times. In six instances, quality management responsibilities are not mentioned in the guidelines. The explicit guidelines mandate the way the DOT will handle DB quality management responsibilities, whereas the

open-ended guidelines allow the quality management responsibilities to be determined on a project-by-project basis, but some quality management responsibilities may be explicitly defined (see Arizona DOT). Examples are given here.

- Explicit (Colorado): The Contractor shall be responsible for Quality Control inspection and testing. The plans should address any QC requirements that the Contractor must follow which are in addition to those already in the reference specifications, policies, and procedures. The Contractor should be required to provide a Quality Control Plan (QCP), which outlines details of inspection and testing to control quality products (plans, construction, etc.). Quality Assurance (QA) is the responsibility of CDOT [Colorado DOT]. QA consists of all the sampling, testing, and inspection necessary for CDOT to assure conformance with the contract requirements (*Design-Build Guidelines* 1997).
- Open-ended (New York): During preparation of the RFP the Department's Project Management Team will need to determine the Design-Builder's inspection requirements and sampling and testing requirements for both Verification Sampling and Testing (by the Department) and QC sampling and testing (by the Design-Builder). . . . The Department's Project Management Team will need to determine the specific QA and QC requirements for each project (*Design-Build Procedures Manual* 2005).
- Open-ended (North Carolina): "The Department will determine the type of Construction Engineering Inspection and Quality Assurance to be required on a project by project basis. The Department will consider the selected design-build team, a third party private engineering firm or existing Department construction staff to provide these services" (*Design-Build Policy & Procedures* 2000).

The Arizona DOT *Design-Build Procurement and Administration Guide*—(2001) allocates quality management responsibilities in the following excerpt:

- Quality Control—always the Design-Builder's.
- Quality Conformance Inspections—either the Design-Builder's or the Department's.
- Quality Acceptance Sampling and Testing—either the Design-Builder's or the Department's.
- Quality Verification—always the Department's including checklist completion.
- Independent Assurance—always the Department's.
- Acceptance of the Work—always the Department's; can use the results from the Design-Builder's quality conformance inspections and quality acceptance sampling and testing in arriving at a decision.

Different reasons may exist for this difference in quality management responsibility allocation that is spelled out in the state DB guidelines. Some states may feel more comfortable with the DB process and have experienced staff to make the necessary quality management responsibility allocation.

Quality Assurance Responsibility Matrices

In addition to communicating effectively within the DOT organization, it is also imperative that the competitors on a DB project understand what is required of them to fulfill the contract requirements. One seemingly effective way to communicate quality tasks is to present the different tasks and the respective responsible parties in the form of a matrix or chart that is easily understood. In the Arizona DOT Cortaro Road Interchange RFP, such a matrix was published, furnishing a clear way to ensure that all parties to a contract understand their quality management responsibilities. In the RFP analysis, this was the only one that included a responsibility matrix for construction and a matrix for design and construction quality responsibilities. This Arizona DOT RFP quality responsibility matrix is reproduced in Appendix B to provide the reader an example from which to develop a similar tool for a future DB project.

The responsibilities were divided into those for which the design-builder is responsible and those for which the DOT is responsible, thus clarifying the design-builder's responsibilities in regard to the project. Washington State DOT, in their *Guidebook for Design-Build Highway Project Development* (2004), has developed a risk matrix (Table 6) to show on a project-by-project basis the shift in QA responsibilities when comparing DBB with DB. The following comes from an example project given in the *Guidebook*. Although the Washington State DOT uses this matrix internally and does not currently include it in its RFPs, the inclusion of this type of matrix in the RFP would facilitate the understanding of the design and construction quality responsibilities in DB projects.

These examples, along with other studies, conclusively show that QC is almost always placed on the DB contractor (Parsons Brinckerhoff 2002; McLawhorn 2003; Bourne 2006). QA, however, is much more varied. A report for the Wisconsin DOT stated that "many states choose to retain QA oversight, but confer QA responsibility on the [design-build] contractor" (McLawhorn 2003). This is nearly the same conclusion reached by a study performed for the Texas DOT that said "Although a few agencies view QA as the sole responsibility and purview of the owner, some owners are moving towards placing the QA responsibility in the hands of the design-builder, while retaining an oversight QA function through monitoring and/or auditing and independent assurance testing"—that is, PQA (Gharaibeh et al. 2005). This report qualified this statement by saying that "Agencies that have experienced quality problems on projects are retaining QA responsibility" (Gharaibeh et al. 2005).

Risk Allocation in Quality Assurance Organizations

Assigning responsibility for quality management tasks essentially creates a distribution of risk among the parties to the DB contract. Therefore, a DOT could undertake a deliberate

TABLE 6
WASHINGTON STATE DOT DESIGN-BUILD PROJECT RISK MATRIX

Risk	Design-Bid-Build			Design-Build Process	
	Owner	Shared	Contractor	Owner	Design-Builder
Design Issues					
Plan conformance with regulations/guidelines/RFP	X				X
Plan accuracy	X				X
Design criteria	X			X	
Conformance to design criteria	X				X
Design review process	X				X
Design QC	X				X
Design QA	X				X
Owner review time	X			X	
Changes in scope	X			X	
Constructability of design	X				X
Construction					
DBE compliance			X		X
Safety/safety QA			X		X
Construction quality/workmanship			X		X
Schedule			X		X
Materials quality			X		X
Materials documentation			X		X
Material availability			X		X
Initial performance requirements of QA plan	X			X	
Final construction/materials QC/QA plan	X				X
Construction/materials QA	X				X
Construction QC			X		X
Construction QA procedural compliance auditing	X			X	
Construction IA testing/inspection	X			X	
Construction staking		X			X
Erosion control		X			X
Spill prevention		X			X
Shop drawings			X		X
Equipment failure/breakdown			X		X
Work methods			X		X
Early construction/at-risk construction		X			X
Community relations	X			X	
Performance of defined mitigation measures	X				X
Warranty	X				X

After *Guidebook for Design-Build Highway Project Development* 2004.

risk analysis similar to the one shown in Table 6 before making its final decision as to the appropriate QA organization that is appropriate for a particular project.

Table 7 is an example of applying the Washington State DOT (*Guidebook for Design-Build Highway Project Development* 2004) risk model to comparing a Type 1 organization (see Figure 15) in which the design-builder is assigned most of the QA responsibility with a Type 8 organization shown in Figure 19 in which the DOT will perform the design and construction QA.

One can clearly see the differences in risk allocation by choosing one organization over the other. In Table 7, one can see that there are more shared risks for the Type 1 organization compared with the Type 8 organization. Shared risk typically translates to the potential for disputes and delays unless the DOT clearly defines how those shared risks will be divided between the parties. Therefore, this type of analysis provides not only a visual way to display the allocation of risk, but also a mechanism for identifying those areas in which further clarification in the DB project's solicitation documents is needed. It might also result in an excellent means with which to communicate the DOT's intent for risk allocation by including the matrix in the DB RFP.

INDEPENDENT CONSULTANTS AND QUALITY IN DESIGN-BUILD

A point to consider in the rearranging of quality tasks in DB is the involvement of outside, independent consultants working either for the design-builder or for the DOT. Conventional wisdom says that DOTs have fewer professionals to manage the increasing workload. Outside professionals hired for a short time can supplement standard DOT forces in times when the workload is heavier than normal. The FHWA's final rule on DB contracting ("Design-Build Contracting: Final Rule" 2002), while retaining the previous rules for QA on federally funded projects, gives DOTs significant latitude with regard to the details of how they meet their federally mandated QA responsibilities. The final rule allows DOTs to rely on a "combination of contractual provisions and

TABLE 7
EXAMPLE RISK ANALYSIS FOR TYPE 1 VERSUS TYPE 8 QUALITY ASSURANCE ORGANIZATIONS

	Type 1			Type 8		
Risk	Owner	Shared	Design-Builder	Owner	Shared	Design-Builder
Design Issues						
Plan conformance with regulations/guidelines/RFP		X				X
Plan accuracy		X				X
Design criteria	X			X		
Conformance to design criteria	X					X
Design review process		X				X
Design QC			X			X
Design QA			X			X
Owner review time			X	X		
Changes in scope	X			X		
Constructability of design			X			X
Construction						
DBE compliance			X			X
Safety/safety QA			X			X
Construction quality/workmanship			X			X
Schedule			X			X
Materials quality		X				X
Materials documentation		X				X
Material availability			X			X
Initial performance requirements of QA plan	X			X		
Final construction/materials QC/QA plan	X					X
Construction/materials QA	X			X		
Construction QC			X			X
Construction QA procedural compliance auditing		X		X		
Construction IA testing/inspection	X			X		
Construction staking			X			X
Erosion control			X			X
Spill prevention			X			X
Shop drawings			X			X
Equipment failure/break			X			X
Work methods			X			X
Early construction/at-risk construction		X				X
Community relations		X			X	
Performance of defined mitigation measures		X				X
Warranty		X				X

acceptance methods." It also permits DOTs to rely on "quality control sampling and testing as part of the acceptance decision, provided that adequate verification of the design-builder's quality control sampling and testing is performed to ensure that the design-builder is providing the quality of materials and construction required by the contract documents" ("Design-Build Contracting: Final Rule" 2002). Therefore, the use of independent consultants in a DB PQA program is not constrained by federal regulations.

In the selection of solicitation documents analyzed, five RFPs were found that required construction QC to be performed by an independent quality firm; three of these came from North Carolina, one from Louisiana, and one from Florida. All chose to require that the design-builder hire the independent consultant and the cost was included in the DB contract. Theoretically, the DOT could itself choose to retain the independent consultant. Excerpts from the RFPs from each state are cited here.

> [North Carolina] The Design-Build team shall employ a private engineering firm to perform Construction Inspection for all work required under this contract. . . . The CEI [construction engineering and inspection] firm shall be responsible for all construction inspection, field materials sampling and testing, and technician level contract administration for the construction of the project (*Design-Build Package: I-77 South* . . . 2005).

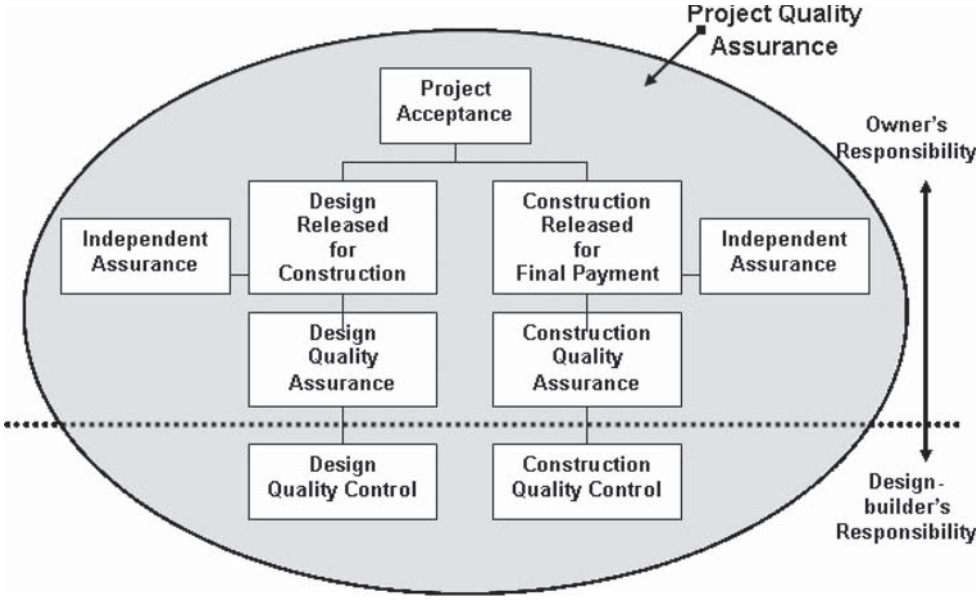

FIGURE 19 Design-build project quality assurance model for a Type 8 quality management organization.

> [Florida] The DESIGN BUILD FIRM will provide a separate (independent) entity to perform Quality Control Engineering (*Interstate 75 over the Peace River Bridges* . . . 2001).

> [Louisiana] The Design-Builder shall retain the services of an independent engineering consulting organization (the QC Engineering Firm) to oversee, manage, certify, and perform construction QC activities . . . (*Request for Proposals, New Mississippi River Bridge* . . . 2005).

For construction QA, independent quality firms were required to participate in only five cases. Two of these were mega-projects (SH 130 in Texas and I-15 in Utah) and three were smaller projects in Virginia. All the construction QA was contractually required to be performed by the independent quality firm operating under contract with the design-builder. In the case of some RFPs from Minnesota, the DOT included the option to use either an independent firm or the DOT forces to perform construction QA.

For design QA and QC, the conclusion from the solicitation documents examined is that design QA responsibility was assigned to either the DOT or the design-builder. In all cases, design QC was performed by either the DOT or the design-builder. This does not indicate, however, that independent firms were not involved in design QA and QC procedures. In some instances, the RFP stated that if a design-builder did not have enough qualified professionals to independently perform the design and the subsequent quality checks, an independent firm must be contracted to perform those services. An excerpt from a RFP from the Maine DOT provides an example.

> If Design Checkers are not available within the design firm conducting the design work, the Design-Builder shall arrange with an independent firm, other than the design firm or subsidiaries of the design firm, to conduct QC checks (*Request for Proposals, I-295 Commercial Street Connector* 2003).

SUMMARY

To produce a quality product, an organization to manage quality activities must be in place. With the changing quality roles found in the DB delivery method, it is imperative that quality responsibilities and the responsible parties are clearly stated in the contract documents. This will alleviate confusion and help both DOTs and design-builders better understand their roles on each project. As found in the solicitation document content analysis and confirmed by the survey responses, there is no single way in which these quality management responsibilities are distributed across all DB projects. Therefore, it is even more important that they be clearly stated in the solicitation documents.

CHAPTER THREE

DESIGN-BUILD QUALITY ASSURANCE PRACTICES DURING PROCUREMENT PHASE

POINT OF GREATEST INFLUENCE

For each transportation DB project, the quality process starts in the procurement phase. For purposes of this report, the procurement phase is defined as including all actions taken by the DOT before awarding the DB project. Thus, it will encompass all preliminary design activities necessary for the identification of right-of-way requirements and environmental clearances, as well as advancing the design to a point at which it becomes an adequate description of the scope of work. This phase also includes the activities undertaken during advertising, qualifications/proposal evaluation, discussions, and best and final offers. Once the DB contract is awarded, the procurement phase is complete.

In a review of the I-15 DB project in Utah, a consultant stated, "it is during the development of the RFQ [request for qualifications] and RFP [request for proposals] that the ultimate quality of the project can be most influenced" (Drennon 1998). The relationship between the influence of quality and the stage of the project is shown in Figure 20. Quality is most influenced in procurement and at the beginning of design but rapidly falls off during the later stages of design, construction, and maintenance. During the procurement phase, decisions are made as to what is included in the RFQ and/or RFP. Some of these decisions are already decided by state law or published department DB guides. Other decisions are left to be made on a project-by-project basis. This chapter discusses the specific quality management decisions involved in this phase.

The major issues that must be determined are as follows:

- Determining the level of design development to be depicted in the RFP;
- Determining the types and details of proposed design development elements that will be required to be contained in the design-builder's proposal and how these will be evaluated;
- Determining the requirements for post-construction operations and maintenance, if appropriate;
- Selecting the type of quality management organization that will be used for this project (see chapter two for details);
- Selecting the qualifications that are required for the design-builder's quality management team and how they will be evaluated;
- Identifying the types and content of QA and/or QC plans required to be submitted with the design-builder's proposal;
- Identifying the types and content of QA and/or QC plans required to be submitted for DOT review and approval after award; and
- Identifying other quality tasks as may be required by the project's specific needs.

DESIGN-BUILD QUALITY MANAGEMENT PROCUREMENT STRATEGY

DB procurement can be done a number of ways, but most methods can commonly be classified as either a one-step or a two-step DB procurement process (Beard et al. 2001). In one-step procurement, the competing design-builders submit their qualifications and past performance information in a single package along with their technical and price proposal. The owner then evaluates all components (qualifications, past performance, technical approach, and price) of the proposals and makes the award decision in a single action.

Two-step procurement models are often likened to the qualifications-based selection model used in architect/engineer design services contracting in that the first step is the submission of qualification/past performance information in response to an RFQ, which is then evaluated by the DOT without regard to price or technical approach. A "short list" of the most qualified competitors is assembled. The short-listed firms are then issued the RFP and submit price and technical proposals. The major advantage of this system is that competitors who are not well qualified are spared the expense of preparing an unsuccessful proposal. In addition, this system has the advantage to the DOT of deepening the pool of potential competitors by reducing the cost of competing (Gransberg et al. 2006). It also reduces the amount of time and energy that a DOT has to invest in the evaluation process by limiting the number of proposals that must be evaluated to only those that come from the best qualified competitors. From a quality management perspective, the two-step process is preferred because it allows the DOT to focus on the potential ability of the pool of competitors to be able to successfully deliver both design and construction quality during the first step without muddying the waters with technical and price information. *Transportation Research Circular E-C090* describes the two-step selection process as "essential for success" (Bourne et al. 2006). It also allows the DOT to be very specific as to the

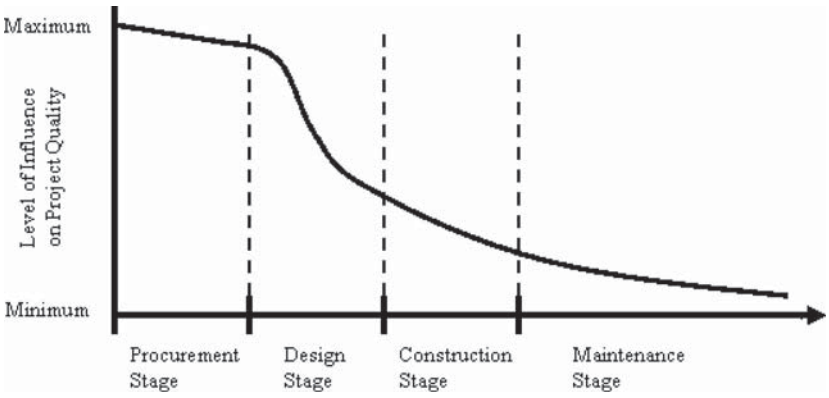

FIGURE 20 Relationship between project stage and influence of quality (adapted from Nickerson and Sabol 2003).

types of personnel and experiences that it believes will enhance the potential for delivering a high-quality completed project.

Leveraging the Two-Step Selection Process

DOTs can leverage their opportunity to influence quality on a DB project by using the two-step selection process. Once the owner issues the RFQ, the design-builders are able to identify the types of design, construction, and quality professionals that they need to be able to make the short list. Additionally, they are able to begin the process of making teaming arrangements with design specialty subconsultants and construction trade contractors to build a highly qualified DB team whose portfolio includes the types of past project experience that the DOT has deemed important to the quality of the given project. They then respond with a statement of qualifications, which is reviewed by the DOT. The short-listing decision is made, and the members of the short list are issued the RFP. In the RFP content analysis of 66 DB projects, 89% of the projects analyzed used the two-step RFQ/RFP process, which shows the wide acceptance and use of this practice.

The two-step process is also a good way to add extra weight to quality components of the project through the requirements stated in the RFQ. This correlates with findings regarding the pre-award evaluation of competitor qualifications reported by Qaasim (2005) for federally funded transit projects. Note that Qaasim calls the competitors "vendors" and "suppliers." He found that

> . . . governmental transit agencies rarely invest in Quality Assurance Pre-Assessments of prospective vendors since they are often constricted by tight budgets and typically use a low bid process. *In fact, using Federal guidelines, even a federally funded 'Best-Value Procurement' often uses a 45% weighting for cost, which in most cases still results in the low bidder receiving the award.* Since we were unable to employ pre-qualification supplier quality audits before contract award, we lost the value of this important tool and had to rely on subsequent quality audits to identify supplier deficiencies (emphasis added by author).

The finding that the two-step process worked successfully in public projects was confirmed in a 1999 study (Molenaar et al. 1999) of 104 public-sector DB projects, which concluded that "public-sector owners should choose the two-step method whenever cost and schedule growth are critical to the project success." The study went on to advocate the use of best-value selection authorized in the 1996 Federal Acquisition Reform Act when it stated that: "The two-phase design/build method outlined by the 1996 Federal Acquisition Reform Act delivers the best overall budget and schedule performance."

This is not the only study to recommend the use of best-value based procurement to achieve higher quality. In the *Recommended AASHTO Design-Build Procurement Guide*, the authors stated the following:

> Procuring design-build projects through best-value methods enables agencies to assess the quality of design, the qualifications of design-builders, and a number of other non-price factors. Traditional design-bid-build project delivery does not allow the agency to consider these important aspects of quality in the procurement decision. In fact, the ability to utilize a qualifications-based selection on the construction contractor as well as the engineer can be of great advantage to the owner. Although low bid procurement has been used for design-builder selection, this Guide strongly recommends the use of best-value procurement primarily based upon the fact that the design is not complete at the time of project award (Molenaar et al. 2005).

Additionally, the AASHTO *Primer on Contracting for the Twenty-First Century* (2001) discusses "quality factors affecting prequalification, bidding, and contract administration . . . [that] allow for the use of past performance information, construction quality, and contract progress." These have been used in DBB as well as DB projects to establish a set of criteria that allows the DOT to identify a competitor with the correct set of credentials that permit it to deliver a quality end product. This guide cites an experience by the Oregon DOT, which used a combination of qualifications and price to award a technically complex bridge project that required special experience, stating that "the Oregon DOT was quite pleased with the use of this contracting method."

Some states, such as Indiana, have laws that require a low-bid award and do not allow a best-value award, which permits the weighting of quality against technical, schedule, and price evaluation criteria. A two-step process called low-bid DB award (Gransberg et al. 2006) allows the DOT to take advantage of the benefits that come from using a more qualified DB firm. This method asks each competitor to submit two envelopes. One contains a statement of qualifications and the other holds the bid price for the project. The first envelope is opened, and those competitors that meet a preestablished set of qualification and past performance criteria form the short list. The bid envelopes of those that do not qualify are returned unopened. Next, the bid envelopes of qualified firms are opened, and the project is awarded to the lowest qualified bidder. As reported in the findings of one study, "any procurement system that does not factor in quality of past performance in determining qualification to bid future projects is flawed" (Strong 2006).

Owners are able to define in the RFQ the most important qualities that they see as necessary for a proposing firm to make the project successful. For example, the North Carolina DOT (NCDOT) DB RFQs require submission of "the D/B Firms' process understanding, team, capabilities, quality program, and past performance" (*Design-Build Policy & Procedures* 2000). Thus, if a company does not have a quality management program that satisfies the NCDOT's performance criteria, it will not be able to propose on the technical aspects of the project. Massachusetts requires an RFQ for each project so that any project-specific issues can be outlined in the RFQ and addressed by qualified design-builders (*Design Build Procurement Guide* 2006). In an analysis of 17 state-published DB guidelines, 73% required using a two-step process for DB procurement; however, only 55% of these required the evaluation of the design-builder's quality program as part of forming the short list of firms.

Using Selection Scoring to Emphasize Quality

In addition to having a two-step process, DOTs can place additional emphasis on quality by how they structure the scoring criteria for DB projects. It is common sense to understand that design-builders in writing their proposals will focus on the aspects of the project that are required in the proposal and that will be scored. Placing a quality component in the RFQ or RFP indicates to the design-builder that quality is an important issue for the DOT and that a proposal emphasizing quality will be evaluated more favorably. An example of this is shown by the philosophy of the MnDOT on its Interstate 494 DB project. Instead of including post-award incentives, MnDOT determined that

> . . . certain aspects of the RFP would provide opportunities for the right contractor with the right approach to win the work. To achieve this, RFP selection process included the following: Areas of great importance receive higher scoring weights; Contractor is rewarded in the proposal scoring for exceeding minimum requirements; and Contractor's past performance is considered during evaluations for future projects (Gladke 2006).

In the solicitation document content analysis, 47 of the project documents had the scoring criteria listed for either the RFQ, RFP, or both. Of those 47 projects, nearly two-thirds evaluated quality directly by listing some aspect of the quality program in the scoring criteria. In other words, either a summary of or the entire quality management plan was required for evaluation in the RFQ, RFP, or both, before the project was awarded. The average weighting for the quality component was 12% with a range from 3% to 25%. In the survey response, 48% of respondents required and evaluated part of the quality management program before awarding the DB contract. Another 11% of respondents reported that either part or the entire quality management program was required to be submitted in the proposal, but it was not evaluated as part of the contract award. Thus, 59% of the respondents required the design-builder to articulate its quality management approach in some form in the DB proposal.

The remaining 41% of the respondents indicated that the submission of the quality management plan was required after the award of the contract. For these respondents, ensuring the quality of the project in the procurement stage rested on the qualifications and past performance of the design-builder—that is, the "quality by qualifications approach" (Gransberg and Molenaar 2004). With this approach, the quality management details are provided by the winning design-builder after contract award. Indeed, of the 41% of respondents who required the quality management plan submitted after award, 64% evaluated, as part of the contract award decision, the qualifications of those who would be directly in charge of the DB quality management program—that is, the DB quality manager, the design quality manager, and/or the construction quality manager. Additionally, 9% required that the qualifications be listed in the proposal, but did not evaluate them as part of the contract award decision. The general survey confirmed the results of the RFP content analysis finding that portions of the quality management program were required to be included in the proposal and were evaluated in approximately one-half of the responses.

Design Development Level in the Request for Proposals

A clearly defined scope of work in the RFP is one of the most important factors in achieving the desired level of quality on a DB project. This was stated in a 2005 study by Strong that concluded that determining the "appropriate level of design completion prior to issuance of the request for proposals" is critical to project success (Strong et al. 2005). The scope must include both design criteria for the design work that will be completed by the DB team as well as preliminary design completed by the DOT or its preliminary design consultant to convey to the design-builders the design intent, scope of work, and other parameters of the project. Without a well-defined

scope, the owner greatly increases the likelihood of nonresponsive proposals. It is important that the owner articulates everything that is known about the project and not assume that qualified design-builders will be able to divine the undefined scope of work. Scopes that are too narrow do not allow design-builders the opportunity to provide innovative solutions to the design problem (Beard et al. 2001). Thus, a major benefit of DB is lost. Furthermore, the owner unintentionally retains a much larger portion of the design risk than necessary. The rule of thumb on design content is that if there is only one technically acceptable design solution for a given feature of work, the DOT should prescriptively specify it. If there is more than one acceptable solution, then the DOT could utilize performance criteria and/or performance specifications (Gransberg et al. 2006).

The level of design development that is included in the RFP is vital in conveying the scope of work and is dependent on the amount of innovation the owner would like to encourage for a given project. However, owners can consider the findings of a previous survey that indicate "the level of contracting agency satisfaction reported for design-build projects was higher for *lower levels of preliminary design completed* before design-build contract award" (*Design-Build Effectiveness Study* . . . 2006). Designs that are nearly complete do not give design-builders adequate room to innovate, whereas designs that are not clearly defined make pricing the project difficult and risky. The New York State DOT has recognized the need to be cautious of designing above the minimum amount necessary to fully define the scope of work; however, it also recognizes that at times it may be necessary to design in more detail to "more accurately estimate the design and construction efforts and their associated costs" (*Design-Build Procedures Manual* 2005). The Massachusetts Bay Transit Authority confirmed this concept when it reported that it had the need to be more prescriptive in future DB RFPs, specifically on transit projects, to ensure that it achieved a high level of intersystem compatibility for its transit stations and track systems (Touran et al. 2007).

It is easy to say that the right level of design must be done and included in the RFP, but it is much more difficult to actually put it into practice. Design professionals across the country are going against well-established norms of providing complete designs to now being called on to "decide on the extent of preliminary design (or engineering) and either doing preliminary design or managing preliminary design by others" (Drennon 1998). It will take time for everyone to adjust. The FHWA's report on DB effectiveness defines it this way:

> The level of preliminary design that should be completed before a design-build contract is procured depends on the size and complexity of the project, the ability of the design-builder to develop a more cost-effective and constructable project design in a timely and competent manner, the degree to which performance specifications are used for the project, and the opportunity to gain valuable design capabilities, with earlier value engineering and constructability reviews as part of the process (*Design-Build Effectiveness Study* . . . 2006).

Guidance on Level of Design

The right amount of design will vary as indicated by AASHTO but "according to FHWA, experience in the highway sector suggests that preliminary design efforts of 10 to 15 percent completion are usually adequate for D-B procurement" (Gharaibeh et al. 2005). Included in the Gharaibeh report is a summary of a survey of DB projects by AASHTO that "indicated that the designs included in the procurement packages ranged from 5 to 40 percent"; however, he also stated that "it appears that most agencies are moving toward lower levels of design." In a survey included in the *Design-Build Effectiveness Study* (2006) carried out for the FHWA, the average level of design prior to the DB contract award was 27%. The authors of that report recommended from their findings that no more than 30% of the design be completed before issuing the DB contract award, while adding the stipulation that "each project should be considered on an individual basis" (*Design-Build Effectiveness Study* . . . 2006). They also suggest that the percentage of preliminary design could decrease as the owners gain more experience in the DB process and learn to rely more on performance-based specifications. Additionally, if the DB project has post-construction options for operations and/or maintenance, the level of design is key to determining the quality performance criteria that must be included in the RFP for the post-construction period. This also lends itself to influencing the competing design-builders' thought process regarding the impact of assuming the liability for operations and maintenance costs after the project is completed.

Some state DOTs have set guidelines or targets for design development to help their engineers transition to DB and also to limit the design risks that the department will carry and to avoid stifling innovative proposals (see *Design-Build Procedures Manual* 2005). Colorado has determined "as a minimum, the design-build project is to be at the Field Inspection Review (FIR) level . . . typically 20% to 30% complete" (Siebels 1997). Massachusetts, after experiencing problems with a low level of design development on a previous DB project (Gharaibeh et al. 2005), has set as a policy "a reasonable target would be a 25% design effort with any specific complex issues being identified in the scope of work prior to advertisement" (*Design Build Procurement Guide* 2006). New York has broken down their appropriate level of design development in the RFP into three categories by design percentage:

- Roadway design: 20% to 30% with the focus on horizontal and vertical alignment.
- Bridge design: to the point where requirements are specified. In many cases, only location is required. Note that if a specific type of structure is specified, the Department may be stifling creativity and innovation as well as adversely affecting cost. A preferred approach regarding structure type is to define the allowable types of structures or what types would not be allowed.
- Project components that must be compatible with existing conditions such as Intelligent Transportation Sys-

tems: progress the design to a 50% to 60% level of completion (*Design-Build Procedures Manual* 2005).

New York has also included in their guidelines an exception to these preliminary design levels.

> Due to Project phasing constraints, access requirements, or difficulties with obtaining approvals or defining criteria for obtaining approvals from certain Stakeholders, it may even be necessary to carry the design of certain elements of a Project to a relatively high level of completion; in some cases, to final design (*Design-Build Procedures Manual* 2005).

This discussion of different DOT approaches to preliminary design development demonstrates that there is not a "one-size-fits-all" level of design in DB. Each project must be individually evaluated to determine the optimal level of design and gain the maximum benefit from using the DB delivery method. One point of agreement for nearly all involved in the DB process is the need for the "preliminary design [to] clearly state the specifications, design criteria, and standards that shall be used in the final design and construction of the project" (*Design-Build Guidelines* 1997). One of the stated goals of this is "to minimize design oversights or regulatory violations that could halt the project during construction" (Gharaibeh et al. 2005).

Schedule compression is one of the primary reasons for using DB project delivery (Songer and Molenaar 1996). The general survey for this synthesis confirmed the literature when it found that 85% of the respondents listed "reduce schedule" as one of the "primary reasons for [the] decision to use DB contracting." Having a clearly defined scope of work is vital to realizing this motivation for using DB. It also must be recognized that it is vital to the DB project success to minimize delays owing to owner-initiated design changes after award. Properly preparing the RFP by furnishing the appropriate level of design development in the RFP as well as other preconstruction issues will help realize the benefit of schedule compression. There are certain preconstruction issues that the majority of DOTs take care of before issuing the RFP. In a previous survey (*Design-Build Effectiveness Study* . . . 2006), three of these were listed with their respective percentages complete at the time of issuing the RFP:

- Right-of-way acquisition (89% complete),
- Permit acquisition (83% complete), and
- Environmental clearance (99% complete).

The DOTs are better able to manage these risks associated with all transportation construction projects (*Design-Build Effectiveness Study* . . . 2006) and they are now required by the recent FHWA rules for using DB project delivery to complete these three major preconstruction activities ("Design-Build Contracting: Final Rule" 2002). It should be noted that the provisions of SAFETEA-LU allow some of these activities to be done after the RFP is awarded; however, the rule making for these newest provisions is currently in progress and will not be completed by the time this report is published. Therefore, the previous discussion of RFP design development sets the stage for defining the resources and systems necessary to manage the quality of any DB project. In essence, this process is meant to create the parameters within which the design-builder must conduct design and construction QA and QC activities. Although they may seem to be overly legalistic, they are extremely important, and the preliminary design that is depicted in the DB RFP must be fully compliant to the standards that the DOT expects to enforce during execution of the DB contract.

Design Development Required in Design-Build Proposal Documents

Nearly of equal concern to owners as the level of RFP design development is the question of how much design will be required of the design-builders in their proposals. This decision varies based on the complexity of the project and how comfortable the owner is with the DB process. These design activities act to further define the scope of work for the contract. From the standard DB contract model shown in Figure 21 one can see that the technical portion of the contract is comprised of the RFP and the winning proposal (Gransberg et al. 2006). Thus, ensuring that the appropriate design submittals are required in the DB proposals serves to further define the required level of quality for the project.

A typical example of this principle comes from the Maine DOT's RFP (2003) for the I-295 Commercial Corridor shown here.

> Roadway Design Features (20 points): Submit preliminary layout plans for the entire Project including horizontal and vertical alignments of roadways, ramps, intersections, and bike/pedestrian trails to demonstrate that the proposed complies with environmental commitments and Right-of-Way limits. Discuss approach to pavement design in order to meet warranty and design life criteria. Identify additional warranty offered, if any, beyond the required five-year term. Show typical section plans for roadway and trail design. Discuss maintainability of roadways and trail. Explain how designs will provide for ease of maintenance and enhanced durability, minimizing the need for excessive maintenance and rehabilitation during the proposed service life (20 years). Discuss approach to drainage. Discuss approach to traffic engineering. Describe the needs, type, and location of landscaping to be used. . . .
>
> Structural Features (20 points): Submit structural concepts for each structure type including retaining walls. Include plans, elevations, and cross-sections depicting structure components for each proposed structure type. Submit a description of each structure type. In addition, for each structure type proposed for the Project, the Proposal shall list assumptions used in development of the substructure and superstructure type. Comment on each major structure concerning: Ease and cost of maintenance for extended structure life; quality of materials proposed for structural components; [and] strategy used for maintaining safety, function, and serviceability of structures. Describe any aesthetic treatments proposed to be used on walls, bridges, and other structures (*Request for Proposals, I-295 Commercial Street Connector* 2003).

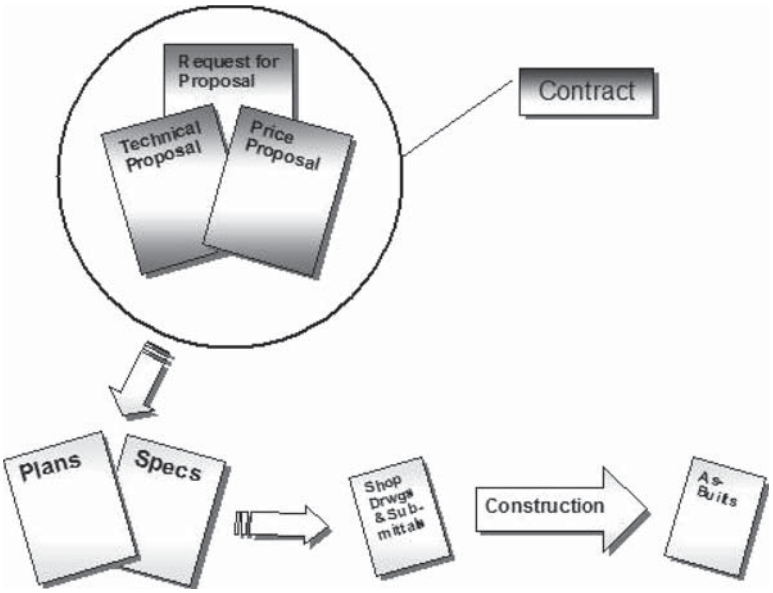

FIGURE 21 Design-build contract model (Gransberg et al. 2006).

These requirements contain the main points determined to be essential in most of the RFPs that delineated the requirements for design; namely, a preliminary layout for the project including vertical and horizontal alignments, structure types, materials, aesthetic treatments, expected maintenance and/or life-cycle costs, as well as the assumptions to be used in developing the proposed design. Other RFPs also request that any innovative design or deviations from standard designs be noted. Sometimes detailed plans on how the new construction will be tied into the existing structures and typical roadway or structure sections are required to allow the owner to be able to gauge the level of quality that is being proposed and priced.

The Arizona DOT *Design-Build Procurement and Administration Guide* (2001) gives a good example of what is required in the proposal. The technical proposal must include the following:

- Preliminary plan sheets showing typical sections;
- Horizontal and vertical alignments;
- Structure locations and identifications;
- Roadway layout concepts;
- Signing, striping and lighting concepts, traffic control, and phasing schemes;
- Other design features as needed; and
- Any sketches or renderings.

Therefore, between the preliminary design provided in the RFP and the expanded design development shown in the DB proposal, the project's design development is advanced to a point at which the competing design-builders are able to commit to a firm, fixed price on a project whose design is not complete. Additionally, the two documents taken together represent the technical benchmark against which all quality management activities will measure success or failure. Therefore, the next requirement is to determine what the quality management system for a given project must look like and to define and allocate roles and responsibilities to the various parties in the DB contract. This is done through the evaluation of project-specific quality management plans.

Proposal Quality Assurance Plan Requirements

The FTA (Carter et al. 2002) in its *Quality Assurance and Quality Control Guidelines* states that one of the "key practices" in ensuring the success of QA and QC programs is to "clearly define requirements of the QA/QC Program in the contract documents." The WSDOT recognizes this importance in their DB guidebook:

> The QC/QA Program is a critical component of the design and construction of the project. It partly represents assurance to the Department that the Design-Builder is executing in accordance with the contract (*Guidebook for Design-Build Highway Project Development* 2004).

Including some form of the proposed QA and QC plan in the proposal is essential if the owner wants to know each design-builder's quality management approach before awarding the DB contract.

Respondents to the survey did not see the quality management plan in such an important light. When asked to rate the impact that quality management plans have on the quality of DB projects on a scale from "no impact" to "very high impact," only 56% believe that a quality management plan has a "very high" or "high" impact on the quality of DB projects. The remaining 44% believe that quality management plans have "some" or "slight" impact on the quality of DB projects. In addition to the survey, the content analysis of 66 RFPs and

RFQs found that 71% of the documents had some reference to a pre-award requirement of proposed project quality plan. This includes complete pre-award project quality management plans, summary plans, and components to these plans or specific sections such as a construction QC plan. This indicates that more than one-fourth of the RFPs failed to furnish a mechanism to verify the quality programs of the design-builders in the RFP/RFQ documents before awarding the contract. Even more interesting is the finding that 21% of the documents reviewed had neither a pre-award nor a post-award quality plan listed as a requirement. The survey responses differ somewhat from what was found in the content analysis. In the survey, 59% of respondents required and evaluated at least part if not all of the quality management program before awarding the DB contract. The remaining 41% of the respondents indicated that the submission of the quality management plan was required after award of the contract.

Those owners who do not require pre-award submission of a quality plan exhibit a high level of trust in their process to award the project to a competent and qualified design-builder. This can be inferred because 79% of the projects in the content analysis that did not require a quality plan in any part of the proposal were carried out with the two-step RFQ/RFP process in which the design-builders must first demonstrate that they meet the required qualifications before they can propose on the project. The finding that the other 21% of these projects did not use a two-step process is disturbing in that this leaves the owner a very limited ability to quantify the requirements for quality management in the contract documents. A study published in 2004 tracks with this finding when it found that "roughly 80% [transportation] project [DB] RFPs require submission of both quality management qualifications and quality management plans . . . 60% require pre-award design quality planning and owner evaluation of those plans" (Gransberg and Molenaar 2004).

In the *Recommended AASHTO Design-Build Procurement Guide,* the authors list four reasons for including a quality management plan in the procurement stage of a project. This practice:

- Allows the agency to use it as a factor in the award decision;
- Encourages the design-builder to devise innovative strategies for quality management;
- Allows the agency to review the plan prior to award; and
- Obligates the design-builder to conform to the plan during design and construction (Molenaar et al. 2005).

All of these reasons benefit the owner and give public agencies an added layer of assurance that the end product will be of acceptable quality before awarding the DB contract. Finally, they clearly define the expectation for design and construction quality and give the competitors an opportunity to include the cost of comprehensive design and construction quality activities in their price proposal.

While recognizing the need for a quality management plan for all DB projects, the scope of the plan can change for different types of projects. Not all DB projects are the same. New York has recognized this in their *Design-Build Procedures Manual* (2005), where it states that: "The Quality Plan Specification . . . should be tailored to fit the size and complexity of the Project." Reason would indicate that the more complex or bigger the project, the more extensive the quality management plan should be. Also, projects that are under intense public scrutiny for political reasons or just for the newness of DB in the state would do well to have a more extensive quality management plan.

Although it is good practice to request at least a summary-level quality management plan in the DB proposal, it is much more difficult to know exactly how to evaluate a quality management plan. One Minnesota survey respondent said that:

> Scoring the quality management requirements during a best-value selection is difficult. We currently require contractors to submit a draft quality management plan in addition to their technical proposal. Sorting through the mountain of information and placing a score on a subjective subject like quality is a very difficult task.

This statement supports the idea that the requirements must be clearly laid out so that the proposals can be fairly evaluated.

A number of states have invested the effort to develop DB guidelines that articulate their stated policies for implementing DB contracting. This study reviewed 17 DOT DB guidelines as well as stand-alone policy documents on quality management topics. In reviewing the policies and guidelines, three different approaches to the topic of crafting QA and QC provisions for DB solicitation documents were found:

- Policy requiring inclusion of QA and QC provisions in all solicitation documents,
- Policy stating that including QA and QC provisions in the solicitation documents is optional, and
- No stated policy regarding QA and QC provisions in the solicitation documents.

It is surprising that the subject of quality management would not be specifically covered in a state's policy for implementing DB. However, the reader must not read too much significance into that finding. Document content analysis is a powerful research tool with one weakness. The methodology only permits the author to record what is written in the document under analysis. It does not seek to infer why the given topic is included or excluded. Therefore, it is entirely possible that the documents reviewed that did not include policy for the inclusion of QA and QC provisions in DB solicitation documents did so for one of two possible reasons. First, the policy document may have had a narrow original purpose that was not discernable to the author. For instance, the DB policy could have been written specifically for describing the flow of the solicitation process from a global perspective

and was not intended to serve as a specific description of RFQ/RFP content. Second, the document may have included a requirement for QA and QC provisions by referring to another state document that was not recognizable to the content analyst. Nevertheless, it seems reasonable to recommend that DOT policy drafters include specific instructions regarding the inclusion of QA and QC provisions in all policies and guidelines for the development of DB solicitation documents. The next sections contain examples that can be used if necessary.

Required Inclusion of QA and QC Provisions

In the documents reviewed, the inclusion of QA and QC provisions appeared to be derived from one of two situations. The first is a conscious decision by the agency to ensure that quality management is an important feature of the solicitation documents, and the other is a legislative requirement that generally came with the formal authorization to use DB project delivery. The following clause from the Massachusetts DOT is a good example of the first.

> The Quality Assurance Program is a critical component of the design and construction of the project. It represents assurances to the Department that the Design Build Entity is executing in accordance with the contract documents. The Department will provide the quality assurance and independent testing, but the established QC/QA Program is the backbone for which the Department will gauge compliance. The Contract Provisions should require that the QC/QA Program submitted with the proposal be brought into conformance with the Department's requirements prior to execution of the contract. *The Department must negotiate the provisions of the QC/QA Program and finalize an acceptable Program prior to award of a contract* (*Design Build Procurement Guide* 2006, italics added).

One can clearly see a departmental emphasis on the importance of quality management in the DB project. This clause also clearly draws the relationship between the traditional quality management system used for DBB projects and the changes that Mass Highways personnel can expect to see as they transition to alternative project delivery methods.

The second reason, legislative mandate, can be seen by the following example of the DB law for Texas.

> "Design criteria package" means a set of documents that provides sufficient information to permit a design-build firm to prepare a response to the department's request for qualifications and request for proposals and includes the criteria for selection. *A design criteria package shall include* a description of the project site, survey information, cost or budget requirements, time schedules, conceptual design, a geotechnical baseline report, *quality assurance and quality control requirements*, special material requirements, applicable ordinances, provisions for utilities, and any other applicable information, as appropriate (*Design-Build Contracts* . . . 2003, italics added).

It is important to note that any variations from traditional QA and QC plans should be mentioned in the DB package as was done in Massachusetts. This will ensure that the differences are called to the attention of the proposing firms and will help prevent confusion and controversy during project execution. The Arkansas DOT specifically mentions this in its DB guide: "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" (*Design-Build Guidelines and Procedures* 2006). Similar requirements are listed in the Colorado (*Design-Build Guidelines* 1997) and Florida (*Design-Build Guidelines* 2006) DOT DB guidelines. It is also important to note any traditional QA and QC functions that do not apply to a DB project. For example, the Arizona DOT in its DB procurement and policy guide notes that a DBB design QC function that requires the designer to submit design-phase plans to the DOT for review generally does not apply in DB projects. This change from DBB design QC is also a requirement listed by the Florida DOT (*Design-Build Guidelines* 2006).

Optional Inclusion of QA and QC Provisions

One of the major themes in the literature regarding the preparation of DB solicitation documents is to ensure that the documents are specific to the project's requirements (Beard et al. 2001; Gransberg et al. 2006). Therefore, it is reasonable for a state's DB guidelines and policies to be somewhat open-ended, giving flexibility to the individual project manager for a given project to use professional judgment on whether or not QA and QC provisions are included in its DB solicitation documents. New York gives the DOT's project management team the authority to "determine the specific QA and QC requirements for each project" (*Design-Build Procedures Manual* 2005). Colorado and Virginia are also good examples of this approach, and the following are excerpts from their DB guidelines:

> The evaluation criteria contained in the RFQ focuses on specialized capabilities required for the project. Individual criteria are weighted according to their relative importance to the successful completion of the project. The actual criteria selected for use should be applicable to the project and the Proposer's ability to perform the work. With this in mind, it is also important to avoid criteria that are so restrictive that few, if any, Proposers can meet the minimum requirements. *Criteria that may be considered* are: Staff available (Project Manager, Design Manager, Construction Superintendent, Quality Manager, etc.); Quality performance; QA/QC organization (*Design-Build Guidelines* 2006, italics added).

> The Project Team will develop the evaluation and scoring criteria to determine a shortlist. *The criteria* should be consistent with the qualifications requested and *may include* a description of the Offeror's project understanding and management approach, organization structure, a demonstration of applicable experience, manpower and equipment resources, experience in obtaining environmental permits, obtaining right-of-way, other Design-Build projects, *approach to quality assurance and quality control*, and their financial ability to do the work (*Design-Build Procurement Manual* 2006, italics added).

In both of these guidelines, there are suggestions as to what is included in the RFP. The phrases "may be considered" and

"may include" give the flexibility to change the RFQ based on each project's unique needs and circumstances.

One common practice in the solicitation documents reviewed in the RFP content analysis requires a summary or an outline of the quality program to be presented in the proposal for evaluation and later requires a final draft of the quality program to be submitted for final approval after contract award. For example, the Maine DOT required that the proposal for one of their DB projects contain the following information concerning the project's quality management program:

> Describe the Proposer's approach to Quality Management during the design, construction, and warranty phases. Provide an outline of the Quality Management Plan. Describe the roles, responsibilities, and accountability relationships of the team members. Describe in detail the methods and measures to be used during construction to maintain quality standards, prevent non-conforming work, correct non-conforming work, develop corrective action procedures, and prevent re-occurrence of non-conforming work. Discuss the approach to inspections and callbacks during the warranty period. Discuss the implementation of the Quality plan as it relates to frequency of inspections, results of quality level testing, experience of inspection staff, and corporate involvement (*Request for Proposals, I-295 Commercial Street Connector* 2003).

The proposal evaluation plan gave this response a weight of 15% of the total scoring criteria. However, the outline quality management plan was not all that would be required of the winning design-builder. After award of the project, the following was required for design and construction quality management:

> The Design-Builder shall provide a Design Quality Management Plan (DQMP) for project design . . . for review and concurrence by the Department. The DQMP objective is intended to place the responsibility for the quality of the design on the Design-Builder, facilitate construction by the Design-Builder, and allow the Department to fulfill its responsibilities of exercising due diligence in overseeing the design process and products. . . . The Design-Builder shall [also] develop, submit, and implement a [construction] Quality Control Plan (QCP), approved by the Department, for those items of work specified that will result in work that meets or exceeds the quality requirements of this Contract. Quality Control for all work is the Design-Builder's responsibility (*Request for Proposals, I-295 Commercial Street Connector* 2003).

It should be noted that the Maine DOT construction quality plan also included details about testing, inspection, noncompliance, qualifications, and responsibilities. Placing these details about the quality program in the RFP effectively makes them contract requirements. This approach of asking for an outline quality management plan in the DB proposal whose final details will be approved by the DOT after award provides a way for owners to ensure they will have a quality program that they can approve and one that will support the ultimate delivery of a well-designed and well-built project.

Design-Builder Quality Management Team Qualifications

As with any construction project, the final quality of a DB project is a function of the quality of the people who design and build it. From the engineers developing the project plans to the workers striping the finished road, it is essential for the success of every project to have a competent workforce. "The success of implementing a project is dependent on the project manager and his/her staff (people), the company's systems (methods), the technology/computer system (machinery), and the supplies and other materials" (Atkison 2005). Specifically regarding quality, it has been said that the experience level of the DB contractor is "crucial to the success" of the quality program (Carter et al. 2002). In the DB process, ensuring workforce competency on a given project begins with the development of the RFQ. Requirements can be listed in this document for the entire design and construction organization as well as individual qualifications and past experience of the project design and construction management team, including QA and QC personnel. Generally, resumes for key personnel are requested, detailing their past experience and performance. The Maryland DOT's Mass Transit Administration indicates that one of the lessons learned from a DB transit project is that "without minimum staffing levels and experience criteria, [an owner] will not get the same level of experience, effort, documentation or comfort as when the [owner] or its professional construction manager perform the QA and QC functions" (*Lesson 27: Quality Assurance and Quality Control . . .* 1997). The FHWA *Design-Build Effectiveness Study* (2006) indicates that "teams with highly qualified and experienced members are likely to perform the best in delivering a quality project consistent with the terms of the contract." The FHWA survey also pointed out one of the challenges with implementing DB: the relative inexperience of all parties with DB project delivery when compared with traditional DBB.

The issue of DB inexperience of both the DOT employees and design-builder employees was echoed in the survey conducted for this synthesis. When asked to identify the challenges to implementing QA on DB projects, the following responses were received:

- Adequate number and quality of contractor design and construction QA/QC staff.
- Teaching the revised thinking/roles to inspectors.
- [DB] requires staff training.
- Staff inexperience.
- Industry finding qualified QA/QC people.
- In rural areas, finding qualified personnel.
- Having the right people to administer the plan.

A remedy for this challenge is for the DOT to demand that the design-builder furnish highly qualified and experienced personnel on its DB projects and use those projects as a training ground upon which its staff can gain the DB experience it lacks.

The only way to guarantee that a design-builder will place qualified individuals on the project team is to list those requirements in the project's solicitation documents (RFQ or

RFP). Maryland's MTA found that the "specification for the QA/QC role in the contract documents must be abundantly clear, specific, and require the D/B contractor to meet minimum requirements relative to staffing levels [and] experience of the staff" (*Lesson 27: Quality Assurance and Quality Control* . . . 1997). Listing the QA and QC personnel requirements in the RFQ or RFP places those requirements in the DB contract and they can be enforced after contract award. An observation from the Pasadena-to-Los Angeles Gold Line Rail project is relevant: ". . . the Authority has observed that the quality of the QC program is largely dependent on the DBs' [design-builders'] own ethics and philosophy. Therefore, past performance in the quality arena could be a significant factor when selecting a DB [design-builder] that will also perform the all-important QC function" (Born and Burner 2003).

Having indicated the need for qualified personnel on DB projects, the next step is defining the term "qualified" in the context of the given project. Again from the MTA, "Prior experience of QA/QC [is] imperative as well as transit construction/operations experience" (*Lesson 27: Quality Assurance and Quality Control* . . . 1997). This is in line with the FTA *Quality Assurance and Quality Control Guidelines*. These guidelines state that:

> QA/QC Management/Supervisors should possess experience managing professional personnel in similar circumstances or on similar projects. They should have experience with matrix organizations and managing multiple projects. They should have excellent communication skills and a working knowledge of QA/QC and quality management. They should possess certification as quality professionals for appropriate certifying bodies or have successfully completed training courses in the quality discipline (Carter et al. 2002).

Quality management personnel "should not just be the construction employees that happen to be available" (Wichern 2004). They need to have related experience and certifications. This usually indicates professional engineers and professional certified quality personnel who have a certain level of similar project experience. Again, there is no silver bullet in qualifications required; different project needs will require different levels of experience, but all projects will require some level of previous QA/QC experience.

A MnDOT RFQ furnishes two good examples of the types of qualifications that could be required for design and construction quality managers:

> [The] Design Quality Control Manager must be a registered professional engineer in the state of Minnesota . . . may work directly for the Design-Builder or may be contracted from an independent firm or organization . . . Must have at least five years of recent experience (within the past ten years) overseeing the design of major urban freeways. [The] Construction Quality Control Manager may work directly for the Design-Builder or may be contracted from an independent firm or organization . . . Must be a registered professional engineer in the state of Minnesota . . . Must have at least five years of recent experience (within the past ten years) overseeing the inspection and materials testing on major highway construction projects . . . (*Request for Qualifications T.H. 52* . . . 2001).

In addition to qualifications for the QA and QC managers, it is also necessary that the QA and QC reviewers, inspectors, and testing technicians for design and construction are qualified for the duties they must perform. The FTA *Quality Assurance and Quality Control Guidelines* define qualifications recommended for inspectors as follows: "Inspectors should have the appropriate education or experience commensurate with the job responsibilities . . . [and] possess the necessary certifications required for assignments [e.g., American Welding Society (AWS), Society for Testing and Materials (ASTM), American Concrete Institute (ACI), etc.]" (Carter et al. 2002).

For the same MnDOT project referenced previously, the RFP further listed qualifications for design quality professionals, in addition to the Design Quality Control Manager. The qualifications were as follows:

> Design QA Engineers: The DQA staff shall include senior experienced engineers to perform audits and quality assurance functions as defined by the Design-Builder's DQMP. An engineer shall be considered a DQA Engineer if he/she is a Registered Professional Engineer in Minnesota and has at least ten years of experience.
>
> Design QC Engineers: The DQC staff shall include experienced engineers to perform detailed checks of all design calculations and review of construction plans as defined by the Design-Builder's quality control plan. An engineer shall be considered a DQC Engineer if he/she is an engineer, has practiced in the design discipline and type of work being checked for at least five years, and has at least an equal level of qualifications and experience as the engineer(s) performing the design [*T.H. 52* (*Rochester*) *Design-Build Request for Proposals* . . . 2002].

Another example of required qualifications for testing and inspection staff comes from an RFP from the NCDOT. The RFP states that: "Technicians performing sampling and testing shall be qualified in accordance with the Department's training and certification requirements for the specific materials, or in accordance with AMRL/CCRL [AASHTO Materials Reference Laboratory/Cement and Concrete Reference Laboratory] accreditation requirements" (*Design-Build Package: I-77 South* . . . 2006).

Often, quality professionals are listed as key personnel or required participants in RFQs and RFPs. In the analysis of RFPs and RFQs, 64% of the projects in the RFP content analysis required a quality professional to monitor quality on a project level, either for design, construction, or both. Of these projects that required a quality professional, 36% required just a project-level quality manager—in other words, a quality manager in charge of both the design and construction quality programs. In addition, eight other project documents required a project-level quality manager along with design and construction quality managers, 33% required both a design and a construction quality manager, and the

remaining 12% of the projects reviewed required either a design or construction quality manager at the project level, but not both. The downside of these statistics is that in 30% of the projects analyzed, the DOT did not establish a contractual requirement for competent quality management personnel. This could lead to post-award disputes regarding the qualifications of the design-builder's assigned quality management personnel. Without including a requirement for specific qualifications in the contract, the design-builder cannot be held to providing personnel with those qualifications. Requiring that key quality management personnel be designated in the proposal and having their qualifications evaluated as part of the award process allows the DOT to set a high standard for quality activities at the very outset of the project.

In addition to requiring competent, experienced quality management personnel, it is important for the DOT to ensure quality by individually approving the persons who will hold quality management positions. This can be done before the award or after the award of the DB contract. When the quality management professionals are required to be named in the proposal documents, the DOT has the opportunity to competitively evaluate the qualifications of the proposed individuals. As stated before, in the solicitation documents reviewed, 42 required a quality professional to monitor quality on a project-wide basis for design, construction, or both. Of these, 60% required the qualifications of the quality professionals in the proposal as part of the evaluated material. Of the remaining documents, 12% required that the quality professionals be named in the full quality plan after award, and the remaining 28% were silent on the matter of naming the quality professionals and listing their qualifications, thus passing up the opportunity to influence the level of experience and professional competence of the design-builder's design and construction quality personnel.

In addition to requiring that quality personnel be identified, many of the documents analyzed also listed specific requirements for the quality personnel. This further narrows the list of qualified people to make sure the "right" type of person is selected for the project. This also appears to be the best way to ensure that the DOT has someone it believes is qualified on the job. Table 8 shows the results from the content analysis of whether or not qualifications were listed with the requirement of the quality manager. More than two-thirds of those projects that required quality managers (69%) also listed specific requirements for whoever would be chosen to fill the position.

Furnishing appropriate qualifications for DB quality personnel in the solicitation is important so that they can form part of the contract. Thus, the design-builder will be contractually required to provide individuals with the qualifications listed in the solicitation documents. Based on observations made in the RFP content analysis, the qualifications of interest can be separated into three main categories: education, experience, and professional certification. It is, however, interesting to note that only 69% of the solicitation documents that required specific quality personnel actually listed the required qualifications for each position. The most commonly required qualifications were professional certification and experience on similar type and size of projects. Experience was most important on the construction side of quality management, whereas professional certification was just as important in all categories of quality management. Often there was more than one requirement for the same person as indicated in the examples cited here. Interestingly, the only education requirements were found for construction quality managers; however, that was not very often. One note on this part of the content analysis, the North Carolina DOT only required a "qualified employee" to serve as the project quality manager without defining in the RFP exactly what "qualified" meant. Adding the North Carolina DOT RFPs to the previous total would bring it to a total of 88% of the solicitation documents being found to have listed the qualifications of the quality personnel.

In the survey, the respondents were asked to indicate if their RFQs or RFPs required the qualifications of the DB quality manager, design quality manager, and/or construction quality manager to be submitted as part of the DB proposal. Seventy-eight percent of the respondents indicated that the qualifications of the DB and design quality managers were required as part of the evaluation decision, and 76% indicated that the qualifications of the construction quality manager were required as part of the evaluation decision. Additionally, 14% required the submission of qualifications for the DB and construction quality managers either before

TABLE 8
REQUEST FOR PROPOSAL CONTENT ANALYSIS RESULTS FOR TYPES OF QUALITY PERSONNEL REQUIRED

Personnel Type	No. of RFPs/RFQs	Qualifications Listed	
		Yes	No
Design and Construction QA/QC Managers	14	9	5
Design QA/QC Manager	3	1	2
Construction QA/QC Manager	2	2	0
Project QA/QC Manager	15	13*	2
Project & Design/Construction Managers	8	4	4
Total	42	29	13

*Eight of these come from North Carolina, which only listed the requirements as a q ualified employee."

or after the award, but did not include those qualifications in the award decision. For design quality manager, the same categories had an 11% response. Only four of the respondents indicated that the quality management personnel qualifications were not required either before or after contract award. In summary, the survey responses indicate that nearly 90% of the time DOTs know who they will have managing the quality on their DB projects. This tracks with the percentage seen in the RFP content analysis when NCDOT RFPs were included and provides a modicum of assurance for DOTs that a quality program will be run by competent personnel in such a way as to assure a quality product.

To illustrate how qualification requirements are written into an RFQ or RFP, three different examples are cited. The following MnDOT RFQ excerpt is an example of quality management personnel qualifications that are submitted before award submission for an urban freeway project.

> Construction Quality Control Manager . . . must be a registered professional engineer in the state of Minnesota . . . have at least five years of recent experience (within the past ten years) overseeing the inspection and materials testing on major highway construction projects. [The] Design Quality Control Manager . . . must be a registered professional engineer in the state of Minnesota . . . [and] have at least five years of recent experience (within the past ten years) overseeing the design of major urban freeways (*Request for Qualifications T.H. 52 Design-Build Project* . . . 2001).

The Mississippi DOT also furnishes an example from an RFP that requires certain quality management qualifications that would be submitted after contract award.

> The lead design firm in the CONTRACTOR's [in this usage, the design-builder's] organization shall employ a Design Quality Control Manager for the Work and shall provide the name, resume, and references for its proposed Design Quality Control Manager to the MDOT for MDOT approval. *The Quality Control Manager shall be a professional engineer licensed by the State of Mississippi with a minimum of 10 years experience in quality management of road and bridge design* . . . The CONTRACTOR shall employ a Construction QC Manager for the Work and shall provide the name, resume, and references for its proposed Construction QC Manager to MDOT for MDOT approval. *The Construction QC Manager shall be a professional engineer licensed in the State of Mississippi with a minimum of 10 years experience in quality management of road and bridge construction* (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005, italics added).

Finally, the Utah DOT provides an example that has specific educational credentials in a DB RFP for a tunnel project.

> . . . the Contractor's Construction Quality Manager shall have a Bachelors degree from an accredited four (4) year institution in engineering or related field and a minimum of five (5) years Project Quality Control experience (*Request for Proposals, SR-92* . . . 2004).

In addition to requiring specific qualifications for the quality managers, quality staff qualifications are also included in the RFQ or RFP. This is the staff that performs the quality checks, inspections, testing, and so forth. If they do not have the necessary qualifications, it will be much harder to have faith in the results of the quality assessment of the project. For example, if an inspector is not certified and trained for the specific job that must be done, there exists little credibility in the results of the inspection.

Table 9 is a summary of the various qualifications for quality managers that were observed during the RFP content analysis. The analysis specifically sought to identify standard requirements for professional credentials (usually a professional engineer's license for the state in which the project is being built), education, and project-related experience. One can see by the low numbers shown in the table that relatively few DB solicitation documents availed themselves of the opportunity to set a standard for quality management personnel qualifications and experience. When one compares these results with the information found in the literature regarding the importance of having competent and qualified quality management personnel, a major disconnect is observed. Therefore, this area appears to be one in which DOTs that are planning on implementing DB project delivery would

TABLE 9
REQUEST FOR PROPOSAL CONTENT ANALYSIS RESULTS FOR QUALIFICATIONS OF QUALITY MANAGERS

	No. of Observations	Percentage*
Design		
Professional certification (always PE)	8	19%
Education	0	0%
Experience	7	17%
Construction		
Professional certification (almost always PE)	8	19%
Education (university degree)	2	5%
Experience	12	29%
Project Level		
Professional certification (always PE)	5	12%
Education	0	0%
Experience	7	17%

*Percentages were figured using the RFPs/RFQs that required quality professionals (i.e., 42).

benefit by establishing a fundamental set of quality management qualification requirements for both the design and construction phases of their typical DB projects.

CONCLUSIONS

First, DOTs procuring DB projects may require that both design and construction quality management plans be submitted in the design-builders' proposals. This allows the evaluation of each potential design-builder's approach to project quality and will mitigate post-award disputes over quality issues during both the design and construction phases of the project. When quality management plans are included in the proposal, they are part of the contract. Second, owners can continue to require quality-specific qualifications for both the design and construction members of the DB team. A strong record of quality performance and quality-specific individual credentials is a powerful method to manage the quality risks inherent to the DB process. Third, owners may establish the project's quality management system before award. DB project delivery is often a competitively negotiated procurement and, as a result, owners can ask competitors to enhance their quality management plans if they are found to be weak or inadequate by the proposal evaluation process in their best and final offers (Gransberg et al. 2006). Indeed, DOTs may be leery of awarding a DB project to a design-builder whose approach to quality management is not responsive to the project's quality requirements.

DB offers an owner a myriad of benefits beyond the typical cost and time savings cited in the literature. That the builder is involved in the design and the designer stays involved during construction furnishes a continuity of detailed project knowledge that does not occur in the traditional DBB project. To maximize the opportunities available in this delivery system, the owner may carefully and thoughtfully prepare the RFQ/RFP documents. The owner cannot assume that the design-builder will automatically produce a quality project. The DB contract itself may determine that the requisite level of quality be designed and built into the project. This study has shown that some DOTs are emphasizing quality in their DB projects by writing their solicitation documents in a way that maximizes the opportunities for enhanced quality, whereas other owners are not availing themselves of this opportunity. Managing the ultimate quality of the design product may be more important than managing the quality of the construction product, because the design product defines the quality standards for the construction. Thus, some DOTs are including detailed requirements for the management of design quality in addition to the traditional requirements for construction quality. Ultimately, this study has shown that there is ample opportunity to improve the quality process if the owners in this nation are willing to shift their procurement culture.

CHAPTER FOUR

DESIGN-BUILD QUALITY ASSURANCE PRACTICES DURING DESIGN PHASE

DEFINING PROJECT'S ULTIMATE QUALITY

The design phase of a DB project is the phase in which the ultimate quality of the constructed facility is quantified through the production of construction documents. A previous study of DB quality management stated that: "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 the final quality of the construction is directly related to the quality of the project's design. Thus, design QA and design QC activities are necessary to assure the final quality of the products produced during design development. An important factor in achieving high-quality design is free and open communication between all parties during the design phase (Beard et al. 2001), and DBIA's *Manual of Policy Statements* states that: "DBIA advocates both formal and informal project partnering and considers the partnering philosophy to be at the foundation of design-build delivery" (*Manual of Policy Statements* 1998).

Design-Build Partnering

Partnering is a concept that seeks to bring the various parties to a contract together in a manner that creates an environment of open communication and trust. It has been used successfully in transportation projects since the late 1980s. A study of the Texas DOT's early DBB partnering program found that partnered projects outperformed nonpartnered projects in every category in which they were compared and provided an effective means to control both cost and time growth (Gransberg et al. 1999). A study of the Naval Facility Engineering Command's DB partnering process produced similar results and dramatically demonstrated the benefits of applying partnering principles to DB projects (Allen et al. 2002). A study of the Arizona DOT's partnering efforts on a major DB project in Phoenix found that partnering DB transportation projects was a natural fit when it stated:

> Design-build by its nature lends itself to the partnering concept. The partnering concept ideas of increased communication, alignment of goals, and development of a dispute resolution system fit perfectly with design-build's overarching theme of single-point responsibility for the owner. Increased pressure because of schedule compression typical of most design-build projects makes partnering a vital necessity (Ernzen et al. 2000).

Because most formal partnering programs begin shortly after contract award, it is logical to include the discussion of the benefits of partnering in the design phase of this report. It may be noted that in many cases, "actual partnering" begins during the design-builder's team-building period that accompanies proposal preparation during the procurement phase for the designers and constructors on the design-builder's team. Additionally, many DOTs apply partnering principles to developing strong working relationships with external stakeholders, such as state environmental agencies, political entities, major property owners that will be affected during the project, and special consultants. These procurement phase partnering efforts often involve internal DOT lawyers, engineering discipline areas, procurement personnel, and so forth and can have the same impact on the project as the DB team partnering prior to contract award.

Notwithstanding the pre-award internal partnering opportunities for the DOT's and the design-builder's teams, the first opportunity to extend that partnering effort to the DOT's and design-builder's project personnel happens on contract award. The goal of the initial partnering meeting should be to create the conduits of communication that are necessary to transmit critical design information and owner preferences to the design-builder's design team as well as to develop the structure for ensuring that not only the designers on the owner's and designer's team are aware of critical information, but also that the constructors are included in the information loop to ensure that the level of constructability on which the price proposal was established is not compromised during the design phase.

Design-Build Partnering Communications Protocol

"Open communications is the key to any partnering process" (Ernzen et al. 2000). The DB team for the Arizona DOT DB project developed a protocol based on a series of weekly joint meetings after the initial partnering workshop to foster an environment of free-flowing communications. Figure 22 displays the content and outcomes of those routine meetings as well as the attendees. Of particular importance for this synthesis is that the design-builder's primary design and construction quality managers were prominently involved in each of the sessions.

Figure 22 shows that the outcomes of one meeting drive the subject of the next meeting starting with design status and eventually ending up with a public relations release that updated the traveling public and other third-party stakeholders of developments of interest in the project. This commitment to partnering

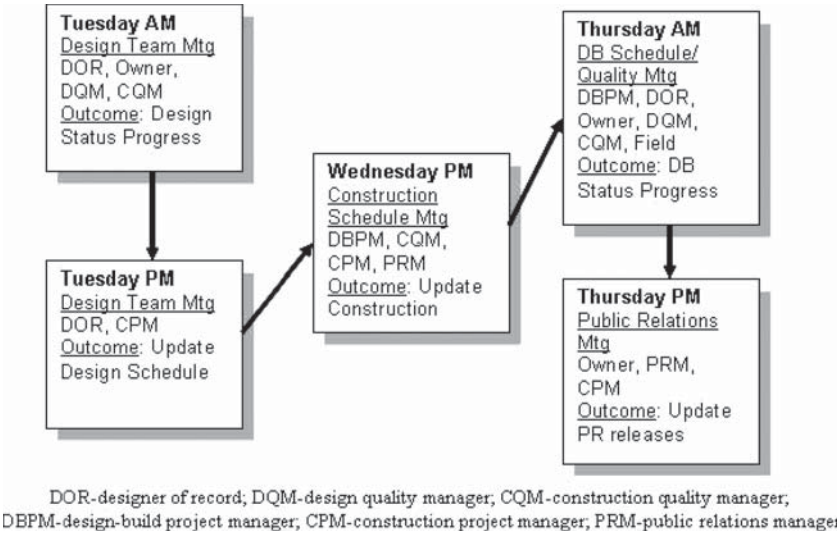

FIGURE 22 Arizona DOT I-17 design-build project partnering communications protocol (after Ernzen et al. 2000).

in DB project execution not only creates a mechanism to ensure that design quality issues are addressed as they are encountered but also extends the design decisions into the construction phase and evaluates their impact on constructability as well as resultant construction quality. The regular and routine involvement of the owner's project team members provides a point at which owner PQA activities, such as over-the-shoulder design reviews and other quality management tasks, can be undertaken if the DOT has decided to assign design and construction QA and QC responsibilities to the design-builder. Some DOTs enhance this effort by requiring that the design-builder's design team be collocated with the construction team and, at times, the DOT DB project personnel.

DESIGN QUALITY MANAGEMENT

Because design details define construction quality requirements, it would follow that DOTs that must commit themselves to the cost of construction before 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. This, 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 a design quality management plan to be submitted 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 complementary design QA plan. Thus, the literature shows that design quality management is an area that has the greatest potential for improvement. Perhaps this is owing to a lack of policy guidance in the area of design management because of the DBB practice of public engineering agencies traditionally doing much of their design work using in-house professional engineers. Therefore, DOTs 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 before award. DOTs give up control of the details of design by selecting DB project delivery; therefore, depending merely on the qualifications process to guarantee design quality, as 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 before award. Thus, it is imperative to have a clear definition of design quality management.

The MnDOT provided an excellent definition for quality management during the design phase of a DB project when it listed the objectives of the Design Quality Management Plan.

> The Design Quality Management Plan is intended 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).

The MnDOT's three-pronged approach not only satisfies its obligations for project oversight as a result of 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. Therefore, it becomes important to not only adopt a good definition for design quality management but to also clearly define the allocation of responsibilities between the DOT and the design-builder after project award.

QUALITY ASSURANCE RESPONSIBILITIES DURING DESIGN

One of the advantages of DB is the opportunity for the DOT to contract out QA and QC activities and thus reduce the workload on the DOT employees. As shown in chapter two, nearly all of the RFPs analyzed allocated the design QA functions to the design-builder, with the owner merely retaining oversight in the form of review and verification of the design's ability to meet the stated contract requirements. In New Mexico, the role of the State Highway and Transportation Department was defined in one RFP as "Oversight and audit of Contractor design and construction, including verification sampling and testing and independent assurance" (*Request for Proposals, US 70 Hondo Valley* 2001). This was followed by defining the responsibilities of the design-builder: "The Contractor will be required to plan, implement, and provide a Quality Assurance/Quality Control (QA/QC) Program for its design and construction operations" (*Request for Proposals, US 70 Hondo Valley* 2001). New Mexico did however include the following paragraph in the RFP:

> The Department may establish and maintain its own quality assurance and/or an independent quality assurance organization to oversee and/or perform quality audits of the Contractor's management, design, construction, and maintenance activities, the Contractor's Quality Assurance procedures, Verification Sampling and Testing and the quality of the final product (*Request for Proposals, US70 Hondo Valley* 2001).

This statement provided the DOT with a contractual safeguard to use if the design-builder did not follow approved quality management procedures. Thus, the assignment of design quality management responsibilities becomes an exercise in risk analysis and management with the agency seeking to optimize the ultimate allocation. A finding in an earlier study indicated that "Agencies that have experienced quality problems on projects are retaining QA responsibility" (Gharaibeh et al. 2005). This experiential adaptation of the quality management system springs from the legal issues associated with the design process, where agencies are being careful to not unintentionally assume design liability by involving themselves too deeply in the design process.

Use of Agency Personnel Versus Consultants

Another issue that surfaces with design QA involves deciding whether to perform the design QA with DOT employees or to retain an independent consultant to perform it on behalf of the owner. The FHWA Eastern Federal Lands Highway Division (EFLHD) contracts out all of its QA, while retaining the responsibility to ensure that the construction conforms to the requirements. The following is an excerpt from an EFLHD RFP that illustrates the approach.

> The Contractor [the design-builder] shall be responsible for all work as described in these RFP documents. The scope of work includes . . . quality control/quality assurance for design and construction, materials sampling, and testing. . . . EFLHD will perform management, design, and construction oversight activities of the Contractor's operations and end products to satisfy the Government that the Contractor meets the contract requirements. Included in the oversight activities will be design reviews, construction acceptance, independent verification testing activities, and oversight of maintenance of traffic and permit compliance as outlined in this RFP [*Request for Proposals IBC-8888(012) Book 1* 2001].

Department of Transportation Design-Build Guideline Approaches for Design Quality Assurance

When reviewing the guidelines published by various state DOTs, there are three different policies established in determining the QA roles in DB projects:

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

Variable Approach

In the first approach, the assignment of design QA 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 QA responsibilities will be different based on individual project needs, as shown in the Arkansas *Design-Build Guidelines and Procedures* (2006):

> 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. If any of the three roles is eliminated, project quality shall be closely monitored and an objective analysis shall be made of the impact of the change on the quality of the project.

DOT Design QA

In the second type of design QA approach, the design-builder is responsible for the design QC and the DOT is responsible

for the design QA. 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* (2001):

> 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 still retain a quality verification role as it does for other quality management issues. For design work, quality verification will be accomplished through the use of design reviews led by the PM and performed by ADOT's technical groups or the general consultant, if one is used.

Design-Builder Design QA

Finally, the third approach assigns the design-builder both design QA and QC, and the DOT steps back from active participation and responsibility and, instead, only performs oversight and verification of design quality. This approach can best be called design PQA in accordance with the definition given in chapter two. This is followed by the New York State DOT.

> The contractual requirements for design management and QA/QC 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 (*Design-Build Procedures Manual* 2005).

Regardless of how the design QA and QC responsibilities are assigned, they must be performed. When the DOT will perform the design QA activities, the contract documents (i.e., the RFP) need not further explain design QA activities. However, when the design-builder is assigned the design QA responsibilities, it is imperative to present the requirements in the RFP so that confusion is eliminated or minimized and the DOT understands exactly what services it will receive with the proposal as well as how to integrate its PQA activities during design.

REVIEWS OF DESIGN DELIVERABLES

One of the traditional ways that DOTs have ensured quality design is by being able to fully review the design before it is advertised for bids. In DB, DOTs 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 the survey, 85% of state DOT respondents to the general survey indicated this as a reason for implementing DB. Another advantage of DB is the transfer of risk from the DOT to the design-builder, and in the survey 53% of state DOT respondents also indicated this risk transfer 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. DOTs 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). Arkansas clearly states this in their *Design-Build Guidelines and Procedures* (2006): "With Design-build contracting, the design risk is placed with the Design-build firm, and the Department's review will determine if the proposed design meets the objectives of the Contract Provisions."

Thus, many states that do place the responsibility for design QA and QC 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 DOTs' responsibility to the public to deliver projects that have been 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 DOT and is in accordance with the performance criteria contained in the contract documents.

Design Review Checkpoints

The RFP content analysis found that there are two general ways that design review checkpoints are determined as summarized in Table 10. The first method, defined reviews, defines them in the RFP. The DOTs state in the RFP which reviews they will conduct and what must be included in the

TABLE 10
GENERAL DESIGN-BUILD DESIGN REVIEW CATEGORIES

Type	Design-Builder Responsibility	DOT 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, DOT 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, DOT or 3rd party	17

review. The design-builders must then account for the required reviews in their proposal and schedule of the project.

The following example comes from a Mississippi DOT RFP and outlines the design review requirements for the project.

> Preliminary Design Phase (Minimum 30% Plans): The CONTRACTOR will prepare and submit a single preliminary design submittal for the entire project. . . . Final Design Review Phase (100% Plans): Final Design may be broken down into packages (i.e., Roadway, portions of Bridges, Drainage, etc.) as determined by the CONTRACTOR. Following completion of the design for each submittal for the Project, the CONTRACTOR shall prepare and submit a Final Design Submittal for review by MDOT. . . . Released for Construction Documents: Following the incorporation of MDOT's comments from the Final Design Review Phase, the CONTRACTOR shall prepare and submit a Release for Construction submittal to MDOT for MDOT's final review and Released for Construction stamp (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Biloxi to Ocean Springs Bridge . . .* 2005).

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 the design would be reviewed.

The second approach, proposed reviews, is to allow the design-builders 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" (*Design-Build Guidelines and Procedures* 2006). The WSDOT used this approach for the Thurston Way Interchange.

> For any designs for which early construction reviews will not be conducted, at least one design review shall be conducted before completion of 100 percent design. The percentage of design will be mutually agreed upon between the Design-Builder and WSDOT, but should be near the mid-point of design . . . (*Request for Proposals, Thurston Way Interchange* 2000).

In the solicitation document content analysis, DOTs employed this approach in only 17% of the projects reviewed.

Appropriate Number of Design Reviews

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

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

Also, in many instances the design-builder is encouraged to request informal reviews that are not required but allow the DOT to provide more frequent input 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 11 provides a summary of the different categories of required number of design reviews and the corresponding percentage of occurrences in the RFP analysis.

No Mandated Reviews

When there is no DOT-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 DOT 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, with 15% using the approach of no DOT-mandated design review checkpoints before the release-for-construction design review. The MnDOT detailed its design PQA 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 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 (*Part I: Scope of Work T.H. 100 . . .* 2001).

TABLE 11
REQUIRED NUMBER OF DESIGN REVIEWS FOUND IN REQUEST FOR PROPOSAL CONTENT ANALYSIS

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

This PQA activity (sometimes termed due diligence) must be accomplished through an oversight approach as stated in the Minnesota RFP referenced earlier or by an audit approach referenced in the following Utah RFP of the design-builder's review procedures. The Utah RFP also shows that although the DOT does not conduct a progress design review, the design-builder must do so with oversight from the DOT.

> The DESIGN-BUILDER will review all designs to ensure the development of the plans and specifications are in accordance with the requirements of the Contract. . . . The *Department will audit*, as needed, the DESIGN-BUILDER processes and Design Documents to verify compliance with the Contract Documents. The Department will be invited to attend all reviews. . . . The *DESIGN-BUILDER shall conduct oversight reviews*, and *the Department may participate in these reviews and comment as requested or as it otherwise deems necessary*. . . . The DESIGN-BUILDER shall determine the materials to be compiled for each review. Formal assembly and submittal of drawings or other documents will not be required, but the Design-Builder is encouraged to provide informal submittals to facilitate reviews. The review may be of progress prints, computer images, draft documents, working calculations, draft specifications or reports, or other design documents. . . . The DESIGN-BUILDER will conduct informal milestone reviews at approximately the 60% stage of project elements to determine whether the Contract requirements and design are being followed. *The Department will be invited* to attend these reviews (*Request for Proposals, SR-92* . . . 2005, italics added).

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 (*Request for Proposals, SR-92* . . . 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 DOT must adhere to furnish timely acceptance.

> When a design package is ready to be released for construction, the DESIGN-BUILDER shall certify all of the following related to the Work:
>
> - The design is in accordance with the Contract requirements.
> - The design has been checked in accordance with UDOT accepted quality procedures.
> - No design exceptions exist that have not previously been approved by the Department.
>
> The Department will conduct its review and accept or reject the final design package within seven (7) Working Days of receipt of the final design documents (*Request for Proposals, SR-92* . . . 2005).

Single Design Review

In the second category of DB design review, the DOT requires a single official review of the design before the review of the final design deliverable. This gives the DOT 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 its DB projects. An example is listed here.

> 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 . . . (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005).

The Mississippi DOT also provides for an "optional design review" with the following RFP clause:

> At the request of the CONTRACTOR, MDOT will provide optional design reviews on design packages as requested by the CONTRACTOR. MDOT as appropriate will review optional design Submittals within 14 Days . . . (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005).

This RFP goes on to define the final design review process as follows:

> Final Design may be broken down into packages (i.e., Roadway, portions of Bridges, Drainage, etc.) as determined by the CONTRACTOR. Following completion of the design for each submittal for the Project, the CONTRACTOR shall prepare and submit a Final Design submittal for review by MDOT. . . . Following the incorporation of MDOT's comments from the Final Design Review Phase, the CONTRACTOR shall prepare and submit a Release for Construction submittal to MDOT for MDOT's final review and Released for Construction stamp (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005).

Another example comes from the WSDOT in the RFP for the Thurston Way Interchange. The exact point of the design review is not listed, but it is left to be decided on execution of the contract.

> For any designs for which early construction reviews will not be conducted, at least one design review shall be conducted before completion of 100 percent design. The percentage of design will be mutually agreed upon between the Design-Builder and WSDOT, but should be near the mid-point of design . . . (*Request for Proposals, Thurston Way Interchange* 2000).

The requirement of only one official review by the DOT is, by far, the most popular design review process currently used as found in the RFP analysis. Of the RFPs analyzed for this paper, 56% used this type of design review process.

Multiple Design Reviews

In the final category of design reviews, the DOT requires more than one official DOT review before the design can be released for construction. This was the process 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]" (*Request for Proposals, I-295 Commercial Street Connector* 2003). The EFLHD also requires more than one design review before the design is released for construction and in an RFP it states the reasons for the reviews:

> Initial submittals are intended to provide the Contractor a means of proposing and obtaining acceptance for horizontal and vertical alignment deviations from the Government preliminary design plans; deviations from the Government preliminary bridge Type, Size, and Location (TS&L) plan; and changes in basic parameters of the project. . . . Intermediate Design Submittal: The purpose of this submittal is to ascertain that the design is progressing in accordance with the requirements of the project, that existing field conditions have been properly identified and dealt with, and that the Contractor has coordinated the design with EFLHD, NPS, the permitting agencies, and the utility companies [*Request for Proposals IBC-8888*(*012*) *Book 1* 2001].

There are two variations on this category that were found and require mentioning in this section. The first is when the DOT requires an independent design QA firm to do the design reviews with the DOT 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 (*Request for Proposals to Construct, Maintain and Repair* . . . 2001).

The second variation is when the DOT requires certain design reviews and 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 DOT in attendance.

> The DQA 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 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 (*Request for Proposals, Everett HOV Design-Build Project* 2004).

In the vein of deciding the appropriate number of DOT design reviews for a given project, it is interesting to note that the U.S. Army Corps of Engineers recently changed its policy for DB design reviews, reducing the number of reviews from four (30%, 60%, 90%, and final) to two (intermediate and final) (*MILCON Transformation Model RFP* 2006). The reason for the change was to reduce the potential for delays owing to waiting for government reviews. In a personal communication with the author, Joel Hoffman of the U.S. Army Corps of Engineers 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." Therefore, 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 previously, 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 reviews fall into the DOT PQA category. These statements are included in RFPs regardless of the number of required design reviews. Almost always, however, a statement is also included that removes liability from the DOT for any comments that may be incorporated from the informal reviews. The following extract comes from the EFLHD RFP referenced earlier:

> Over-the-Shoulder reviews may be scheduled by the Contractor or EFLHD. Over-the-Shoulder reviews are strongly encouraged to enhance the partnering efforts between the Contractor and the Government. . . . The number and timing of the reviews will be discussed at the Start-up Conference. . . . Over-the-Shoulder reviews will be conducted for informal review of designs. The intent of Over-the-Shoulder reviews is to provide guidance to the Contractor during the course of the project. Over-the-Shoulder reviews do not take the place of the Overall Project Submittals [*Request for Proposals IBC-8888 (012) Book I* 2001].

The WSDOT included this in one RFP: "Throughout the design process, the Design-Builder may request additional oversight visits by Washington State DOT to discuss and verify design progress and to assist the Design-Builder and/or its designer(s) in resolving design questions and issues" (*Request for Proposals, Thurston Way Interchange* . . . 2000).

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

TABLE 12
COMMUNICATING DESIGN REVIEW RESPONSIBILITIES

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 DOTDs desi gnated representative
Major Temporary Components	Designer and Design Quality Control Manager	Design Quality Control Manager
Temporary Components	Designer and Checker	Not applicable

From Louisiana Department of Transportation and Development (DOTD) (*Request for Proposals, New Mississippi River Bridge* . . . 2005).

design reviews using one of the three approaches outlined in the preceding paragraphs.

Design Review Responsibility

Communicating who is responsible for the design reviews is also essential to the smooth execution of these quality activities. There are a variety of ways this can be done, including lists, charts, diagrams, or designating responsibility in contract clauses. Table 12 is taken from a Louisiana Department of Transportation and Development (DOTD) DB RFP and provides a good example of how to effectively communicate design review responsibility.

In addition to deciding which reviews will be conducted and when, deciding who will perform the reviews is just as critical to the success of DB projects. Because the DOT is not performing the design with its own designers, design QA and QC responsibilities will shift in DB. Table 12 shows that the Louisiana DOTD has assigned virtually all the design QA and QC responsibility to its design-builder, only entering the process to verify the as-built plans. Because the design phase defines the standard of quality for the constructed project, it is imperative that the design documents are professionally reviewed and checked to ensure a quality project. The general survey sought to identify the trend in design quality responsibilities by asking the respondents to indicate the entity that was *primarily* assigned the responsibility for a list of common design quality management tasks. However, a large number of the respondents did not confine themselves to furnishing a single answer to each question. Many indicated that the responsibility for the tasks was indeed shared among some combination of the agency, the design-builder, and the agency's consultants. This response defeated the original intent of the question; however, it still yielded valuable information regarding the distribution of design quality management responsibility among the parties to a DB contract. Table 13 summarizes the survey responses to the question of assigned responsibility for design quality management tasks.

Table 13 shows that the design-builder or a third-party consultant has been given more responsibility than is seen in traditional DBB in performing design quality management tasks that lead up to the final acceptance of the design. Agencies are assigning the design-builder the responsibility for

TABLE 13
SURVEY RESPONSES FOR DESIGN QUALITY MANAGEMENT TASK RESPONSIBILITY

Who Performs the Following Design Quality Management Tasks? (Type Task)	Agency Personnel	Agency-Hired Consultant	Design-Builder's Design Staff	Design-Builder's Construction Staff
Checking of Design Calculations (QC)	15.4%	15.2%	68.7%	0.8%
Checking of Quantities (QC)	13.8%	11.2%	53.1%	21.8%
Review of Specifications (QC)	32.9%	25.0%	38.9%	3.2%
Technical Review of Design Deliverables (QC)	30.9%	28.6%	40.0%	0.6%
Acceptance of Design Deliverables (QA)	57.9%	15.8%	22.9%	3.3%
Approval of Final Construction Plans and Other Design Documents (QA)	82.0%	5.2%	9.9%	2.9%
Approval of Progress Payments for Design Progress (QA)	81.8%	9.1%	2.0%	7.1%
Approval of Post-Award Design QM/QA/QC Plans (QA)	84.4%	9.7%	5.9%	0.0%

design QC tasks, such as the checking of design calculations, the checking of quantities, the technical review of design deliverables, and the review of specifications. Because these tasks are primarily associated with the production of design deliverables, the DOT is facilitating the overall schedule by stepping back from these tasks and giving the design-builder control. Additionally, it effectively prevents the unintentional assumption of design liability through directive design review comments (Gransberg et al. 2006). For the design QA tasks of accepting and approving final construction plans and design documents, DOTs have by and large retained the responsibility. This makes sense because DOTs still have ultimate responsibility for the design and construction and final quality of each project. DOTs cannot contractually assign their public duty to another party. They can have design-builders and third-party consultants help achieve an assurance of quality, but, at the end of the day, they must be able to affirm that each project has been constructed to the requisite quality level.

The survey asked each respondent to cite the number of DB projects in which its agency had been involved. This allowed the responses to be divided by experience level. In this case, the responses from agencies with more than five DB projects were assembled as a single group for comparison with the responses of the total population shown in Table 13. The idea is to capture the potential differences from an agency whose quality management system has been able to benefit from lessons learned in early DB projects and those by agencies that are embarking on their first series of projects. Intuitively, those with more DB quality management experience may have a better knowledge of how to distribute the responsibility for design quality. Table 14 shows the survey responses from this group and the agency and agency-hired consultant numbers have been summed, as have the numbers for the two design-builder entities, to give a clearer picture of how experienced agencies divide design quality management responsibilities between the two parties to the DB contract. It is interesting to note that in every category the more experienced DOTs retain a higher percentage of responsibility for design QC tasks and most of the time they retain responsibility for design QA tasks and give less responsibility to the design-builder than the general population. The differences between the experienced respondents are especially significant in the categories of the technical review of design deliverables, the acceptance of design deliverables, the review of specifications, the approval of progress payments for design, and the post-award design quality management plan approval. These are the points in the design process at which the final design decisions are made, and the experienced DOTs appear to feel the need to impose themselves in the design quality management process at these points.

Additionally, although it is not shown in Table 13, only 20% of the survey responses of the more experienced DOTs indicated that they were using a third-party consultant to perform design QA tasks. This is less often than was indicated by the less experienced DOTs, where a consultant was used by 50% of the respondents. This makes sense because a DOT with little or no previous DB experience could mitigate the risks associated with inexperienced agency personnel by retaining an experienced DB consultant to assist it with the quality management during its first series of DB projects.

CONCLUSIONS

The design phase of a DB project is the phase in which the ultimate quality of the constructed facility is quantified through the production of construction documents. Because this is the point of the project at which quality is defined, it is essential that the design quality management responsibilities be clearly defined in the solicitation documents. DOTs might require that some form of design quality management planning be included in the design-builders' proposals to demonstrate the importance of design quality to the competitors and give themselves an opportunity to evaluate each design-builder's proposed approach. This also allows the design-builders the opportunity to include the cost of design quality management resources and activities in their price proposal and, more importantly, in their schedule.

It may be important to determine the number of design reviews that will be conducted during the DB project design

TABLE 14
SURVEY RESPONSES FOR DESIGN QUALITY MANAGEMENT TASK RESPONSIBILITY FOR RESPONDENTS WITH MORE THAN FIVE DESIGN-BUILD PROJECTS

Who Performs the Following Design Quality Management Tasks? (Type Task)	Agency or Agency-Hired Consultant	Design-Builder
Checking of Design Calculations (QC)	38.5%	61.5%
Checking of Quantities (QC)	41.5%	58.5%
Review of Specifications (QC)	71.9%	28.1%
Technical Review of Design Deliverables (QC)	65.4%	34.6%
Acceptance of Design Deliverables (QA)	84.6%	15.4%
Approval of Final Construction Plans and Other Design Documents (QA)	92.3%	7.7%
Approval of Progress Payments for Design Progress (QA)	100%	0%
Approval of Post-Award Design QM/QA/QC Plans (QA)	100%	0%

phase and clearly assign the responsibility for conducting those reviews. Publishing them in the project's solicitation documents creates the necessary contractual requirements for both parties to the DB contract. The RFP content analysis and the survey response data indicate that there is no optimum number, but rather that this is really a function of the project's magnitude and technical complexity. A more complex project would receive more intermediate design reviews, as would a larger project. The key issue is to ensure that a DB project with an aggressive schedule is not unintentionally delayed by unnecessary reviews. Therefore, a DOT can seek to minimize the number of design reviews and consider using alternative techniques, such as the over-the-shoulder design review, to supplement the formal reviews and fulfill its PQA responsibilities.

One of the advantages of DB is the opportunity for the DOT to contract out QA and QC activities to the design-builder or a third-party consultant, thus reducing the workload on the DOT employees. It is common practice to assign the design QC to the design-builder in DB projects. In many cases, the design QA is also given to the design-builder. The owner may, however, retain oversight in some manner to fulfill its federally mandated quality responsibilities as well as its ultimate responsibility for the quality of the constructed project. Many different ways to perform the oversight have been outlined in this chapter. The most important issue is to clearly define at what point PQA activities will occur and how the DOT and the design-builder will interact regarding their assigned design QA and QC responsibilities.

CHAPTER FIVE

DESIGN-BUILD QUALITY ASSURANCE PRACTICES DURING CONSTRUCTION PHASE

INTRODUCTION

DOTs are accustomed to describing in great detail the means and methods used to carry out the construction of their transportation projects in the standard specifications for construction. These specifications have been used in DBB and proven over time to be successful in yielding a quality product. In DB, however, DOTs 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. However, with this opportunity there also comes the risk that the means and methods used by the design-builder may not achieve the same quality as those prescribed in DBB contracts. Thus, one of the major quality management decisions that must be made in a DB highway project is to articulate the amount of flexibility that the design-builder will have over construction means and methods.

STANDARD SPECIFICATIONS AND CONSTRUCTION MEANS AND METHODS

In DBB, DOTs make their standard set of specifications for bridges and roads a contract requirement. In the RFP content analysis, 76% of the solicitation documents referenced the DOT standard specifications for construction. Of these, six allowed for the design-builder to also be evaluated on proposed means and methods, if they differed from the DOT standard specifications. Four other RFPs scored the design-builders on proposed means and methods without mentioning the DOT standard specifications for construction. Two projects, the San Joaquin Hills Transportation Corridor in California and the Southeast Corridor Multi Modal Project in Colorado, required the contractors to present their means and methods after award. Incidentally, these were both classified as "mega-projects" using an FHWA definition found in the literature (Capka 2007). Therefore, the relative size of these two projects may have had an impact on the decision to ask for construction details after award. Additionally, the survey conducted for this report asked respondents if their agency mandates the use of standard agency (DOT) design/construction specifications for their DB projects. Just as in the solicitation document analysis, 78% of the respondents answered "yes, on all projects." Only 8% reported that they never mandate the use of their standard construction specifications. This does not, however, conclude that the standards are not referenced in the solicitation documents. The remaining 14% indicated that mandating the use of the DOTs' standard specifications was project dependent. When these figures are grouped according to the DB experience of the parties, the percentages change significantly. For those respondents who had experience with more than five DB projects, 91% indicated that the DOT mandated the use of DOT standard specifications. The other 9% of respondents indicated that the use of DOT-mandated standard specifications depended on the project. However, only 73% of the respondents who had five or fewer DB projects mandated the use of agency standard specifications on all projects, whereas 12% indicated that they never mandated the use of the DOT standard specifications.

Methods for Incorporating Standard Specifications and Methods

When asked about mandating the use of the standard DOT-approved construction means and methods, 24% of the respondents indicated that they always mandate the use of their means and methods on DB projects, whereas 58% indicated that they never did. The remaining 18% stated that it depended on the project as to whether or not they mandated the DOT standard means and methods. The results of the survey helped identify two methods to approach the use of standard specifications and construction means and methods in the quality management of DB projects.

Incorporating Standard Specifications in Construction Only

The first method relies on incorporating the state's standard set of specifications in the construction phase of the DB project. This makes sense in that the physical construction activities in DB are no different than in DBB. The only difference becomes the determination of responsibility for controlling the quality of those activities. This decision cannot be made out of the DB context. Choosing to implement the means and methods required in the standard specifications can unintentionally constrain the design process. Therefore, most states have chosen to use the standard specifications to describe the requirements for quality management during construction. This method is used by the NCDOT, which places QC responsibilities on the design-builder and requires it to

follow the details of the standard specifications in accomplishing those duties as shown by the following:

> The Design-Builder shall perform all quality control for the Quality Management System (QMS) for Asphalt Pavements in accordance with section 609 of the Standard Specifications (*Design-Build Package: I-77 from I-485 to SR 2136* . . . 2005).

Thus, in this case NCDOT is only imposing the means and methods that might be referenced in its quality management program for asphalt pavements rather than directing that asphalt pavements be built in accordance with the standard construction specifications themselves. This approach allows the DOT to constrain the means and methods to ones in which it has confidence without becoming overly prescriptive and unintentionally creating ambiguities that would be detrimental to the design process.

Incorporating Standard Specifications by Reference

The second approach is to incorporate the standard specifications and/or construction means and methods merely by reference. Often, in this approach, the quality management clauses shift construction quality to the design-builder and take a hands-off approach to means and methods. This allows the design-builder to utilize those means and methods that best suit its design. An example of this approach is taken from a Utah DOT project:

> Design-Builder shall be responsible for and have control over the design including QC and QA, construction means, methods, techniques, sequence, procedures, Site security, and Site safety, and shall be solely responsible for coordinating all portions of the Work under the Contract Documents, subject, however to all requirements contained in the Contract Documents (*Request for Proposals, SR-92* . . . 2005).

The reader can see that in this clause the owner has made it clear that the design-builder is fully responsible for determining the construction means and methods that best suit the design completed by the design-builder, rather than trying to impose specific control over the construction process through binding the design-builder to the prescriptive provisions in the state's standard specifications. A similar approach was used in the San Joaquin Hills project:

> CONTRACTOR shall be solely responsible for and have control over construction means, methods, techniques, sequences, and procedures and for coordinating all portions of the Work under the Contract Documents, subject, however, to all requirements contained in the Contract Documents (*Design/Build Services: San Joaquin Hills* . . . 1991).

To summarize, standard specifications and construction means and methods can be handled either by treating them no differently than they would have been treated in traditional DBB project delivery or by shifting the responsibility for determining appropriate and effective means and methods to the design-builder using the standard specifications as a foundation. Very few of the RFPs reviewed contained specific references to construction means and methods. This leads to the conclusion that although use of appropriate construction means and methods is extremely important to ensure final project quality, most DOTs have chosen to relinquish direct control over them and shift the responsibility for the quality of the means and methods used in a DB project to the design-builder.

CONSTRUCTION QUALITY ASSURANCE AND QUALITY CONTROL POLICIES ON DESIGN-BUILD PROJECTS

In trying to identify certain trends about who conducts the construction QA and QC functions on DB projects some specific activities were looked for in the solicitation document analysis, such as assigning responsibilities for the following QA and QC activities:

- Performance of shop and/or working drawing review and approval,
- Establishment of horizontal and vertical control on the project site,
- Performance of routine QC inspections,
- QC testing, and
- Nonconforming work (punch list).

Construction Shop Drawing Review

In the RFP content analysis, 26 project documents specified responsibility for construction shop drawing reviews. The majority of these projects (62%) placed all shop drawing review on the design-builder, which makes sense because the designer-of-record works for the design-builder in DB contracts. In 15% of the projects, the DOT retained the responsibility and risk of reviewing and approving construction shop drawings. In the remaining 23% of the cases, the design-builder was responsible for reviewing and approving the shop drawings, although the DOT retained an active role in verifying the design-builder-performed review. Also confirming this finding is the survey response to the question of who primarily performs the technical review of construction shop drawings. Of the respondents, 72% indicated that this QA responsibility is placed on the design-builder, whereas the other 28% indicated that the DOT or a third party would review the shop drawings. An RFP issued by the Florida DOT presents a summary of this type of review:

> The Design-Build Firm shall be responsible for the preparation and approval of all Shop Drawings. . . . The Department shall review the Shop Drawing(s) to evaluate compliance with project requirements and provide any findings to the Design-Build Firm. The Department's procedural review of shop drawings is to assure that the Contractor and the EOR [engineer-of-record] have both accepted and signed the drawing, the drawing has been independently reviewed, and is in general conformance with the plans. The Departments review is not meant to be a

> complete and detailed review (*Request for Proposal, Milling and Resurfacing of Interstate 95* 2003).

In other cases, the DOT chose to review only specific elements of the project that were of direct interest, such as structures or lighting (see *Part I: Scope of Work T.H. 100* . . . 2001; *Request for Proposals, Interstate 229* . . . 2000; *Guidebook for Design-Build Highway Project Development* 2004). The review in these situations was again just to ensure compliance with contract requirements and the RFP required that the shop drawings be first reviewed by the design-builder. This furnishes added confidence in the quality of the constructed product for features of specific interest without usurping the design-builder's responsibility for total quality management. It also reduces the amount of construction administration that the DOT must conduct to that which adds value to the process.

Horizontal and Vertical Control

Horizontal and vertical control on the project site is another item analyzed in the RFP content analysis. Forty-two solicitation documents contained information on this topic. In all cases, the DOT gave control of the construction staking and grades to the design-builder. In 88% of the cases, the design-builder was also responsible for establishing horizontal and vertical control except for some limited preproposal surveying, such as that referenced in the Mississippi DOT RFP: "The Department will establish, one time only, State Plane Coordinate System horizontal control monuments. It shall be the responsibility of the Contractor to establish additional control as may be required to facilitate the staking of the right-of-way" (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005). In the remaining 12% of the projects there was a more extensive shared responsibility between the DOT and the design-builder. This also occurred in the two examples from EFLHD and the Ohio DOT as shown here:

> EFLHD: The Government has established basic survey control points for vertical and horizontal control of the project [*Request for Proposals IBC-8888*(*012*) *Book 1* 2001].

> Ohio DOT: The Department survey crews have provided the necessary survey requirements, listed below: Mainline centerline control and bench marks; Mainline monumentation control . . . Vertical clearances for overhead structures, to serve as a check for the existing vertical clearances (*Request for Proposals, SR11* 2001).

The survey confirms the finding of placing the horizontal and vertical control responsibility in the hands of the design-builder. Respondents indicated that this was the case 92% of the time.

Routine Construction Inspection

Routine construction inspection is another construction quality aspect that has overwhelmingly been shifted away from the DOT. As written in an RFP issued by the Virginia DOT, this shift was clearly delineated: "The construction QA person will perform all of the construction inspection and sampling and testing work that is normally performed by the VDOT" (*Request for Proposals, A Design-Build Project Design and Construction* . . . 2002). Once again, the content analysis showed that the majority of the projects (82%) placed routine construction inspection in the hands of the design-builder or both the design-builder and an independent firm. The DOT retained the construction inspection duties in only 13% of the cases (interestingly, all projects in this category were by DOTs that had performed more than five DB projects) and shared the duties with the design-builder in 5% of the cases. The survey results for who performs routine construction inspection also differ significantly for the more experienced and less experienced survey groups. Seventy-five percent of the less experienced respondents indicated that their agency gave the routine inspection responsibility to the design-builder. Only 53% of the more experienced respondents indicated the same. In addition, 14% of the less experienced group placed the responsibility on their own agency, whereas 32% of the more experienced respondents indicated that the DOT retained the construction inspection responsibility. It is interesting that the DOTs with more experience are less prone to give the routine construction inspection procedures to the design-builder.

Although there are numerous ways to outline construction inspection responsibility, the content analysis showed that the approach taken needs to be project specific rather than merely a matter of policy. Below are examples of how the NCDOT, an agency with extensive DB experience, dealt with routine construction inspection requirements on three different projects.

1. Design-Builder Responsibility: "The Design Build Team shall provide a schedule indicating the minimum number of inspectors that will be supplied at different stages during the project duration" (*Design-Build Package: I-40 from West of SR 1224* . . . 2005).
2. DOT Responsibility: "Construction engineering and management will be the responsibility of the Design-Build Team. Construction Engineering Inspection [by a third party] will NOT be required in this contract" (*Design-Build Package: US64 Knightdale Bypass* . . . 2002).
3. Shared Responsibility between Design-Builder and an Independent Firm: "Construction engineering and management, including quality control and inspection, will be the responsibility of the Design Build Team. . . . The Design-Build team shall employ a private engineering firm to perform Construction Inspection for all work required under this contract. This private engineering firm is to be a separate entity, unaffiliated with the Design-Builder in any way. Private engineering firms must be prequalified under the Department's normal prequalification procedures prior to bid submission. This Scope of

> Work describes and defines requirements for the construction inspection, materials sampling and testing, and technician level contract administration by the private engineering firm (commonly referred to as 'Construction Engineering & Inspection' [CEI] firms) required for construction of this project" (*Design-Build Package: I-77 from I-485 to SR 2136* . . . 2005).

One can see that the NCDOT has made a conscious decision in each case to apply an appropriate level of control based on the technical requirements of each project.

The WSDOT provides a fourth approach to construction inspection responsibility distribution, as described the *Guidebook for Design-Build Highway Project Development* (2004):

> WSDOT's inspection involvement will be less extensive than under design-bid-build, depending on the construction schedule and the type of project. The primary role is to monitor the progression of the construction against the Construction Documents submitted by the Design-Builder. *The inspector's authority has not changed, although* [*the inspector's*] *work will be coordinated with the Design-Builder inspector*. On projects where WSDOT performed final design on portions of the project, the WSDOT inspector's role will be similar to that under design-bid-build projects. With mixed assignments on-site, the WSDOT and Design-Builder inspectors will need to maintain close coordination to ensure none of the required QC measures are missed (italics added).

Witness and Hold Points

The WSDOT implemented this policy in its RFP for the Thurston Way Interchange project through the use of a DB construction inspection technique drawn from the building construction industry called "witness and hold points" (Gransberg et al. 2006). A "witness point" is defined in the WSDOT *Guidebook* as an oversight activity and "hold points" are mandatory inspections held at specific points in construction progress (*Guidebook for Design-Build Highway Project Development* 2004). Often these are points at which the design-builder is ready to bury a major feature of work, such as a utility line, or to cover a feature up by casting it in concrete. They represent points in the DB project schedule at which the design-builder must notify the DOT and arrange for a mutual inspection of those features of work that are identified in the contract. The WSDOT RFP language is as follows:

> Witness and Hold Points are to be established where notification of WSDOT is required for WSDOT's option of observing or visually examining a specific work operation or test. Witness Points are points identified within the inspection plan which require notification of WSDOT. Work may proceed beyond a witness point with or without participation by WSDOT provided proper notification has been given. Hold Points are mandatory verification points identified within the inspection plan beyond which work cannot proceed until mandatory verification is performed and a written release is granted by WSDOT. Witness and Hold Points should be identified in the construction process where critical characteristics are to be measured and maintained, and at points where it is nearly impossible to determine the adequacy of either materials or workmanship once work proceeds past this point . . . The QC Plan shall contain inspection plans for each construction work item included in the project whether performed by the Design-Builder or a subcontractor or vendor (*Request for Proposals, Thurston Way Interchange* 2000).

The Arizona DOT also uses witness and hold points as a mechanism to control the adequacy of routine construction inspections (*Design-Build Procurement and Administration Guide* 2001). In doing so, it sets "quality checkpoints" coupled with quality incentives. Typically, the Arizona DOT covers DB construction inspection by "requiring the D/B firm to provide independent inspections and materials testing with ADOT oversight and having the contractor perform the QC and the QA by an independent portion of the D/B firm with ADOT providing oversight and independent sampling and testing" (*Design-Build Procurement and Administration Guide* 2001).

Quality Control Testing

The central aspect of construction quality control is QC testing. QC testing is also an area where the content analysis found that DOTs have overwhelmingly given responsibility to the design-builder. In the 39 projects that specifically mentioned construction QC testing in the DB RFP, the DOT 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. DOTs, 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 it 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 (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Over St. Louis Bay* . . . 2005).

The Texas DOT was one of the exceptions in their DB RFP for State Highway 130, a mega-project with its own unique characteristics. Because of the magnitude of the project, the Texas DOT 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 (*SH 130 Turnpike Project Exclusive Development Agreement* 2001).

Both exceptions are based on the idea that the DOT must ultimately ensure that the construction QC system supports rather than constrains project progress and, by either giving the design-builder full responsibility or inserting an independent quality firm, the DOT is ensuring that it has clearly delineated the requirement for QC testing during the course of construction.

The survey results, however, once again come to a different conclusion as to who is responsible for construction QC testing. In the less experienced group, the design-builder was responsible for the construction QC testing in 88% of the responses. In the more experienced group, the design-builder was responsible in only 60% of the responses. There is a similar discrepancy in the amount of construction QC testing responsibility that the DOT retains. The less experienced group retained the responsibility in less than 1% of the responses, whereas the more experienced group indicated that 26% retained the construction QC testing responsibility. These responses raise the question of why would more experienced DOTs retain construction QC responsibilities when these responsibilities could be given to the design-builder.

Nonconforming Work

The final construction QC issue is the disposition of nonconforming work (often called the "punch list") and determining the party that will be responsible for making the final inspections and reporting final conformance. Twenty-five of the projects specified who was responsible for reporting nonconforming work. Intuitively, this is the point in construction quality management that most of the DOTs seem to have retained control. In 64% of the RFPs analyzed, the DOT retained the responsibility for reporting and determining nonconforming work. For example, a Utah DOT RFP stated that: "Nonconforming Work is Work that *the Department determines* does not conform to the requirements of the Contract Documents" (*Request for Proposals SR-201* . . . 2004, italics added). This is a clear statement of the DOT's perceived responsibility for final acceptance of the completed project.

Interestingly, in 32% of the projects, the design-builder was assigned responsibility for conducting inspections and preparing the reports of the nonconforming work. This is not meant to imply that the DOT was absolving itself from responsibility for final acceptance of the project, but rather that the DOT was requiring the DB team to conduct what would best be termed a "rolling punch list." This approach reports nonconformance as it is discovered and encourages the design-builder to make corrections as soon as practical rather than waiting to the end of the project. These inspections are used as the basis for a final report that documents the findings. Presumably, the DOT would then use this as a basis with which to conduct its own final acceptance activities. The two following examples, from the Colorado and Utah DOTs, show how this was expressed in RFPs:

> [Colorado] The Contractor shall establish and maintain a nonconformance system and procedures for uniform reporting, controlling, and disposition of nonconformance (*Request for Proposal, Book 1* . . . 2000).

> [Utah] The CPOC [construction proof of compliance] shall identify and document in a nonconformance report (NCR) all elements of the Work that have not, or are believed to have not, been constructed in accordance with the approved drawings and specifications. The NCR shall be submitted to the IQM [independent quality manager] in writing within 24 hours of identification, and a copy sent to the design engineer. . . . The Department will not grant acceptance for any portion of Work that has an outstanding NCR (*Request for Proposals Parley's Crossing Tunnel @I-215* . . . 2004).

A word of caution on this method comes from a survey respondent who stated that:

> Design-builders are often afraid of reporting nonconforming work. Many teams feel that their record for nonconforming work will be held against them when they are being scored on the next best-value design-build project (*Request for Qualifications T.H. 52* . . . 2001).

Use of an Independent Firm to Manage Nonconforming Work

In North Carolina, the nonconformance report comes from an independent firm, which is the same firm that performed the construction QC inspection as follows: "The CEI firm shall document any observed omissions, substitutions, defects, and deficiencies noted in the work, take corrective action necessary, and advise the DEPARTMENT accordingly" (*Design-Build Package: US64 Knightdale Bypass* . . . 2002).

In regard to who reports nonconforming work, the survey confirmed the findings of the RFP analysis. Of the survey respondents, 78% indicated that either the DOT or a third-party consultant hired by the DOT reported nonconforming work. The remaining 22% indicated that either the design-builder's construction or design staff was responsible for reporting nonconforming work.

Verification and Acceptance Testing

To support final project acceptance, the responsibility for final inspections as well as any verification or acceptance testing must be determined. The content analysis set out to find who was responsible for the verification and acceptance testing. As with the report of nonconforming work, DOTs have generally retained this quality function. Of the 40 projects that listed who was responsible for verification and acceptance testing, 88% assigned the responsibility to the DOT. Another 5% required an independent firm that worked directly for the DOT to accept this responsibility. Interestingly, three RFPs assigned this responsibility to the design-builder. The survey responses support these findings by indicating that 88% of the time the DOT or a third party hired by the DOT performs verification and acceptance testing,

whereas the design-builder is responsible only 12% of the time. Although 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 DOTs indicated in the RFP that the DOT reserved the right to appoint a representative to perform the tests (see the following example from the Florida DOT). Standard RFP clauses are represented.

> [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 (*Contracts and Specifications Section* . . . 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 (*Request for Proposal, Milling and Resurfacing of Interstate 95* 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] [*T.H. 52* (*Rochester*) *Design-Build Request* 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 (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Biloxi to Ocean Springs Bridge* . . . 2005).

> [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 (*Request for Proposals, SR-92* . . . 2005).

Design-Builder Verification and Acceptance Testing

In three of the projects reviewed, the design-builder was responsible for the verification and acceptance testing. One of these projects, the RFP for the Eastern Transportation Corridor in California, was a toll collection and revenue management system for which 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 Southeast 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 (*Request for Proposal, Book 1* . . . 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 (*Final Request for Proposals for The New I-64 Design-Build Project* 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 that:

> 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 the conducted hereunder (*Design/Build Services: San Joaquin Hills Transportation Corridor* . . . 1991).

Finally, in Utah's I-15 mega-project, a third party was specifically listed as assisting the DOT to fulfill its verification and acceptance testing responsibilities (*Request for Proposals, I-15 Corridor Reconstruction Project* . . . 1997).

To summarize this section of the report, it is fair to say that in the majority of the cases the DOT assigned the responsibilities for construction quality management primarily to the design-builder while retaining either traditional QA or PQA for itself or a third-party consultant that worked as the DOT's agent.

POST-AWARD CONSTRUCTION QUALITY PLANS

In the RFP content analysis, 45% of the projects required some part of a construction quality plan either before or after award of the contract, and 40% required an entire post-award construction quality plan (presumably including both QC and QA) that would not be scored in the proposal evaluation. In addition, 41% of the survey respondents also indicated that they require a post-award construction quality management plan. In one RFP, the San Joaquin Hills Transportation Corridor, post-award construction QC and QA plans were specifically required. In four other projects, only post-award construction QC plans were required. Most often, the submission required the quality plan to be submitted for DOT approval within a specific number of days before the start of construction. For example, a project in Washington, D.C.,

required the contractor to comply with the following: "Before the start of *any construction*, submit a written quality control plan for acceptance" [*Request for Proposals IBC-8888*(*012*) . . . 2001]. In another example, from the Mississippi DOT, a specific time is listed for the submission of the construction QC plan and the requirements:

> The CONTRACTOR shall submit a Quality Control Plan that outlines how the CONTRACTOR shall assure that the materials and Work are in compliance with the CONTRACT Documents. The initial plan shall be submitted to the [DOT] for review and approval at least 30 days prior to the beginning of any construction activity (*Request for Proposals, Addendum 1, A Design-Build Project Bridge Replacement on US 90 Biloxi to Ocean Springs Bridge* . . . 2005).

The New Mexico DOT included the following in an RFQ about a construction quality plan:

> The Contractor will be required to plan, implement, and provide a Quality Assurance/Quality Control (QA/QC) Program for its design and construction operations. . . . The Department will review the Contractor's program to assure that it meets guidelines and minimum requirements established by the Department. Department approval of the program will constitute Department agreement that it meets these criteria, but the Contractor shall maintain ownership of the program and shall be fully responsible for its execution (*Request for Proposals, US 70 Hondo Valley* . . . 2001).

Some of the post-award construction quality plans are required as a follow-up to a draft or summary presented in the proposal. This was the case in 13 of the 17 projects that required a post-award construction quality plan. The RFP first required a pre-award draft of the plan so that the DOT understood and could evaluate the design-builder's quality management approach before awarding the contract. The rationale seems to be that because the design is not complete, it is neither feasible nor necessary to require a complete quality plan in the proposal. This also serves to reduce proposal preparation costs for the competing design-builders. The MnDOT has used this method. Its RFP states:

> [After award,] the Design-Builder shall submit a Construction Quality Management Plan (CQMP) (based on the Draft CQMP submitted in its Proposal) that addresses Construction Quality Control (CQC), including coordination of the Department's Construction Quality Assurance (CQA) and Independent Assurance (IA) procedures [*T.H. 52* (*Rochester*) *Design-Build Request* . . . 2002].

It would seem that this last approach would be the most reasonable. It makes quality management planning an evaluated portion of the proposal, but does not impose an undue burden on the competitors by asking for a detailed document that is based on their hypothetical approach to the project. Additionally, because the winning proposal typically becomes a part of the contract (Beard and Belle 2003), the award is permitted to be made without the need to subsequently modify the contract as the quality management plans are modified in accordance with the final approved design. Finally, it is surprising that nearly half the RFPs did not ask the design-builders to provide some detail as to their quality management approach for the project. These RFPs obviously were using the "Quality by Qualifications" (Gransberg and Molenaar 2004) approach to articulating their requirements for quality management, which relies on the evaluation of the design-builders' qualifications and past performance record to ensure that quality will be brought to the design and construction through the quality of the personnel and firms that complete the work.

CONSTRUCTION QUALITY PERSONNEL REQUIREMENTS

The quality of the people who perform the construction quality management functions on a project is an important factor in the reliability of the results of the inspections and tests. Therefore, the DOT is interested in those who supervise and perform these inspections and tests. As discussed in chapter three, 59% of the projects in the content analysis required that a project or construction quality manager be listed in the proposal as part of the competitive evaluation. Also, as was discussed in the same chapter, the primary qualifications for these personnel were experience and professional licensing or certification as appropriate for their assigned duties, as well some education requirements.

Fifteen of the projects had requirements for construction quality personnel in the RFP that must be identified and approved after the contract has been awarded. The majority of these projects (73%) required that all personnel who had a construction quality function or task be identified with their levels of certification and other qualifications. Many of them (64%) also specify the number of full-time personnel who will be assigned to the project. An excerpt from a South Dakota RFP is a good example:

> The CQMP shall provide the information regarding the Design/Builder's organization in providing quality management of all of the construction processes. The number of full-time equivalent employees with specific Quality Control responsibilities shall be included, as well as a chart showing lines of authority and reporting authority. . . . The Design/Builder shall identify the names, positions, qualifications, duties, responsibilities, and authorities of each person proposed in a quality function for construction (*Request for Proposals, Interstate 229* . . . 2000).

Another 33% of the RFPs required that QC testing and/or inspection supervisors be submitted and approved after award of the contract. The following comes from the EFLHD RFP describing the contents of a post-award construction QC plan:

> Personnel qualifications . . . Document the name, authority, relevant experience, and qualifications of person with overall responsibility for the inspection system . . . Document the names, authority, and relevant experience of all personnel directly responsible for inspection and testing [*Request for Proposals IBC-8888*(*012*) . . . 2001].

A quality product requires people who perform in a qualified manner. To ensure that construction is performed at a

minimum level of quality, the DOTs must know the qualifications of those who will work on their projects.

CONCLUSIONS

As can be seen from the various examples and statistics cited in this chapter, there are myriad combinations that can be used to ensure construction quality on a DB project. The main conclusion is that each project is unique and to gain the greatest benefit of DB, each project must have a construction quality management plan crafted specifically for that project. As DOTs gain more experience with DB, they will better understand how to best manage construction quality in a DB project.

CHAPTER SIX

VARIATIONS ON DESIGN-BUILD QUALITY ASSURANCE FOR POST-CONSTRUCTION OPERATIONS, MAINTENANCE, AND FINANCING ARRANGEMENTS

INTRODUCTION

Quality issues are always present during the design and construction phases of a project. DB, however, also adds the option of allowing financing and post-construction services to be included in the DB contract. Following the success of SEP-14, Innovative Contracting, the FHWA in 2004 issued SEP-15, Public Private Partnerships, to "encourage tests and experimentation in the entire development process for transportation projects" (Blanding 2006). The most common examples of additional services in DB are design-build-maintain, design-build-operate-maintain, and finance-design-build-operate-maintain (also known as concession or PPP). These delivery methods that extend beyond the completion of construction provide DOTs with more options to deliver quality projects that meet long-term financial goals.

At face value, the impact of adding post-construction options to a DB project would appear to have a positive effect on quality, because the design-builder is financially tied to the cost of operating and maintaining the project. Therefore, if the constructed product is of high quality, it would follow that its post-construction operation and maintenance costs would be minimized. The report of the AASHTO Construction Management scan tour to Canada and Europe (DeWitt et al. 2005) found that five of the six countries visited "rely on the private sector for essentially all highway maintenance. This is accomplished through a series of term maintenance agreements in which routine maintenance and repair is done in accordance with performance contracts." The team also observed project delivery methods that "allocate more risk to the private sector and/or create more motivation for total life cycle maintenance and operation solutions from the private sector" (DeWitt et al. 2005). Apparently, the Canadians and Europeans have found ways to realize the potential benefit of linking DB projects with post-construction operations and maintenance through their performance contracts.

U.S. Experience

Things are not quite as clear cut in the United States. An interview with the project manager of the Hudson–Bergen design-build-operate-maintain (DBOM) project, a $600 million light rail project in New Jersey, indicated that with the post-construction operations and maintenance portion of the contract, the agency did not feel the same pressure to independently verify quality during design and construction that it did in other project delivery methods (Touran et al. 2007). However, these options are rare in the United States, and Nancy Smith, a well-known construction attorney who was involved in a number of the large DB projects, puts it this way:

> It is unclear whether a 5-, 10-, or 15-year maintenance/warranty obligation provides the contractor with a real incentive to ensure project quality. Since there are very few contracts in place that require long-term maintenance or warranties, it remains to be seen whether such an approach will ultimately be successful in assuring project quality (Smith 2001).

Therefore, it appears that the jury is out regarding the relative impact on U.S. project quality that post-construction options might create. The literature is sparse on this subject, as are RFPs for these types of projects. The Finnish Road Administration published a report detailing its strategy for selecting project delivery methods and reviewed its experience with DBOM and finance-design-build-operate-maintain (FDBOM). It found that "from the standpoint of the quality assurance of contracts, specification of functional or performance requirements will become very important . . . requirements that are poorly specified or difficult to objectively measure, appear in tenders that produce high prices from contractors or even make it impossible to achieve the desired level of service" ("Procurement Strategy of the Finnish Road Administration" 2003). Here it appears that an experienced public owner has discovered that being able to adequately define and perhaps, more importantly, measure quality in the post-construction phase is of primary importance. Another report that detailed the lessons learned by the U.S. Department of Energy in its privatized projects stated that the "team responsible for managing the contract also includes engineers and managers *who ensure conformity to product specifications, schedule adherence, safety, and quality assurance*." Therefore, it can be concluded that how quality is defined in these long-term post-construction contracts is just as important as how quality is defined in design and construction contracts.

Synthesis Survey Results

The national survey yielded some interesting results for this particular issue. Four questions directly addressed the use of post-construction options and their impact on the quality of the project. One question asked those with experience if the quality management plans required in projects with post-

construction options were different than those normally used in typical DB contracts. Interestingly, only 35% of the respondents said "yes," most likely because this system is so new to the United States that DOTs have not yet gained enough experience with its results that they would feel comfortable modifying their tried and true systems. Another question asked the respondents to rank the impact on project quality of three common post-construction options. (Note: those without experience could answer "N/A.") The results were as follows:

1. Warranty provisions: 56% rated this option as having either "high" or "very high" impact on project quality.
2. Follow-on maintenance agreement: 62% rated this option as having either "high" or "very high" impact on project quality.
3. PPP/Concession: 58% rated this option as having either "high" or "very high" impact on project quality.

In the last two questions that relate specifically to follow-on maintenance and PPPs, the most popular answer was "very high impact." Thus, the respondents confirm the idea that the addition of a post-construction option to a DB project will influence the quality of the constructed product. This finding is validated by the results of the perception survey in which the majority of the respondents held the belief that using DB project delivery positively affects final project quality.

DESIGN-BUILD-MAINTAIN

The idea of attaching a post-construction maintenance contract to a construction project as a mechanism to create a financial incentive to enhance construction quality has been debated for years. It is based on the theory that putting the construction contractor at risk for the cost of maintenance after completion will cause the contractor to be more careful during production. It is intended to "(a) reduce the amount of highway agency resources required on a highway project; (b) reallocate performance risk; (c) increase contractor innovation; (d) increase the quality of constructed products; and (e) reduce life cycle costs of highway projects" (Queiroz 1999). Thus, it is merely a natural extension of the concept of linking a post-construction maintenance contract to a DB project to create design-build-maintain (DBM) project delivery. This practice has been done regularly in Europe, where warranties have been used to defuse the issue of supposed lower quality on DB projects (Carpenter et al. 2003).

U.S. Design-Build-Maintain Experience

One of the early experiments with DBM was a project to widen two-lane New Mexico State Highway 44 to a four-lane road redesignated as US Route 550. The project became known as NM-44 and consisted of the reconstruction of 118 miles of state highway. The use of DBM project delivery with public-private financing allowed the project's delivery period to be reduced from the original estimate of 27 years to 3 years ("Contractor to Honor Road Warranty" 2004). The project came with a 20-year warranty at a cost of $62 million. The New Mexico DOT was complimented in the press for "not telling Koch [the DBM contractor] how to build the road . . . avoiding micromanagement allows the contractor to use innovative practices often not available to the public sector" ("Contractor to Honor Road Warranty" 2004). Several years after the road opened to traffic, it began to reveal distresses that were not associated with normal wear and tear, starting a controversy that was avidly followed by the local press. A New Mexico DOT official told a pavement symposium that the "DOT should have been more involved in quality control" ("Contractor to Honor Road Warranty" 2004). Therefore, even though there was a post-construction contract for maintenance, this project had quality problems associated with either design deficiencies or construction quality.

Adding maintenance to a DB contract was also used by the Utah DOT when it issued the RFP for the I-15 makeover in anticipation of the 2002 Winter Olympics (Postma et al. 2002). Initially, the Utah DOT decided to request that a 20-year maintenance period be included in the proposals; however, some contractors believed that this was not possible at a "reasonable cost" (Postma et al. 2002). Taking this into consideration, the Utah DOT changed the requirements to include only 10 years of maintenance on specific parts of the project. The requirement was for the "Contractor to provide a cost option to provide maintenance for the first five years and options for five one-year periods up to a total of ten years of maintenance" (Postma et al. 2002). Included in the contract for the maintenance option was the requirement that the contractor provide a "Maintenance Quality Management Plan" that would be approved by the Utah DOT if the option were to be exercised. In the end, the Utah DOT did not exercise the maintenance option because it was "very comfortable with the quality of the completed project and felt that they could perform the required maintenance more efficiently and at a lower cost with their normal maintenance program" (Postma et al. 2002).

There were some issues associated with this project that led the Utah DOT to not exercise the maintenance option. The contract for I-15 was written so that the contractor would receive a cost adjustment based on the Federal-Aid-Highway Construction Urban (Composite) Index. The index was very volatile at the time of the contract and "UDOT [Utah DOT] was reluctant to proceed with the adjustment" (Postma et al. 2002). The Utah DOT recommended that a different cost index be used that takes into account the time value of money (Postma et al. 2002). Another issue written into the contract was the sharing between the Utah DOT and the contractor of some of the catastrophic risks that may occur over the life of the project. Simply stated, "UDOT was not willing to take this risk" (Postma et al. 2002). Another issue from the Utah DOT experience is the importance of having a maintenance plan that clearly defines what the

DOT wants in the RFP. Because of how the specifications were written for the project,

> . . . an effective Maintenance Plan would be difficult to develop. The requirements for maintenance were spread throughout the contract, which made it difficult to identify and monitor. The specifications also had some ambiguities, which made it difficult to interpret the requirements and assure UDOT would get what they intended (Postma et al. 2002).

In spite of the issues, the major outcome was that the Utah DOT was satisfied with both the design and construction quality and made the business decision to not exercise its option to invoke the follow-on maintenance agreement. Thus, this project stands in contrast to the New Mexico project regarding the impact of a post-construction maintenance warranty on the constructed quality of a major transportation project.

In addition to these examples of DB projects, it is worth mentioning the results of some DBB projects that included warranties. A previous survey of DOTs in Arizona, Florida, Michigan, Ohio, Virginia, and Washington State (*Final Report: Six-State Survey* . . . 2001) "found that using warranties resulted in improved quality in the highway work contracted" (Carpenter et al. 2003). A similar study done by the Wisconsin DOT also found that warranted projects performed better than similar nonwarranted projects when measured with the Performance Distress Index and the International Roughness Index (*Asphaltic Pavement Warranties* . . . 1998).

Maintenance Contract Transfer Criteria

Including a post-construction option to operate and/or maintain a DB project adds another set of quality factors that must be included in the project's quality management planning. These entail the quality performance criteria for operations, maintenance, and transfer after the contract period is completed. As previously stated, the DOT is probably trading the ability to "relax" its QA activities during design and construction for having to evolve an entirely new PQA responsibility for conducting quality management activities that measure the quality of maintenance and operations. "Maintenance quality assurance is a process that uses quantitative quality indicators and statistical analysis to assess the performance of maintenance programs" (Adams and Smith 2006). This study found that, even though the experience with maintenance quality assurance is evolving and more DOTs are gaining some experience, no published standard exists from which owners can benchmark their own programs.

There is also a requirement in post-construction QA to develop a set of criteria for the quality of the project at the end of the concession period. The agreement with the concessionaire on the Texas DOT SH 130 project included a 15-year maintenance agreement and contained 36 separate transfer criteria on everything from pavement condition to traffic signals (*SH 130 Turnpike Project Exclusive Development Agreement* 2002).

These quality performance criteria must be connected to the compensation arrangement associated with the post-construction option. A study in Australia confirmed this statement when it found that "payments will also be related to performance criteria" (Pelevin 1998). A similar arrangement is in effect in Portugal where payment to the concessionaire is made based on criteria for safety and lane closure performance each month (Fernandes and Viegas 1999). Therefore, it can be seen that although making the design-builder financially liable for the post-construction operations and maintenance may alleviate some quality management issues, it brings an entirely new set of quality management requirements for the owner, and because this process is new in the United States, there is not much experience available for DOTs to leverage in developing these new PQA criteria and processes.

DESIGN-BUILD-OPERATE-MAINTAIN

DBOM is a system that is widely used in Europe as a primary way to deal with QA issues. A report by Cox et al. (2002) cites several advantages for this project delivery method:

> Adding maintenance or operation and maintenance has numerous advantages. The primary advantage is that these contracts create a lifecycle responsibility for the design-builder. The same company that designs and constructs the highway is also responsible for maintaining quality over a period of years. This situation provides an incentive to deliver better quality in the initial design and construction of the project because the design-builder will be responsible for additional maintenance and repair costs if the initial quality is inadequate.

Another report addresses this issue as follows:

> Design quality is ensured because the team must operate what they build. The process is not necessarily driven by the lowest bid; therefore, quality and robust design become more important over the life of the project life and the DBOM team's commitment period (Wiss et al. 2002).

Nevertheless, the addition of follow-on maintenance and operation contracts create a new level of quality management for the public agency. The Cox report states it like this:

> The addition of operation and maintenance to the design-build contract solves the problems of design administration, construction administration, quality control, and use of warranties. However, the drafting and enforcing of operation and maintenance performance criteria creates new issues that are not commonly dealt with in most highways agencies in both Europe and the United States (Cox et al. 2002).

The conundrum articulated previously is solved by the use of measurable performance requirements. These are then used as benchmarks against which the public agency can evaluate the design-builder and/or maintenance contractor's quality of performance. The idea is to require that the entity that designs the project is accountable for its product because "it owns the design and construction

methods used to achieve the performance requirement" (Cox et al. 2002).

FINANCE-DESIGN-BUILD-OPERATE-MAINTAIN (CONCESSIONS—PUBLIC-PRIVATE PARTNERSHIP)

FDBOM project delivery is increasing in use in the United States owing to the deterioration of the nation's infrastructure and the limited amount of funding provided by government. This is often called a concession or a PPP to credit the private participation in financing. The U.S.DOT defines a PPP as "a contractual agreement formed between public and private sector partners, which allows more private sector participation than is traditional" (Saunders 2006). This is another tool that DOTs can use to deliver needed infrastructure projects when there are not sufficient public funds for project financing. PPPs are commonly used in Europe, most notably the United Kingdom, with Australia, New Zealand, and South Africa also leading the way (Carpenter et al. 2003; Saunders 2006). "The French national highway system is almost exclusively operated by concessionaires . . . . Portugal is the most aggressive employer of concessions" (Cox et al. 2002). In Portugal, the method can be described in the following terms:

> The [PPP] scheme merges two decisions—one involves the allocation of responsibility and risk for the production and maintenance of a motorway to a private consortium, and the other the reimbursement for this effort over a period of years by the state (Fernandes and Viegas 1999).

The inclusion of private financing changes the equation with regard to project quality. In projects that are fully funded with public funds, the owner can take the moral high ground and insist on getting the project for which it is paying. In PPP, the owner is no longer furnishing 100% of the funding, but it still has a constituency, the traveling public, to protect. The contract creates a legal structure between the public agency and its private partner (often called a developer or concessionaire in these projects). The public agency must develop a system "to monitor the performance of the concessionaire adequately, ensuring that [the] public interest is defended properly throughout the concession period" (Fernandes and Viegas 1999).

Quality Assurance Organization in Privately Funded Projects

The shift of financial input that occurs in a PPP is from the owner providing 100% of the financing during design, construction, and operations to the concessionaire furnishing a significant amount of funding. Although this may seem inherently to invalidate the need for owner-controlled QA activities, FHWA Technical Advisory 6120.3 requires that DOTs perform design and construction quality oversight to satisfy their legal responsibilities to the public. As a result, this causes a shift in the DB project QA model introduced in chapter two to accommodate the shift in financial liability that accompanies a PPP project. The Texas DOT is currently in the process of delivering a number of PPP projects using the authority of FHWA Special Experimental Program 15 (SEP-15) (*SEP-15 Program—Public Private Partnerships* 2006). To receive FHWA approval for use of federal funds for portions of a project under SEP-15, the DOT must consummate an "early development agreement" (EDA) with the FHWA that details the DOT's approach to assuring quality in the project. The EDA for the Trans-Texas Corridor ties the post-construction warranty to the quality when it states that "TxDOT anticipates that a long-term general warranty will be a critical part of any Facility Agreement . . . to *ensure quality in design and construction* of the Facility" (*TTC35 Early Development Agreement* 2005, italics added). The DOT carries this approach further when it develops the final agreement with the concessionaire in which quality management roles and responsibilities are spelled out. Another example from Texas, the "Exclusive Development Agreement" (not to be confused with the previously defined EDA) for the SH 130 Turnpike Project (*SH 130 Turnpike Project Exclusive Development Agreement* 2002) illustrates this principle.

> Developer shall complete and manage such portions of the Development Work . . . in a manner satisfactory to the TTA [Texas Turnpike Authority] and in accordance with the Project Schedule, including . . . *Providing quality control and quality assurance* with respect to the Development Work, subject to TTA oversight, involvement and directives; TTA shall carry out certain design and construction related activities, including . . . *Performing certain quality assurance oversight services* in connection with the Development Work (italics added).

Figure 23 results from combining an analysis of the above project's contractual quality management requirements, information found in the literature (Yuan et al. 2007), and consultations with appropriate members of the Texas DOT staff. It illustrates how the DB project QA model that is developed in chapter two applies to a PPP project. In this specific case, Figure 23 provides an example of the PQA model as applied to a PPP by the Texas DOT ("Quality Assurance Program Components" 2007). It must be noted that in this form of project delivery, the design-builder is called the concessionaire and will operate and maintain the completed project for some concession period after construction completion. This adds an additional set of quality requirements for post-construction service, operation, and maintenance to the DB PQA universe. Additionally, the concessionaire brings its own financing to the project and, as a result, the model's use of the design and construction acceptance decision points is modified because the concessionaire becomes financially liable to correct any design or construction deficiencies during the operations and maintenance period. Thus, in this case, the owner has chosen to retain an independent engineering consultant to perform what the Texas DOT terms as "owner verification testing." This supplements the IA and QA

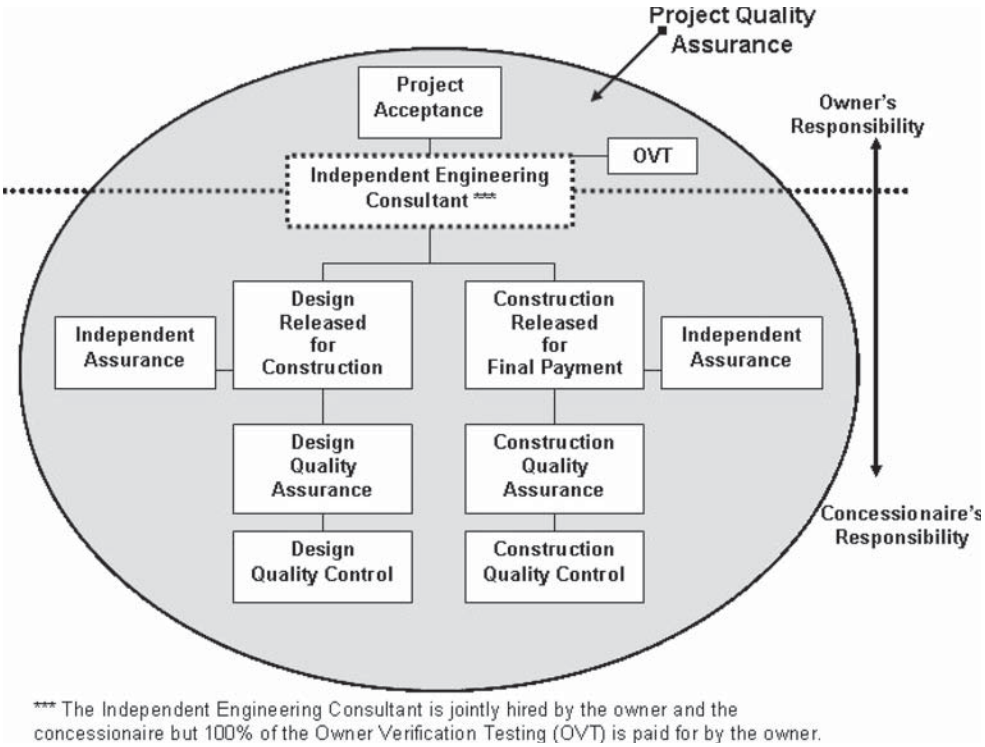

FIGURE 23 Design-build project quality assurance model for a public-private partnership.

activities, which are now assigned as the concessionaire's responsibility. Additionally, this entity may perform the QA activities necessary to verify that the concessionaire is meeting its contractual requirements for the quality of service, operations, and maintenance after construction is complete and the project has been opened to traffic.

Financial Incentives for Public-Private Partnership Quality

To influence the concessionaire's quality-related design and construction decision, the owner in a PPP must create a financial incentive for the developer to aspire to a high level of quality. Portugal has extensive experience with this type of project delivery and has found that good quality can be obtained "by making them the objectives of the concessionaire . . . there are bonuses and penalties based on performance, so the concessionaire has pecuniary incentives to present high standards" (Fernandes and Viegas 1999). This process is also used in the Netherlands, where a "fixed lump-sum payment [is made] every 3 to 6 months if the desired performance criteria are achieved" (Cox et al. 2002). In Canada, the incentive is provided through the use of a specific pay item for quality management performance. A paper presented at the 55th Annual Quality Congress details the process as follows:

> A novel feature of the DDB [PPP] Agreement is the identification of Quality Management as a "line item" in the Guaranteed Maximum Price (GMP) of the project. This item, approximately 4% of the GMP, is scheduled as a series of maximum monthly amounts (varying with season and certain project milestones) to be paid out based on an independent assessment of the effectiveness of the QMS [quality management system]. . . . The method of assessment introduced by the IA [independent auditor] at the commencement of the agreement used a random auditing of an exhaustive list of requirements in the DDB [PPP] agreement. Random samples proportional to the budgeted or estimated cost of fulfilling each requirement were audited each month. The degree of conformance was reported as the total conformances divided by the total month's sample size (% of conforming observations) (Collier et al. 2001).

The Canadian public agency then uses the degree of conformance to determine the percentage of the monthly QMS payment earned in accordance with Figure 24. Thus, the developer has essentially 4% of its project cash flow at risk and the aggressive payment algorithm creates a financial incentive to ensure satisfactory quality. The authors of this report go on to conclude:

> To compete . . . in today's environment, a company must be willing to agree to world-class requirements for quality. By aligning quality requirements . . . and incorporating them directly into the agreements, the advantage went to the proponent [proposal] who would accept extra responsibility and seek to delegate it effectively. This arrangement also allies the Owner and the Developer closely in pursuit of their common interest—the Public-Private-Partnership (Collier et al. 2001).

A similar performance payment scheme has been used in public transit projects in Utah and Oregon (Touran et al. 2007), although these projects were not PPP projects. Interestingly, both of the U.S. projects used the same 4% formula as was used in Canada, although their monthly payment algorithm was not as aggressive as the Canadian one. Both

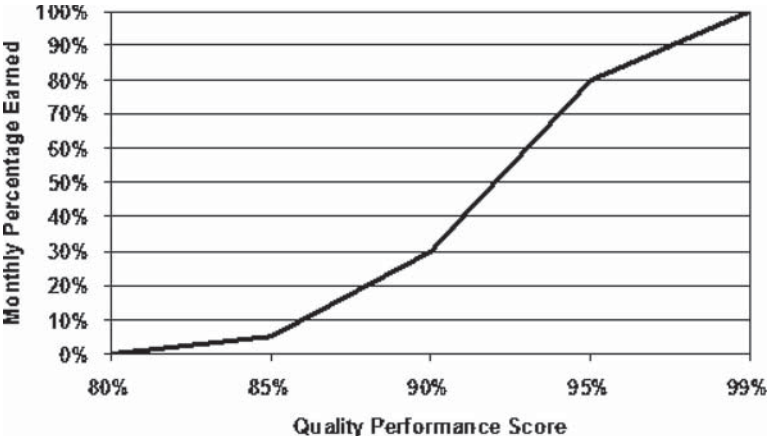

FIGURE 24 Percentage of monthly payment as a function of quality performance score (Collier et al. 2001).

public agencies reported that they were satisfied with the resultant quality of their constructed facilities. Additionally, they believed that the scheme drove the design-builder to be proactive in identifying potential issues and correcting them before they were assessed by the owner. This impression was confirmed through an interview with one of the project design-builders.

SUMMARY

The relative newness of post-construction options for operations and maintenance makes it difficult to draw any conclusions on their impact on the quality of transportation projects. Intuitively, the idea of holding the design-builder liable for the potential costs of inadequate quality through either an extended warranty or an operational period would seem to create an incentive toward a robust design and well-constructed project. However, the experiences in the United States are decidedly mixed. The trends observed in previous studies of warranties seem to confirm the notion, but the experience on the New Mexico 44 project graphically refutes it. Although this may have been an anomaly, the one conclusion that can be made from this portion of the analysis is that DOTs would benefit from investing a significant amount of creative energy and thorough investigation when deciding to deliver a project using some form of post-construction option. The issues identified in the Utah I-15 project are very instructive, and the results of the AASHTO European scan report point to the potential adoption of methods and measures used overseas, where they have a decent amount of post-construction option experience, rather than to the few U.S. projects. Finally, if the decision to employ a post-construction option is made, the DOT may recognize that although it may have found a mechanism to mitigate the risk of design and construction quality, it has now created a situation in which it must manage the new set of quality factors associated with quality during post-construction operations and maintenance.

CHAPTER SEVEN

CONCLUSIONS AND COMMONLY USED PRACTICES

This study has generally confirmed that quality issues pervade the procurement, design, and construction phases of a design-build (DB) project. The issues range from the quality of the design-builder's personnel who will accomplish the actual work, to the quality of the experience of the various firms that make up the design-builder's team, to the quality of the plans that will be used to implement quality management practices after the DB contract is awarded, not to mention the classic design and construction quality issues present in traditional projects. Because of this, the management of quality in the DB project is of utmost importance and requires that a department of transportation (DOT) contemplating the use of a DB project delivery prepare a thorough and thoughtful approach to communicating the DB project's quality requirements as well as the administrative and technical mechanisms that the DOT intends to use to manage both design and construction quality. The study of the literature combined with the analysis of the content of the DB solicitation and policy documents and the responses to the two surveys have converged on a number of points that are summarized in this chapter.

CONCLUSIONS

This study used an intersection between the literature, the content analyses, and the survey responses as the criterion to making the following conclusions. When there was a disagreement between those sources, greater weight was given to the output from the content analyses and survey responses from DOTs with more than five DB projects' worth of experience. Based on that output, an overarching theme for the outcome of this study that applies to all stages of DB projects is that there is no one-size-fits-all quality management organization for every DB project. Each DB project is unique and requires careful planning and execution to reach a successful conclusion. This was confirmed in the Request for Proposal (RFP) content analysis by finding that state DOTs that have mature DB programs—such as Florida, North Carolina, and Virginia—are using more than one type of quality management organization based on the individual requirements of each project. This was also confirmed by the survey responses that indicated that 45% of the agencies use two or more approaches to DB quality assurance (QA), depending on the project. The literature validates this conclusion in a Design Build Institute of America document on DB QA and quality control (QC) that recognizes "*quality as a flexible aspiration* that is fixed only as the business drivers of the owner and specific performance needs of the project become apparent" (italics added). In addition, survey responses indicated that the more experienced DOTs retain more quality responsibilities in DB than less experienced DOTs. This is again validated in the literature. An American Council of Engineering Companies report on DB QA and QC specifically advocates that an owner with a third-party design consultant should be involved in design QA and that, when a design consultant is the engineer-of-record on a DB team, that consultant should take responsibility for construction QA. Although there are many insights than can be derived from the foregoing analysis, the synthesis yielded seven major conclusions.

- Quality Management Guidance in Design-Build Policy Documents

DOT DB policy documents, such as guidelines and model RFPs that contain specific guidance with regard to the agency's quality management approach and how it can be modified and adjusted to fit the specific needs of each project, are most useful as a foundation from which to develop DB solicitation document quality requirements. By creating a specific requirement to evaluate the activities that are necessary to the delivery of a quality project at this fundamental policy level, the DOT is indicating the need to consider project quality from its inception and then creating a mechanism to map the conceptual quality requirements directly into the procurement documents. This will furnish not only much needed guidance to the DOT's project managers but also promote consistency in its DB projects and make estimating the cost of quality management activities easier for the competing design-builders. Additionally, it will make the agency less reliant on the qualifications-based short-listing process (i.e., "quality by qualifications") to ensure that quality management has been included in the DB evaluation plan.

- Design-Build Project Quality Assurance Model

The content analysis identified a new set of quality management activities. This finding was confirmed in the literature by *Transportation Research Circular E-C090: Design-Build: A Quality Process*, which states that, "*a new definition of QA* [is needed that] includes oversight to provide confidence that the design-builder is performing in accordance with the QC plan" (italics added), as well as by the survey

responses ("Design-builder is responsible for QA/QC and owner established *an extensive quality oversight program*"). Those are the activities that the owner undertakes to ensure a quality project when it has assigned QA responsibilities to the design-builder. This was termed "project quality assurance (PQA)."

The content analysis also showed that experienced DOTs are not opting for a one-size-fits-all quality management approach. They tailor the quality management assignments on a project-by-project basis to fit the individual needs of the project. Although a variety of possible quality management organizational structures were identified through both the RFP content analysis and the general survey responses, an analysis of the projects completed by DOTs with more than five DB projects' worth of experience showed that they were stepping back somewhat from completely outsourcing the responsibility for quality management in DB projects. The consensus seems to indicate that experienced DOTs assign the design-builder responsibility for both design and construction QC as well as portions of construction QA. These DOTs retain design QA and perform construction PQA with their own forces or with the assistance of a third-party consultant. Table 15 provides the distribution of quality management responsibilities for a typical DB project that has no post-construction operations and/or maintenance options used by experienced DOTs. Ninety-two percent of the experienced DOTs rated level of agency involvement in the quality management process as having a high or very high impact on the project's ultimate quality.

The one exception to the above is for projects with post-construction operations and/or maintenance options. The respondents that used design-build-maintain, design-build-operate-maintain, or public-private partnership (PPP) believed that there was less need to be involved in design QA, trusting the post-construction operational period to act as a warranty on the design. They typically assigned all QA and QC responsibilities to the design-builder and then conducted PQA on both the design and the construction.

- Two-Step Selection Process

Both the literature [the two-step selection process as "essential for success" (Bourne) and "the best overall budget and schedule performance" (Molenaar et al.)] and the RFP content analysis [89% of the projects analyzed used the two-step Request for Qualification (RFQ)/RFP process] showed that most DOTs use a two-step selection process for awarding DB projects. They can leverage this process to promote quality by including a quality management submittal in both steps. DOTs can require that the design-builders' Step 1 submittal include qualifications and past performance information on the key quality management personnel on the design-builder's team. As a minimum, the design-builder's project quality manager, design quality manager, and construction quality manager can be identified and evaluation criteria can be established for their qualifications and past experience. Of the experienced DOTs, 92% rated the qualifications of the design-builder's staff as having a high or very high impact on the project's ultimate quality. During Step 2, the RFP can contain evaluation criteria for a summary/outline quality management plan in the proposal and clearly indicate the requirement to submit a complete plan after award for review and final approval. The summary quality management plan would be focused on the salient features of work and any quality challenges that the DOT has identified during its preliminary engineering work. Both the Step 1 and 2 submittals would be given an appropriate weight within the overall context of the project's evaluation and award scheme. Including some form of the proposed quality management plan in the proposal is essential if the DOT wants to know each design-builder's quality management approach before awarding the DB contract.

- Best Value Award Process

DOT's use of a best value award process was also indicated by the literature and the DB solicitation document analysis. Most of the RFPs analyzed (90%) used some form of best value award. Qaasim states that "best value award is a good way to add extra weight to quality components," and one DOT

TABLE 15
POSSIBLE ASSIGNMENT OF QUALITY MANAGEMENT RESPONSIBILITIES IN A DESIGN-BUILD PROJECT

Responsible Entity		Design	Construction
Design-Builders Project Quality Manager	Design-Builder's Construction Quality Manager	Coordination/communication as required	Construction quality control: the responsibility of the construction quality manager
	Design-Builder's Design Quality Manager	Design quality control: the responsibility of the Design Quality Manager	Construction quality assurance: the responsibility of the design quality manager
Department of Transportation plus 3rd-party quality consultants (if required)		Design quality assurance: verification and reviews by the DOT and/or 3rd-party quality consultants; includes over-the-shoulder reviews, compliance checks, and audits	Project quality assurance: audits and inspections of the construction performed by the DOT and/or 3rd-party quality consultants; includes testing, audits, and independent verification/acceptance

indicated that "placing a quality component in the RFQ or RFP brings extra attention to the design-builder that quality is an important issue for the DOT and that a proposal emphasizing quality will be evaluated more favorably" (Gladke). In the evaluation and award scheme, a best value award process furnishes an incentive for the design-builder to propose a level of quality that is better than the stated minimum, thereby enhancing the competitiveness of its proposal and its chance to win. After award, the contents of the design-builder's proposal are incorporated into the DB contract, which potentially opens the door for the DOT to receive quality betterments on the project. The same is true for the quality management plans and personnel that are contained in the proposal.

- Design Quality Management Emphasis

Design quality management may not be not receiving sufficient emphasis by DOTs in their DB quality management programs. The RFP content analysis revealed that only about one-third of the documents contained specific references to design quality, whereas two-thirds of the survey respondents indicated that they rated detailed design criteria as having a high or very high impact on the project's ultimate quality. The literature clearly shows that the design phase is the time when the quality of the constructed product is articulated, and a previous study found that only half of transportation project DB RFPs included design quality management aspects. Therefore, it would make sense that DOTs place a special quality emphasis on that aspect of the DB project. The second conclusion discussed previously supported this premise when it found that experienced DOTs were not assigning design QA responsibilities to the design-builder but rather were retaining that responsibility. Therefore, it seems that DOTs need to develop specific policy to pay strict attention to design quality management and promulgate that policy in their DB solicitation documents by making it a part of both their best value award proposal evaluation plan and the final DB contract.

- Incorporation of Standard Specifications by Reference

The more experienced DOTs chose to incorporate the DOT's standard specifications by reference and allow the design-builder to optimize specific construction means and methods with its design approach. Of the experienced DOTs, 82% indicated that the use of performance criteria and specifications have a high or very high impact on the project's ultimate quality. Only 67% of the same group assigned that impact rating to the use of standard agency specifications and design details. Therefore, one can infer that this group is in favor of allowing the design-builder greater design freedom. These DOTs are comfortable with this because they remain involved in the design process by retaining the responsibility for design QA.

- Perceptions Barrier to Implementation

Perceptions that teaming the engineer-of-record with the construction contractor will degrade the quality of the project remain a barrier to implementation in spite of the FHWA DB effectiveness study that found DB quality was unchanged from that found in DBB projects. DOTs might remain sensitive to this issue in developing their DB quality management programs. By retaining design QA responsibilities, as cited in other previously stated conclusions, a DOT may overcome this perception.

COMMONLY USED PRACTICES

The analyses have also led to the identification of 10 commonly used practices as defined in chapter one (i.e., found in the literature or confirmed by the survey or content analysis). Once again, if there was a conflict in the output more weight was given to the responses and solicitation documents that came from DOTs with a more mature DB program, as evidenced by having more than five DB projects. The practices fall within the entire life cycle of the DB project. These are listed here without the supporting information, which can be found in the body of this report. These will be covered in life cycle order; however, it should be noted that because some of them span more than one phase, they will be included in the phase to which they are most strongly associated.

- Procurement Phase

There were four commonly used practices identified in this particular phase:

1. Use of the best value two-step DB award process: Asking for quality-oriented qualifications for key members of the design-builder's quality management team in the first step and requiring that summary-level or outline quality management plans be submitted for both design and construction during the second step. Stating that full design and construction quality management plans be required for review and approval after award of the DB contract in the project's RFP. Indicating the weight of the quality-related components of the proposal in relation to the other evaluated factors including price.
2. Clearly identifying the quality management organizational approach that will be used on the DB project in the solicitation documents. Clearly assigning the responsibility for all levels of quality management in both design and construction, ensuring that those roles that are reserved for the DOT or its third-party quality consultant are also clearly indicated.
3. Demanding that the design-builder provide highly qualified and experienced personnel on its DB projects and if the DOT is new to DB, use those projects as a training ground on which the DOT staff can gain the DB experience it lacks. Asking that the RFQ/RFP list require quality-specific qualifications on both the design and construction members of the DB team.
4. To ensure that the competitors understand the requisite level of design and construction quality, preliminary design documents in the RFP clearly state the specifi-

cations, design criteria, and standards to be used in the final design and construction of the project.

- Design Phase

There were two commonly used practices identified for the design phase:

1. Determining the number of design reviews that will be conducted during the DB project design phase and clearly assigning the responsibility for conducting those reviews. These are normally published in the project's solicitation documents to create the necessary contractual requirements for both parties to the DB contract.
2. Unless the DB project has a follow-on maintenance or operations option, the DOT usually retains the responsibility for design QA. This can be accomplished either with its own forces or through the employment of a third-party quality consultant.

- Construction Phase

There were four commonly used practices identified for the construction phase:

1. The design-builder's engineer-of-record is usually assigned the responsibility of conducting construction QA.
2. The design-builder's construction quality manager is usually assigned the responsibility of conducting construction QC.
3. The DOT conducts PQA activities during construction to satisfy its federally mandated oversight responsibilities. This can be accomplished either with its own forces or through the employment of a third-party quality consultant.
4. Incorporating standard state specifications by reference in the DB contract and allowing the design-builder to optimize construction means and methods with the design approach.

SUGGESTIONS FOR FURTHER STUDY

The final objective of this synthesis was to identify those areas in which further study is warranted. There are five such areas.

- Design-Build Project Quality Assurance Model Definition

The owner's role in the DB quality management process needs further definition. This report coined the term PQA to capture all those activities that the DOT would conduct to satisfy its federally mandated oversight responsibility. The literature contains a profusion of terminology that is used to identify owner quality management tasks that fall into this category. Many of the terms, such as independent assurance and verification testing, are used in traditional DBB projects. Thus, there is confusion on both the part of the DOT and more importantly on the part of the competing DB teams as to what activities might be included under the PQA umbrella. Because of this confusion, design-builders may have difficulty pricing their DB quality management efforts and possibly may include unnecessary contingencies. A respondent comment on the perceptions survey confirms this by saying that: "DB changes roles and the level of owner QA involvement is not yet clear." Additionally, the effectiveness of various quality management organizations needs to be studied to determine which organizations best allocate the risk of unsatisfactory project quality. This may differ between projects based on their order of magnitude and technical complexity. Therefore, the future review must seek to differentiate between different sizes of projects as well as different types of projects. It could also investigate the quality management requirements for urban versus rural projects.

- Design Quality Management Program

The synthesis showed that there is a lack of clear guidance on how to properly develop and administer design quality management activities in the DB context. DOTs are faced with a dilemma of determining the requisite level of design development that might be conducted for the DB RFP to properly articulate the scope of work. This dilemma stems from a natural aversion to creating liability for the preliminary engineering and the need to clearly articulate the technical constraints associated with the project so that the design-builders can prepare accurate price proposals. This issue is further complicated by the traditional DBB design phase, which is often completed by DOT design engineers. Thus, the theoretical and contractual foundation that provides the details of an owner's design quality management plan has not yet been produced to the level of detail currently available for the construction phase. Therefore, it might be prudent to investigate the marriage of the project's design development during both the procurement and design phases of DB project delivery and optimize that with the roles and responsibilities required to develop a proper design quality management plan. Future study could use the same set of information as this synthesis to identify the possible forms that the DOT design quality management plan could take and produce a guidebook that could be used by DOTs that have not developed a specific set of DB design quality management policies and procedures. It could validate those recommendations by seeking test projects on which case studies could be developed and against which project performance metrics could be benchmarked to furnish a quantitative as well as qualitative result.

- Design-Build Program Evolution

The process of how experienced DOTs' DB programs matured from the first projects to the current forms could be documented to furnish a reference for DOTs that have not experimented with DB. This would allow these less-experienced DOTs to capture lessons learned and be able to start their own

programs at a point that is higher up the learning curve than is currently possible. The synthesis found that experienced DOTs had started their early projects giving the design-builder the majority of the QA responsibility and then, over time and with experience, the DOTs had pulled back to a point at which they were more involved in later projects than in earlier ones, especially in the area of design QA. The reasons behind this shift in quality management policy might be documented and carefully analyzed to furnish guidance for the DB programs of less-experienced DOTs. This proposed review would examine the five or six most experienced DOTs, gathering both DB project QA policy and implementation data as well as project performance data to document the change in performance over time as the DOTs' DB programs matured. It would also collect information on legal and contractual issues that may have arisen, causing a change in DB QA policy implementation.

- Evaluating Quality Management Plans During Procurement

The subject of evaluating quality management plans during the procurement phase also needs additional study. The literature contained a number of examples in which authors indicated that applying a weighting to the proposed quality management plans during proposal evaluation could result in design-builders offering quality enhancements over the minimums specified in the RFP. At this point in time this is merely an assertion that needs to be proven. The analysis in this area could take a two-pronged approach, with the first phase examining completed projects and comparing their results with the weights that quality aspects received in the RFP proposal evaluation plan. This phase would allow a measuring of whether this assertion is really successful in the form of proposed betterments that actually end up being constructed in the DB project. Next, the project would seek to recruit DOTs to experiment with the weights for quality aspects illustrated in upcoming DB projects and determine if the resulting proposals indeed offer betterments as a result of the weighting and the value of those betterments. The result of the study could be a model DB quality management evaluation plan and a decision-making tool to assist DOTs in developing DB solicitation documents that encourage innovation and creativity in the quality management arena.

- Quality Management Program for Post-Construction

Finally, the area of QA in post-construction options for operations and maintenance, as well as the impact of private funding in PPP projects, deserves immediate attention. FHWA's SEP-15 program specifically allows DOTs to use PPP and other forms of post-construction options, and the DOTs are responding to the opportunity by developing large, complex projects whose values often exceed $1 billion. This is being done without the benefit of fundamental research on this subject. PPP projects are common overseas and could furnish the foundation from which a study could begin and then expand into how the overseas agencies' concepts can be "Americanized" for our industry, legal, and regulatory environment. It is very important to quantify the changes that must occur to the QA process when the design-builder not only is liable for operations and maintenance but also furnishes much, if not all, of the financing. The role in project QA of private banking institutions that provide financing for these kinds of projects is not well understood and must be analyzed as soon as possible to permit DOTs to leverage this source of funding for the good of this nation's transportation infrastructure.

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GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

GLOSSARY

Acceptance—process of deciding, through inspection, whether to accept or reject a product, including what pay factor to apply.

Acceptance plan—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. In this report, it is to be considered to represent only those functions associated with acceptance.

Betterments—design-builder-proposed aspects of design and/or construction that exceed the minimum level of quality specified in the design-build (DB) request for proposal (RFP).

Concessionaire—see definition for developer.

Design-bid-build—project delivery system in which the design and construction are awarded in two separate contracts to a designer and a contractor.

Design-build—project delivery method in which both the design and construction are awarded to one entity (the design-builder) in the same contract.

Design-builder—entity that holds the DB contract with the owner. This entity can be organized in a number of manners ranging from a single firm that offers both design and construction services to a joint venture made up of design and construction firms. Most commonly this will be a general construction contractor who has a design services subcontract with an engineering firm.

Design-build solicitation documents—documents that are issued by the DB project owner to request qualifications and/or proposals from design-builders. This includes request for qualifications (RFQs), RFPs, and invitations to/for bid (ITBs or IFBs). These documents elicit a response from proposers and are part of the final DB contract.

Developer—entity with which the contracting agency has executed a public-private agreement for the development, design, construction, financing, operation, and maintenance of one or more projects under a public-private partnership. Depending on the context of the public-private agreement, the term ''developer'' may include affiliated entities of the developer.

Final design—any design activities following preliminary design. Final design activities are not necessary to complete the National Environmental Protection Act process as outlined in federal regulations.

Hold point—mandatory owner inspection of a specified feature of work that is held at a specific point in construction progress.

Independent assurance—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—act of examining, measuring, or testing to determine the degree of compliance with requirements.

One-step design-build procurement process—process for selecting a design-builder based on its response to an RFP. Design-builders submit a proposal including qualifications, technical approach, and price in response to the RFP.

Over-the-shoulder design review—informal review of the design by the owner. Over-the-shoulder reviews are not hold points that restrict the progress of design. They are simply reviews of the design as it progresses and opportunities for the owner to provide comments and feedback on the design.

Owner independent assessment—oversight performed by the department (or agent) to satisfy Virginia DOT and FHWA's requirements for documenting that proper quality control (QC) and quality assurance (QA) are being performed. This oversight provides an independent assessment of design-builder's implementation of and compliance with the approved QC and QA plan.

Owner independent validation—oversight performed by the department (or agent). The focus of owner independent validation is to verify design-builder's QC and QA compliance and confirm that the quality characteristics of the products incorporated in the project are valid for acceptance and payment.

Owner verification testing—testing done by the owner in a public-private partnership project to verify that the design-builder's test results are valid.

Preliminary design—all design activities necessary to complete the National Environmental Protection Act alternatives analysis and review process as outlined in federal regulations.

Project quality assurance—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 testing as well as owner oversight actions when the design-builder is responsible for QA.

Procurement—the stage in the life of a project that comprises all aspects of project development and management leading up to, but not including, project design. This includes DOT preparation of the RFQ and RFP as well as design-builder's proposals in response to the RFQ/RFP.

Proposers—those companies who, in response to an RFQ or RFP, submit a proposal to the agency that issued the RFQ/RFP. Proposers are also referred to as design-builders.

Public-private partnership—agreement between a public agency and a private party under which the private party shares in the responsibilities, risks, and benefits of constructing a project.

Such agreement may involve an at-risk equity investment by the private party in the project.

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

Quality assurance—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—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—totality of the system used to manage the ultimate quality of the design as well as the construction encompassing the quality functions described previously as QA, QC, independent assurance, and verification.

Request for proposal—document issued by an agency requesting for proposals to be given to perform a specific activity or project.

Request for qualifications— document issued before issuing an RFP requesting potential designers, contractors, design-builders, and so forth to submit qualifications to show that they are qualified to submit a detailed technical proposal in response to an RFP. An RFQ is the first step in the two-step project award method.

Two-step design-build procurement process—process for selecting a design-builder based first on its response to an RFQ and afterwards its response to an RFP. Respondents to the RFQ are narrowed down to a short list of three to five design-builders who are then issued the RFP. Only those design-builders on the short list are allowed to submit a proposal in response to the RFP.

Validation—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—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).]

Witness point—oversight activity carried out by the owner who specifies those features of work that it wants to observe during construction. These are not meant to impede construction progress.

ABBREVIATIONS AND ACRONYMS

ADOT	Arizona Department of Transportation
CDOT	Colorado Department of Transportation
CEI	Construction engineering & inspection
CPOC	Construction proof of compliance
CQA	Construction quality assurance
CQMP	Construction quality management plan
DB	Design-build
DBB	Design-bid-build
DBIA	Design-Build Institute of America
DBM	Design-build-maintain
DBOM	Design-build-operate-maintain
DBr	Design-builder
DOT	Department of Transportation
DQA	Design quality assurance
DQC	Design quality control
DQMP	Design quality management plan
EFLHD	Eastern Federal Lands Highway Division
FDBOM	Finance-design-build-operate-maintain
IA	Independent assurance
MnDOT	Minnesota Department of Transportation
NCDOT	North Carolina Department of Transportation
NCR	Nonconformance report
NMSHTD	New Mexico State Highway and Transportation Department
NSPE	National Society of Professional Engineers
PPP	Public-private partnership
PQA	Project quality assurance
QA	Quality assurance
QC	Quality control
QCP	Quality control plan
QM	Quality management
QMS	Quality management system
RFP	Request for proposal
RFQ	Request for qualification
SEC	Southeast corridor
SEP-14	Special Experimental Project No. 14
TTA	Texas Turnpike Authority
UDOT	Utah Department of Transportation
VDOT	Virginia Department of Transportation
WSDOT	Washington State Department of Transportation

APPENDIX A

Annotated Bibliography

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The term "quality" is defined as the conformance to predetermined requirements or specifications. An overview of contract quality warranties for steel bridge coatings is presented as a practical example, and a hybrid assessment model that can be used to quantitatively measure quality attributes is proposed. The hybrid model combines image processing and neural networks for defect (specifically, rust) recognition and measurement and uses statistical analysis for quality acceptance or rejection on the basis of the contract warranty clauses. The hybrid model incorporates human experience through the training stage to benefit from experts' knowledge and to correct for other external factors.

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Many transportation agencies are dealing with constrained budgets and reduced funding for maintenance by establishing formal programs to evaluate maintenance priorities. One approach is to relate highway maintenance to highway performance through maintenance quality assurance (MQA). MQA programs help decision makers understand maintenance conditions, set priorities, and document the relationship between dollars spent and outcomes. There are guidelines to assist agencies in the creation of MQA programs, but few resources to guide the selection of the quantitative measures. This paper presents a synthesis of MQA measures used by 26 state transportation agencies.

Akao, Y. and G.H. Mazur, "The Leading Edge in QFD: Past, Present and Future," *The International Journal of Quality & Reliability Management*, Vol. 20, No. 1, 2003, pp. 20–35.

Quality function deployment has been practiced by leading companies around the world since 1966. Its twofold purpose is to assure that true customer needs are properly deployed throughout the design, build, and delivery of a new product, whether it be assembled, processed, serviced, or even software, and to improve the product development process itself. This paper describes the evolution of the method, its current best practice, and proposals for future direction, not only to log its history and key players correctly, but also to convey the richness and depth of the applications throughout multiple industries.

Allen, L.N., D.D. Gransberg, and K.R. Molenaar, "Partnering Successful Design-Build Contracts in the Naval Facilities Engineering Command Southwest Division," *The Military Engineer,* SAME, Vol. 94, No. 616, Mar. 2002, pp. 47–48.

Results of a study of NAVFAC design-build (DB) projects that found that DB projects outperformed similar design-build-bid (DBB) by lower cost and time growth and equal quality.

Anderson, S. and M.I. Schneider, *Design-Build Project Delivery*, American Council of Engineering Companies, Washington, D.C., 2000, pp. 1–10.

American Council of Engineering Companies report on DB quality assurance (QA) and quality control (QC) specifically advocates that an owner with a third-party design consultant should be involved in design QA and when a design consultant is the engineer-of-record on a DB team that the consultant should take responsibility for construction QA.

"Approach to Quality Management," Minnesota DOT Design-Build Program White Paper No. 1, St. Paul, Sep. 23, 2005, 2 pp.

This is a brief discussion of the Minnesota DOT (MnDOT) quality management approach.

Arditi, D. and D. Lee, "Service Quality Performance of Design/Build Contractors Using Quality Function Deployment," *Construction Management and Economics*, Vol. 22, No. 2, Feb. 2004, pp. 123–157.

This note describes a model that measures the quality of the project service of a DB firm using quality function deployment. This model is an add-on to a model developed previously by the authors to measure the corporate service quality performance of DB firms. The project service quality performance model makes use of 10 service quality factors and their relative weights (transferred from the corporate service quality performance model), three components of quality management systems in place in DB projects (ranked by senior managers in DB firms), and the relationships between service quality factors and quality system requirements (established by a professional quality system assessor). It uses quality function deployment to calculate a quality performance index.

Arizona Department of Transportation Intermodal Transportation Division, *Design-Build Procurement and Administration Guide*, 2nd ed., ADOT Construction Group, Phoenix, Dec. 2001 [Online]. Available: http://www.azdot.gov/Highways/ConstGrp/DesignBuildGuide.asp [accessed Jan. 24, 2007].

Arizona DOT's guide to DB.

Aschenbrener, T., R. DeDios, and S. Shuler, "Effect of Performance Warranties on Cost and Quality of Asphalt Pavements," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 14 pp.

This study documents the cost–benefit relationship for these projects during the warranty period and beyond and compares the performance of these projects with comparable nonwarranty pavements. Cost comparisons include the initial hot-mix asphalt, maintenance, pavement evaluation team, weigh-in-motion station, and construction engineering. An analysis was also conducted on the competition, performance, and use of experimental features.

Ashley, D.B., J.E. Diekmann, and K.R. Molenaar, *Guide to Risk Assessment and Allocation for Highway Construction Management*, Report FHWA-PL-06-032, Federal Highway Administration, Washington, D.C., Oct. 2006, 72 pp.

In 2004, a team of representatives from the FHWA, state highway agencies (SHAs), industry, and academia visited Canada, Finland, Germany, the Netherlands, Scotland, and the United Kingdom. The purpose of this International Technology Scanning Program study was to identify practices that might be evaluated and applied in the United States to improve construction management.

Asphaltic Pavement Warranties: Three-Year Progress Report, Wisconsin Department of Transportation, Madison, 1998.

Report for the Wisconsin DOT on the performance of roads with asphalt pavement warranties.

Atkison, W., "Build Quality in, Don't Add It on," *Design/Build Business*, Vol. 70, No. 8, Oct. 2005, p. 44.

In DB quality, those who actually practice what they preach insist that quality is not an add-on; it is part of the culture.

Barner, C., "For Missouri Highway Job, Designs Cross State Lines," *Engineering News-Record*, Vol. 257, No. 22, Dec. 4, 2006, p. 16.

Design innovation, regardless of Missouri state codes, is the key to a $535 million reconstruction of a 10.5-mile-long segment of Interstate 64 in St. Louis. It is the state's first DB effort. Standards from other state agencies were allowed to be proposed if they had previously received the approval of AASHTO or FHWA.

Battikah, M.G., "Quality Management Practice in Highway Construction," *The International Journal of Quality & Reliability Management*, Vol. 20, No. 4/5, 2003, pp. 532–550.

This paper describes the quality management function as practiced in highway construction. This function is displayed as an interrelated system, which identifies the main quality activities. A model for multilevel quality management involvement is defined, encompassing contractors, engineers, and managers. The model describes the quality management tasks and the roles assumed in a scheme relating construction QC, QA, and the interface between them.

Beard, J.L., M.C. Loulakis, and E.C. Wundram, *Design Build Planning Through Development*, McGraw–Hill, New York, N.Y., 2001.

An overview and guide to the DB process. The seminal work on DB theory.

Benson, P.E., "Performance Review of a Quality Control/Quality Assurance Specification for Asphalt Concrete," In *Transportation Research Record 1654*, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 88–94.

A statistical review of 50 jobs recently completed by using California's QC/QA specification for asphalt concrete is presented. Performance is contrasted to the quality achieved under method and end-result specifications. A cost analysis is made and issues related to verification are discussed. Improvements to the current specification are proposed. However, a significant lack of agreement between the contractor QC and agency QA testing brings this finding into question.

Benson, P.E., "Process for Selecting Innovative Quality Assurance Practices for Materials," In *Transportation Research Record: Journal of the Transportation Research Board, No. 1900*, Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 67–78.

A process used in California to evaluate and implement innovative QA practices for materials is described. The process involves three distinct phases: an audit of current practice, a structured evaluation of innovative practices, and the planned development of a materials management system. Analyses of these data reveal that testing and inspection costs are higher, dollar for dollar, for materials whose consequence of failure is low. This suggests that innovative practices such as QC/QA, pre- or post-qualification of bidders, and warranties should be considered seriously for these materials.

Biggar, J.L., "Total Quality Management in Construction," *Transactions of the American Association of Cost Engineers 1990*, American Association of Cost Engineers, Morgantown, W.Va., pp. Q.1.1–Q.1.4.

Total quality management is the key to the implementation of an effective management system. In studying U.S. industries, Dumas found a correlation between the maturity of a firm's approach to quality management and the definition of quality used. The final level of maturity is reaching the "it develops" stage. At this stage, the firm strives to develop its customers through education and exposure to ways of better utilizing its products and receiving greater value. The Chemicals Division of Eastman Kodak Co. has begun to be recognized as a leader in the implementation of an effective total quality management program.

Blanding, J., "Quality Incentives: A Federal Perspective," *Transportation Research Circular E-C090: Design-Build: A Quality Process*, Transportation Research Board of the National Academies, Washington, D.C., 2006, 9 pp.

Special Experimental Project No. 14 (SEP-14), Innovative Contracting, was initiated in 1990. The objective was to evaluate project-specific contracting practices that maintain product quality and reduce life-cycle cost. Special Experimental Project No. 15 (SEP-15), Public Private Partnerships, was introduced as a new FHWA program to encourage tests and experimentation in the entire development process for transportation projects.

Born, M. and C. Burner, "Experience, Economics, and Evolution: From Starter Lines to Growing Systems," In *Transportation Research Circular E-C058*, 9th National Light Rail Transit Conference, Portland, Ore., Nov. 16–18, 2003, pp. 576–581.

The building of the Gold Line using the DB model has been an enriching experience to all the members of the Project Management Consultant and the design-builders. There have been many lessons learned during the course of bringing light rail transit to the communities affected by the Gold Line. This paper has outlined the most successful and the most challenging of these lessons learned in an effort for others to learn from and apply these lessons to the next project.

Bourne, J., S. DeWitt, and P. Drennon, "Ensuring Quality Is Built into the Request for Proposal Process," In *Transportation Research Circular E-C090: Design-Build: A Quality Process*, Transportation Research Board of the National Academies, Washington, D.C., 2006.

There are cultural challenges that must be overcome within transportation agencies, the contracting industry, and private engineering firms to make DB successful. These challenges include fear of change, maintenance of control of a different way, and avoidance of personnel preferences. The tenets of teamwork, trust, and ownership are critical for the success of DB projects. The owner is critical in making sure all of this happens. Communication, commitments, information sharing, a sense of urgency, and short turnaround times are all important.

Buckley, B., "Building Confidence," *Texas Construction*, Vol. 14, No. 9, Sep. 2006, p. 25.

DB is driving the progress of SH 130, a major component of the Central Texas Turnpike System. The first 29 miles will soon open—early and under budget. A paving crew lays a 13-in. layer of steel-reinforced concrete on a main lane of segment two, part of SH 130 that is scheduled to open nearly a year ahead of schedule. Design treatments for elements such as abutments and retaining walls have a decidedly Texas feel.

Burati, J.L., R.M. Weed, C.S. Hughes, and H.S. Hill, *Optimal Procedures for Quality Assurance Specifications*, Report FHWA-RD-02-095, Federal Highway Administration, Washington, D.C., 2003, 47 pp.

This manual is a comprehensive guide that a highway agency can use when developing new, or modifying existing, acceptance plans and QA specifications. It provides necessary instruction and illustrative

examples to lead the agency through the entire process of acceptance plan development.

Burati, J.L., R.M. Weed, C.S. Hughes, and H.S. Hill, *Evaluation of Procedures for Quality Assurance Specifications*, Report FHWA-HRT-05-046, Federal Highway Administration, Washington, D.C., 2004, 418 pp.

This technical report summarizes the steps taken to develop a comprehensive QA manual, supported by scientific evidence and statistical theory, along with the analyses that were conducted to support the recommendations made in the QA manual (FHWA-RD-02-095).

Byrd, L.G. and A.A. Grant, *Prerequisites for a Successful Design/Build/Warranty Highway Construction Contract*, Federal Highway Administration, Washington, D.C., Mar. 1993 [Online]. Available: http://www.fhwa.dot.gov/programadmin/contracts/byrd.cfm [accessed Feb. 4, 2007].

Keys to receiving a successful design-build-warranty highway project.

Calderon, E., R. West, T. Jurkofsky, H. Crockett, and D.S. Alexander II, *Contracting Out Bench Marking Study Phase 1—Part 2—External Data Collection*, Federal Lands Highway, Federal Highway Administration, Washington, D.C., Sep. 25, 2000, 108 pp.

The Contracting Out–Bench Marking Study Group has worked very hard in a short amount of time to provide accurate and timely data to support the Executive Quality Council's effort to collect data and report on the (1) status of FLH (Federal Lands Highway) current activities, (2) information on state and consultant activities, and (3) best practices identified during our effort.

Capka, J.R., "Memo of Major Project Guidance from FHWA Administrator to the Division Administrators," Jan. 19, 2007 [Online]. Available: http://www.fhwa.dot.gov/programadmin/mega/011907.cfm [accessed Feb. 21, 2007].

The FHWA issued Interim Major Project Guidance on January 27, 2006. This final guidance was developed in close consultation with several FHWA Division Offices and states to ensure it was informed by the knowledge and experience of those who are most familiar with these day-to-day responsibilities. This material is intended to be a tool to assist FHWA field offices in fulfilling current law.

Carpenter, B., E. Fekpe, and D. Gopalakrishna, *Performance-Based Contracting for the Highway Construction Industry: An Evaluation of the Use of Innovative Contracting and Performance Specification in Highway Construction Final Report*, Battelle, Columbus, Ohio, Feb. 2003, 49 pp.

The objectives of this project are to synthesize information on the shortcomings and limitations of traditional methods of highway construction and maintenance contracting, identify new and innovative alternatives to include performance-based outputs, and make recommendations that are mutually beneficial. The findings presented in this report are based on a review of literature and a survey of state DOT officials, representatives of the highway construction industry, and experts in highway construction management.

Carter, R., O. Tomeh, G. Darido, D. Schneck, and F. Waesche, *Quality Assurance and Quality Control Guidelines*, Federal Highway Administration, Washington, D.C., 2002 [Online]. Available: http://www.fta.dot.gov/1311_ENG_HTML.htm [accessed Jan. 24, 2007].

This report was developed in 1992 and subsequently updated in 2002 under FTA sponsorship to assist transit agencies in developing quality management systems and plans for their FTA-funded transit capital improvement projects. FTA regulations require each FTA-funded major capital program to submit a Program Management Plan for FTA approval. These regulations also stipulate that a Quality Plan must be referenced or included as part of the Program Management Plan.

Chen, C. and J.I. Messner, "An Investigation of Chinese BOT Projects in Water Supply: A Comparative Perspective," *Construction Management and Economics*, Vol. 23, Nov. 2005, pp. 913–925.

Three representative build-operate-transfer (BOT) water projects in China were compared to provide both descriptive and predictive insights to both public and private parties involved in water BOT projects in China. Four generic strategies used by private sponsors were identified through these case studies including cost leadership, transaction size maximization, localization, and involvement of multilateral financial organization.

Collier, P., M. Corbett, and B. Lundrigan, "Quality Performance in a Design-Build Mega-Project," American Society for Quality 55th Annual Quality Congress, Charlotte, N.C., 2001, 10 pp.

This paper outlines several significant lessons drawn from quality management of a major highway project from the initial proposal through three seasons of construction. It describes solutions and innovations in integrated quality management and assessment, including a web-based quality management tool developed for the project. Measurement and reporting of quality performance are used to drive an effective, participative quality improvement process with tangible benefits for both the Developer and the Owner.

Committee on Management of Quality Assurance, *Transportation Research Circular E-C037: Glossary of Highway Quality Assurance Terms,* Transportation Research Board, National Research Council, Washington, D.C., Apr. 2002, 27 pp.

A glossary of terms associated with QA for highway projects.

"Contractor to Honor Road Warranty," *Albuquerque Journal*, Vol. A12, Sep. 1, 2004, p. 1.

The private contractor that oversaw the widening of U.S. 550 pledged Thursday to live up to the terms of a $62 million warranty to fix problems on newly widened U.S. 550.

Cornick, T.C. and N.J. Barre, "Quality Management and Design-Build: The Opportunities for This Method of Procurement," *The International Journal of Quality & Reliability Management*, Vol. 8, No. 3, 1991, pp. 17–20.

The single and continuous responsibility for design and production that the standard promotes should encourage building procurement routes that reflect the links between design and production. The essential mechanisms of implementing a quality management system to building—namely, design review, project audit, and feedback—can be directly applied within the DB method and, as a single company is responsible for all processes, the professional–commercial separation no longer exists. The design and build method of procurement ensures effective and consistent communication of all aspects of design and production.

Cox, D.O., et al., *Contract Administration: Technology and Practice in Europe,* Report FHWA-PL-02-0xx, Federal Highway Administration, Washington, D.C., Oct. 2002, 106 pp.

In June 2001, a team comprising federal, state, contracting, legal, and academic representatives traveled to Portugal, the Netherlands, France, and England to investigate and document alternative contract administration procedures for possible implementation in the United States. The scan team discovered that European highway agencies appear to be better at exploiting the efficiencies and resources that the private sector offers, through the use of innovative

financing, alternative contracting techniques, DB, concessions, performance contracting, and active asset management.

Dahl, P., M. Horman, T. Pohlman, and M. Pulaski, "Evaluating Design-Build-Operate-Maintain Delivery as a Tool for Sustainability," *Proceedings of the Construction Research Congress 2005: Broadening Perspectives*, San Diego, Calif., Apr. 5–7, 2005.

Building and other capital projects usually have a clear distinction between project development phases (i.e., design and construction), and the operations and maintenance phases of a facility. Over the life of the facility, operations and maintenance expenses often far exceed the initial cost of a facility. Importantly, the decisions made early in a project have a strong affect on the life cycle costs of a building. Operation and maintenance knowledge needs to be incorporated early in design to make these critical decisions. DB has been shown to introduce often crucial and reliable construction input during design to improve the performance of a project. Likewise, the design-build-operate-maintain (DBOM) project delivery system brings critical operations and maintenance knowledge into design. This paper defines the DBOM delivery system, explores the benefits of DBOM, investigates the ability of DBOM to achieve important sustainable initiatives, and concludes that this is a promising development for the advancement of sustainable projects.

DeCorso, E., *How Owners Communicate Quality in Public Sector Design-Build Requests for Proposals*, Honors thesis, University of Oklahoma, Norman, 2004.

An analysis of how design quality is communicated in requests for proposals (RFPs) for the public sector.

Defazio, P.A., "Rep. Peter A. Defazio Holds a Hearing on Public-Private Partnerships," House Transportation and Infrastructure Committee, Subcommittee on Highways and Transit, FDCH Political Transcripts, Washington, D.C., Feb. 13, 2007.

There is an annual deficit in this country in terms of meeting our transportation infrastructure needs, both for maintenance of the existing system and enhancements to that system to mitigate congestion and better move our citizens and our freight and bolster the economy. We are confronted with these sorts of twin problems—that is, the need for more investment and the overdependence on the gas tax, which has not been increased since 1991; [this] is leading to the point where we may not even have full funding for the last transportation bill, let alone a new transportation bill for the 21st century.

Design-Build Effectiveness Study—As Required by TEA-21 Section 1307(f): *Final Report*, Federal Highway Administration, Washington, D.C., Jan. 2006, 215 pp. [Online]. Available: http://www.fhwa.dot.gov/reports/designbuild/designbuild0.htm [accessible Aug. 30, 2006].

This study focuses on completed DB projects authorized under SEP-14. This is the first comprehensive study of the SEP-14 program involving both program and project managers who have been directly responsible for federal-aid highway projects delivered under the DB contracting approach. Its findings and conclusions are based on the results of an extensive literature search, interviews with key stakeholders involved in the federal-aid highway program and SEP-14, and an integrated set of surveys of transportation agency personnel responsible for DB programs and projects developed under SEP-14.

Design-Build Guidelines, Colorado Department of Transportation, Denver, Aug. 1, 1997.

The original Colorado DOT DB guidelines.

Design-Build Guidelines, Florida Department of Transportation, Tallahassee, Feb. 8, 2006.

Florida DOT DB guidelines.

Design-Build Guidelines, Montana Department of Transportation, Helena, Mar. 1, 2004.

The Montana DOT guide to DB.

Design-Build Guidelines and Procedures, Arkansas Department of Transportation, Little Rock, Apr. 2006.

Arkansas DOT's guide to DB.

Design-Build Institute of America, "Non-Residential Construction in the United States," Unpublished presentation slides based on data from Lawson International Research and *Engineering News-Record*, 2005.

Presentation on nonresidential construction in the United States contains data on DB growth over time.

"Design/Build in the Public Sector," Position Statement #1726, National Society of Professional Engineers Board of Directors, Alexandria, Va., 1995 [Online]. Available: http://www.nspe.org/govrel/gr2-ps1726.asp [accessed Nov. 17, 2006].

In the public sector, DB is used as a specialized project delivery system in certain limited situations. Public agencies have used an array of DB arrangements for project construction. Government officials, design professionals, and construction contractors involved in these efforts report mixed opinions on the organization and success of this system.

Design-Build Manual, Colorado Department of Transportation, Denver, April 16, 2006, 46 pp.

The most recent Colorado DOT DB guidelines.

Design-Build Manual and Instructions for Completing the Scope of Services Form, Ohio Department of Transportation, Columbus, Oct. 20, 2006.

The Ohio DOT guide to DB.

Design-Build Manual of Practice, Design-Build Institute of America, Washington, D.C., 1996.

An introduction and overview of the DB process.

Design-Build Policy & Procedures, North Carolina Department of Transportation, Raleigh, Jan. 6, 2000.

North Carolina DOT DB guidelines.

Design-Build Policy Guide Draft B, Kansas Department of Transportation, Topeka, n.d.

The Kansas DOT guide to DB.

Design-Build Procedures Manual, Vol. 1, New York State Department of Transportation, Albany, Sep. 2005, 141 pp.

New York State DOT DB guidelines.

Design Build Procurement Guide, Massachusetts Highway Department, Boston, Jan. 19, 2006.

Massachusetts Highway Department DB guidelines.

DeWitt, S., et al., *Construction Management Practices in Canada and Europe*, Report FHWA-PL-05-010, Federal Highway Administration, Washington, D.C., 2005, 57 pp.

Construction management is an essential element of transportation project success, and evolving industry roles are creating changes in conventional U.S. construction management practices. FHWA, AASHTO, and NCHRP sponsored a scanning study of construction management practices used in Canada and Europe for effective project delivery, contract compliance, and QA.

Drennon, P.W., "Utah's I-15, a Transportation Case Study: Role of the Owner's Design Professional in Design/Build and in the Provisions for Quality," *American Society for Quality 52nd Annual Quality Congress Proceedings*, Milwaukee, Wis., 1998, p. 166.

Once an owner has made the decision to use DB as an alternate delivery method (assisted possibly by a design professional) and has decided that additional professional expertise is required to prepare DB contract documents and procedures for proposals (or bidding), evaluation and/or award, the role of the owner's design professional begins. The design professional may be identified in a number of ways, including criteria professional, owner's consultant, or program manager. The responsibility of the design professional may vary with the capability and/or capacity of each owner from support of the owner's staff to a full program manager responsible for all the work or to somewhere in-between.

Dunn, K.D., R.G. Hicks, and J. Gower, "Performance Factors and Quality Control/Quality Assurance for Porous Pavements," *Transportation Research Record 1575*, Transportation Research Record, National Research Council, Washington, D.C., 2002, pp. 10–17.

As a part of a larger research effort, a survey was administered to various national and international agencies inquiring about their knowledge of and experience with porous pavements. Administration of this survey was sponsored by ODOT [Oregon Department of Transportation]; the purpose of the larger research effort was to develop an improved specification for porous pavements that would contain pay incentives and disincentives. Findings from this survey are reported. Because this study was conducted to determine appropriate pay factors for open-graded mixtures, the survey was designed to learn about how other agencies were dealing with specifications and adjustment factors for porous pavements.

Eby, M., "The Inevitability of Design/Build," *Electrical Construction and Maintenance Magazine*, 2005 [Online]. Available: http://ecmweb.com/ar/viewpoint_0605/ [accessed Feb. 2, 2007].

It appears that old habits die hard when it comes to choosing a project delivery method, because some private owners and public-sector representatives are still hanging on to the traditional design/bid/build method for completion of their projects. However, recent data suggest that the tide is changing and that DB is destined to become the preferred choice of project delivery in the North American construction industry, as it already is in Europe and Japan. I, for one, believe this change is long overdue.

Ellicott, M.A., "Best-Value Contracting," *Proceedings, Area Engineer's Conference*, TransAtlantic Division, U.S. Army Corps of Engineers, Winchester, Va., 1994.

A presentation on best-value contracting.

Elliot, R.P. and Y. Qiu, "Analysis of Contractor Pay Adjustment Schedule Using Simulation," *Transportation Research Record 1544*, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 109–115.

A common provision in QC/QA construction contracts is the adjustment of the contractor's pay on the basis of the quality of the construction. The expected impact of the provision on the pay should be examined to ensure that the adjustments are neither unduly severe nor excessively lenient. The analyses demonstrate that the pay adjustments are at least as sensitive to construction variability as they are to construction averages. It is also shown that the simulation process can provide a better, more detailed examination of the pay schedule than is possible by simply determining the expected pay. In particular, the simulation process can provide an indication of the variability of pay at various quality levels and can identify the factors most responsible for pay adjustments.

Ellis, R.D., Z. Herbsman, and A. Kumar, *Evaluation of the FDOT Design/Build Program*, Final Report, Submitted to Florida Department of Transportation, State Project No. 99700-7543-010, Department of Civil Engineering, University of Florida, Gainesville, 1991.

An overview and analysis of the Florida DOT DB program.

Ernzen, J. and K. Vogelsang, "Evaluating Design-Build Procurement Documents for Highway Projects: How Good Are They?" *Transportation Research Record 1761*, Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 148–158.

Recent innovations by the Arizona DOT in the use of DB procurement for highway construction are presented. The primary method of data gathering was by written survey of all the proposing teams followed by unstructured interviews with responding principals. Analysis of the data gathered clearly showed the areas in which the procurement documents were unclear and in which the department needed to make corrections for future projects.

Ernzen, J. and T. Feeney, "Contractor-Led Quality Control and Quality Assurance Plus Design-Build: Who Is Watching the Quality?" In *Transportation Research Record: Journal of the Transportation Research Board, No. 1813*, Transportation Research Board of the National Academies, Washington, D.C., 2002, pp. 253–259.

In 1996, the department spearheaded the passage of a pilot DB law aimed at completing public-sector construction projects more rapidly than could be done by traditional methods. An evaluation of the material quality program used in the second DB project in this program is described. The agency assigned the Design-Builder responsibility for the QC and QA functions on the project, with Arizona DOT providing verification sampling and testing only. The concrete compressive strength and material density for the project are examined and are compared with statewide averages for traditional DBB projects in which Arizona DOT performed the QA function. Analysis of the data shows that despite a highly compressed schedule, the quality of the material on the project exceeded the project specifications and was similar to the quality of work completed for the state under traditional contracting methods with an Arizona DOT-operated QA program.

Ernzen, J., G. Murdough, and D. Drecksel, "Partnering on a Design-Build Project: Making the Three-Way Love Affair Work," *Transportation Research Record 1712*, Transportation Research Board, National Research Council, Washington, D.C., 2000, pp. 202–212.

TRB paper detailing the use of partnering on an Arizona DOT DB project.

Federal Acquisition Regulation (FAR), "Two-Phase Design Build Selection," *Federal Register*, Vol. 62, No. 1, 62 FR 271, 1997.

Federal design-build selection procedures and regulations.

Federal Highway Administration, U.S. Department of Transportation, Title 23 Code of Federal Regulations Part 637 Subpart B (23 CFR 637B): "Quality Assurance Procedures for Construction," *Federal Register*, June 1995 [Online]. Available: http://a257.g.akamaitech.net/7/257/2422/14mar20010800/edocket.access.gpo.gov/cfr_2003/aprqtr/pdf/23cfr637.207.pdf.

QA procedures for construction: Proscribes policies, procedures, and guidelines to ensure the quality of materials and construction in all federal-aid highway projects on the National Highway System.

Federal Highway Administration, "Design-Build Contracting: Final Rule," *Federal Register*, Vol. 67, No. 237, Dec. 10, 2002, pp. 75902–75935.

Final federal rule for DB contracting in the United States.

Federal Transit Administration Best Practices Procurement Manual, U.S. Department of Transportation, Washington, D.C., 1999, 556 pp.

This manual provides recipients of FTA funds suggestions on conducting third-party procurements to assist them in meeting the standards of FTA Circular 4220.1D (the Circular). The *Manual* consists of suggested procedures, methods, and examples that FTA encourages. These are based on the federal acquisition process, comptroller general decisions, and best practices of grantees and others in the industry.

Fernandes, C. and J.M. Viegas, "Private Financing of Road Infrastructure: The Portuguese Experience," *Transportation Research Record 1659*, Transportation Research Board, National Research Council, Washington, D.C., 1999, pp. 23–31.

Traditionally, road financing has come either through state investment or mixed investment (e.g., tolled motorway). It was decided to bring private investment into the road construction market. The national road agency tendered six contracts under a design-build-finance-operate (DBFO) model, for a total of 830 km of roadways. Under each contract, the private sector would build or upgrade a road and maintain it for 30 years. The Portuguese government has made preliminary and ongoing evaluations to support its choice of the DBFO model. The first impressions are that the initial judgments of the private sector's interest in this business—as well as of the advantages for the public and for the population as a whole—are justified.

Final Report: Six-State Survey of Construction Administration Practices and Procedures, Ohio Department of Transportation, Columbus, 2001.

State DOT survey of construction administration practices and procedures.

Finley, R.C., "Design-Build Done Right," *Bridges*, Sep.–Oct. 2005, p. 10.

. . . I consider how this "master builder" approach is best applied, as well as how the project can break down and cause a project to go off track.

Gharaibeh, N.G., J.W. Button, and P. Jalvi, *Pavement Aspects in Design-Build Contracting for Highway Projects Synthesis of Highway Practice*, Report TTI-2005-1, Texas Transportation Institute, Texas Department of Transportation, Austin, 2005, 96 pp.

The primary objective of this report is to provide pertinent state-of-the-practice information to the Texas DOT to aid them in the development of RFPs for innovative DB delivery of large projects on major highways, particularly those that will comprise the Trans Texas Corridor.

Gladke, J., "Incentives on Design-Build Projects: Two Different Approaches," In *Transportation Research Circular E-C090: Design-Build: A Quality Process,* Transportation Research Board, National Research Council, Washington, D.C., 2006, p. 8.

Two project approaches are offered to illustrate how incentives were used by the MnDOT to achieve project objectives.

Gonderinger, C., "TH 14/218 Design-Build Project Technical Memorandum Quality Management Plan (QC/QA Requirements)," Minnesota Department of Transportation, St. Paul, 2001, pp. 1–17.

Memo containing an overview of Minnesota DOT's QA/QC program in DB transportation.

Gordon & Rees, Inc., "The Basics of Design-Build," *Gordon & Rees Construction Newsletter*, San Francisco, Calif., Apr. 2005, 8 pp.

In the construction industry, DB continues to grow as the project delivery system of choice. Currently in California there are many new laws, as well as significant pending legislation, on the issue of DB. Given the rising interest in this type of project delivery system, the purpose of this *Construction Newsletter* is to offer a primer on DB issues for those not fully familiar with the process.

Graham, P., *Evaluation of Design-Build Practice in Colorado*, Project IR IM(CX)025-3(113): Report CDOT-DTD-R-01-3, Colorado Department of Transportation Research Branch, Denver, 2001, pp. 25–26.

This report summarizes construction activities of the DB project, "IR IM(CX) 025-3(113)" in Region IV. Under SEP-14, FHWA approved the DB concept to be used for the reconstruction of I-25 north of Denver in Region IV. Included in the report is an overview of the significant events, results of the activities that took place during construction, discussion of construction modification orders, and QC/QA processes. The ultimate goal of this research was to identify and document the pros and cons of the DB practice and to examine its overall applicability to Colorado DOT.

Gransberg, D.D., W.D. Dillon, H.L. Reynolds, and J. Boyd, "Quantitative Analysis of Partnered Project Performance," *Journal of Construction Engineering and Management,* Vol. 125, No. 3, June 1999, pp. 161–166.

Study of $2 billion of Texas DOT DBB projects that compares performance of partnered versus nonpartnered projects using 13 different metrics. Study concludes that partnering enhances project performance.

Gransberg, D.D., J.E. Koch, and K.R. Molenaar, *Preparing for Design-Build Projects: A Primer for Owners, Engineers, and Contractors,* ASCE Press, Reston, Va., 2006, 266 pp.

This book is an introduction to DB from developing the project scope and writing DB performance criteria to preparing RFQs and RFPs and evaluating the responses. Also included is instruction on preparing DB proposals.

Gransberg, D.D. and K.R. Molenaar, "Analysis of Owner's Design and Construction Quality Management Approaches in Design-Build Projects," *Journal of Management in Engineering*, Vol. 20, No. 4, 2004.

This paper explores and classifies current approaches to evaluating quality in DB proposals. It does so by a thorough content analysis of 78 RFPs for public DB projects with an aggregate contract value of more than $3 billion advertised between 1997 and 2002. In DB, with cost and schedule fixed, the scope and hence the level of quality is the main element of competition. This paper identifies the six owner approaches to articulating DB quality requirements in their RFPs. These are important for DB contractors to understand so that they can craft their proposal in a manner that is both responsive to the owners' requirements and consistent with the owner's system to make the best value contract award decision.

Gransberg, D.D. and K.R. Molenaar, *The Impact of Design-Build on the Public Workforce,* Keston Institute for Public Finance

and Infrastructure Policy, University of Southern California, Los Angeles, 2007, pp. 20–26.

This study employed a combination of literature review, surveys of state DOTs, and DB RFP content analysis to answer the following question: What is the impact on the state DOT professional workforce when the state authorizes it to deliver infrastructure projects utilizing DB project delivery?

Guidebook for Design-Build Highway Project Development, Washington State Department of Transportation, Olympia, June 20, 2004, 85 pp.

Washington State DOT DB guidebook.

Hall, M. and C. Tomkins, "A Cost of Quality Analysis of a Building Project: Towards a Complete Methodology for Design and Build," *Construction Management and Economics*, Vol. 19, 2001, pp. 727–740.

A number of studies have been published that claim to carry out cost of quality (COQ) studies on construction projects. These studies, however, have largely ignored the contribution of prevention and appraisal costs to COQ, and have limited their analysis to the impact of quality failures on the main contractor. This paper presents a methodology for assessing the "complete" COQ for construction projects and reports on the findings of a building project in the United Kingdom on which the methodology was piloted. The company that applied this approach has now extended it to other projects.

Hancher, D.E., "Contracting Methods for Highway Construction," *TR News*, Nov.–Dec. 1999, pp. 10–14.

An overview of different highway construction contracting methods.

Heild, C., "Bump in the Road," *Albuquerque Journal*, Aug. 29, 2004, p. A1.

State, construction firm bickering over details of U.S. 550 roadwork warranty. Less than three years after completion, New Mexico's $296 million highway to Farmington is showing unexpected and troubling signs of distress.

Heild, C., "Transportation Department Won't Release Papers," *Albuquerque Journal*, Aug. 29, 2004, p. A8.

The state DOT refused to release 24 documents in response to a state Inspection of Public Records Act request filed by the *Albuquerque Journal*. In a log explaining the reason for withholding the records, agency attorneys stated that the documents in question "concerned litigation" or were prepared in "anticipation of litigation" or "for trial."

Heild, C., "Contractor to Honor Road Warranty," *Albuquerque Journal*, Sep. 17, 2004, p. B3.

The private contractor that oversaw the widening of U.S. 550 pledged Thursday to live up to the terms of a $62 million warranty to fix problems on newly widened U.S. 550.

Heild, C., "Audit Criticizes U.S. 550 Builder," *Albuquerque Journal*, Oct. 5, 2004, p. A1.

State report blames design and construction flaws for problems on $323 million road project.

SANTA FE—Flaws in design or construction appear to have caused heaving and cracking problems on the newly widened U.S. 550.

Highway Agencies, "Safe Roads, Reliable Journeys, Informed Travellers" [Online]. Available: http://www.highways.gov.uk/business/2665.aspx [accessed March 6, 2007].

Website on DBFO for the United Kingdom Highway Agencies.

Holt, R. and D. Rowe, "Total Quality, Public Management and Critical Leadership in Civil Construction Projects," *The International Journal of Quality & Reliability Management*, Vol. 17, No. 4/5, 2000, p. 541.

Project management in the construction industry tends toward being a strictly reactive science. Time costs and overruns, which may affect quality, are common. This approach conformed to the interpretative methodology that was adopted; one that was searching for meaning from a specific situated perspective rather than searching for facts through experimentation.

Hughes, C.S., *NCHRP Synthesis of Highway Practice 346: State Construction Quality Assurance Programs*, Transportation Research Board, National Research Council, Washington, D.C., 2005, 45 pp.

This synthesis describes the current QA practices of state and federal DOTs with regard to highway materials and construction. The report focuses on the strategies and practices used by agencies to ensure quality. Because QA is viewed differently among the agencies, methods and procedures that constitute the QA programs of highway agencies also differ significantly. This synthesis summarizes these methods and procedures to the greatest extent feasible, including information on QC, acceptance, independent assurance, and training/certification. It includes discussion of statistically based specifications, QA specifications, FHWA QA procedures for construction (complying with 23 CFR 637), performance-related specifications, optimal procedures for QA specifications, the use of consultants, and resource allocation.

"International Transit Studies Program Report on the Spring 2001 Mission Design-Build Transit Infrastructure Projects in Asia and Australia," *Research Results Digest*, Federal Transit Administration, U.S. Department of Transportation, Washington, D.C., Nov. 2002, No. 53, 31 pp.

The theme of this study mission was "Design-Build Transit Infrastructure Projects in Asia and Australia." Transit projects in the United States have traditionally been constructed using the DBB system, in which the transit agency hires an engineering firm to design a project and then puts the design specifications out for construction bids. U.S. transit agencies and owners are, however, increasingly turning to the DB project delivery system as a means of cutting costs and accelerating project delivery.

Johnson, B., "TH 212 Project Advances in Fast-Track Design-Build Environment," *Transportline*, Vol. 16, No. 1, May 2006, pp. 1–3.

An overview of the MnDOT Trunk Highway 212 project built using the DB method.

Kanji, G.K. and A. Wong, "Quality Culture in the Construction Industry," *Total Quality Management*, Vol. 9, No. 4/5, July 1998, pp. S133–S140.

Partnering, supply chain management, and total quality management are all concepts or approaches that can be applied as initiatives to solve the problems in the construction industry and meet the needs of final customers. With the help of a study on the operations of a leading Hong Kong construction company, the application of the different concepts or approaches and their relationships are discussed. It can be concluded that the concepts or approaches mentioned are useful for the company in achieving best results. However, an incident adversely affecting the company is also quoted, to highlight the need for creating a quality culture in the construction industry to ensure continued quality performance by the company.

Khalid, M.S., T.J. Scott, P. Patel, and T. Mero, "The Use of Design-Build Procurement Methods to Rehabilitate Urban Roadways," 85th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 22–26, 2006, 12 pp.

The purpose of this research is to present the benefits of using a DB contract procurement method to facilitate completion of a comprehensive, city-wide roadway rehabilitation effort in Washington, D.C. Through the use of an innovative all-encompassing DB contract awarded through the efforts of the District DOT and the Eastern Federal Lands Highway Division of FHWA, more than 108 urban roadways were improved in Wards 3 and 4 of the District of Columbia. This paper presents a case study for reconstructing urban streets using the DB methodology and elaborates on the keys to success so that other jurisdictions can apply this approach to addressing critical infrastructure improvement needs.

Killingsworth, B.M. and C.S. Hughes, "Issues Related to Use of Contractor Quality Control Data in Acceptance Decision and Payment: Benefits and Pitfalls," In *Transportation Research Record: Journal of the Transportation Research Board, No. 1813*, Transportation Research Board of the National Academies, Washington, D.C., pp. 249–252.

Several agencies throughout the United States use contractor data as a means of acceptance. This is permissible as long as certain safeguards are in place and as long as the functions of QC and quality acceptance remain separate. Discussion is needed to address the adjustment, and the state should plan training sessions to address the reasons for this decision and the importance of the steps that will be taken to implement it. The other impact will be the need to implement and monitor the validation system.

Lahdenpera, P., *Design-Build Procedures: Introduction, Illustration and Comparison of U.S. Modes,* Valtion teknillinen tutkimuskeskus (VTT), Finland, 2001.

A comparison of different DB practices in the United States.

Lesson 27: Quality Assurance and Quality Control on a Design/Build Transit Project, Project Management Oversight Lessons Learned References in Guidelines FTA Pub 1380, Mass Transit Administration of the Maryland Department of Transportation, Baltimore, 1997 [Online]. Available: http://www.fta.dot.gov/printer_friendly/publications_1380.html [accessed Aug. 22, 2006].

The Mass Transit Administration of the Maryland DOT is responsible for a fixed guideway system, including heavy and light rail lines, in the Baltimore region. The Central Light Rail Line (CLRL) component was phased. Phase I of the CLRL is an operating 22-mile line connecting Dorsey Road in the south in Anne Arundel County, through Baltimore City, to Timonium in the north in Baltimore County. Phase II will complete the CLRL component by extending the line north to the Hunt Valley business district, southwest with a spur to Baltimore–Washington International Airport, and a third extension will connect the Phase I CLRL to Amtrak's Pennsylvania Station for multi-modal connections to the MARC (commuter rail) Penn Line and Amtrak trains.

Ling, F.Y.Y., "Models for Predicting Quality of Building Projects," *Engineering, Construction and Architectural Management*, Vol. 12, No. 1, 2005, pp. 6–20.

The objectives of this paper are to: (1) find out whether DBB or DB procurement method gives better quality building, (2) identify variables that significantly affect quality scores of DBB and DB projects, and (3) construct models to predict quality scores of DB and DBB projects. There was no significant difference between the quality scores of DB and DBB projects. To ensure that buildings procured through DBB have high quality, owners should adopt the following practices: (1) engage experienced consultants, (2) shortlist bidders, and (3) select contractors based on a combination of price and ability. For both types of projects, owners should allow contractors to propose changes to the contract with a view to improving its quality.

Mahdi, I.M. and K. Alreshaid, "Decision Support System for Selecting the Proper Project Delivery Method Using Analytical Hierarchy Process (AHP)," *International Journal of Project Management*, Vol. 23, No. 7, 2005, pp. 564–572.

Owners are presented with different options for their project delivery process, which include the traditional method (DBB), construction management, or DB delivery methods. This paper examines the compatibility of various project delivery methods with specific types of owners and projects. Although no project delivery option is perfect, one may be better suited than another based on the requirements of a particular project. These requirements should be evaluated to determine which of the various options would most likely produce the best outcome for the owners. The proper selection of a project delivery method is based on a high degree of technical factors and low construction costs. In this study, a multi-criterion decision-making methodology using the analytical hierarchy process is provided to assist decision makers in selecting the proper delivery method for their projects. An example application for selecting the proper project delivery system for an actual project is provided.

"Market Trends, Water/Wastewater Outsourcing Revenues Jump in 1999," *Design-Build Institute of America Dateline*, Design Build Institute of America, Washington, D.C., Apr. 2000, p.13.

Public Works Financing's fourth annual survey of the U.S. water/wastewater privatization market shows a banner year in 1999 for revenue growth overall owing to big gains in DB and industrial markets. The data supporting the conclusion were derived from the survey responses of the 16 largest outsourcing firms that reported revenues, profits, and new contract data for calendar 1999.

McArthur, E.P., *Final Report for SEP 14 Design-Build Project: MCS Facility–West of Wibaux,* Wibaux County Project No. IM 94-7(24)240, Montana Department of Transportation, Helena, Feb. 1, 2006, 25 pp.

Use of the DB contracting method for the first MDT [Montana DOT] Pilot Project has accomplished the purpose of the program as stated in the work plan by producing a savings in time and reduction in the MDT resources necessary to design and construct the project. The time savings are clearly evident because the project proceeded from preliminary engineering through right-of-way acquisition to contract award in 6 months, and the design and construction was completed in 12 months. This time period is much less than similar DBB projects that can typically require as much as 36 months from preliminary engineering to contract award. This project has been the first step in the process that will allow MDT to explore this innovative contracting method. Based on in-house and industry reactions and comments received during the post-construction debriefings, the initial opinion is that the DB contracting method has been successful for this project.

McLawhorn, N., "Implementing Design-Build," *Transportation Synthesis Report*, Wisconsin Department of Transportation RD&T Program, Madison, 2003, 9 pp.

In this report we rely heavily on AASHTO for a broad-brush examination of the state of the practice, perspectives augmented by a survey conducted for Illinois DOT, and a few of the several state-developed state-of-the practice reports. We then focus on five states at the forefront of DB practices (Arizona, Florida, North Carolina, Ohio, and Utah,), selected either for their reputation or representative experience. We review the way in which these agencies use DB, the benefits they experience, and the drawbacks (sometimes merely potential) they grapple with.

McManamy, R., "Public Sector Continues to Embrace Design-Build," *Public Works*, July 2004, p. 72.

Historically, public works projects in most states and municipalities have had to follow public procurement laws that require the architect to represent the client, whereas the construction contract is awarded separately to the lowest responsible bidder. For this reason, as the alternative project delivery's popularity has surged in the private sector, its use in the public sector has lagged.

Migliaccio, G.C., G.E. Gibson, Jr., and J.T. O'Connor, "Delivering Highway Projects Through Design-Build: An Analysis of the Comprehensive Development Agreement (CDA) Procurement Process in Texas," Construction Research Congress 2005, ASCE, San Diego, Calif., Apr. 5–7, 2005, 10 pp.

The knowledge of the activities to be included in a DB procurement process and their critical sequencing is a central issue in conducting projects under DB. Although many recent studies focused on the evaluation aspect of the procurement, much less attention has been paid to the sequencing of activities to be performed by a STD between the "go/no go" decision and the contract execution.

MILCON Transformation Model RFP, Department of the Army, U.S. Army Corps of Engineers, Washington, D.C., 2006 [Online]. Available: ftp://ftp.usace.army.mil/pub/hqusace/MILCON%20TRANSFORMATION [accessed April 14, 2007].

Draft model RFP for the U.S. Army Corps of Engineers.

Miller, J.B. and R.H. Evje, "The Practical Application of Delivery Methods to Project Portfolios," *Construction Management and Economics*, Vol. 17, 1999, pp. 669–677.

This paper presents a tool called CHOICES (c)TM, which permits convenient comparisons of alternative delivery scenarios for a portfolio of capital projects and services. CHOICES (c)TM is designed to help formulate a portfolio infrastructure strategy, test that strategy, and adjust it to meet strategic goals within capital constraints.

Miller, J.B., M.J. Garvin, C.W. Ibbs, and S.E. Mahoney, "Toward a New Paradigm: Simultaneous Use of Multiple Project Delivery Methods," *Journal of Management in Engineering*, May/June 2000, pp. 58–67.

This paper focuses on shifting from the current paradigm toward a new model that supports simultaneous use of multiple project delivery methods. The discussion and frameworks provided are the result of a variety of research efforts by the Infrastructure Systems Development Research team at the Massachusetts Institute of Technology. Studies of the history of American infrastructure, analyses of case studies across the country, development of decision support models for capital programming, and real applications to municipal infrastructure planning provide the underpinnings for the results and conclusions presented.

Miyamoto K., Y. Sato, and K. Kitazume, "Private-Sector Participation in Infrastructure Projects and Value for Money Economic and Financial Impacts," In *Transportation Research Record: Journal of the Transportation Research Board, No. 1932*, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 16–22.

Private-sector participation in infrastructure projects has gained worldwide acceptance as a way of ensuring more efficient and effective projects and of supplementing public financing. The aim of the present study was to develop a comprehensive system of estimating the various impacts caused by changes in the scheme of public works or procurement of public services and evaluating the final impacts on stakeholders in the society. As a case study, a road project adhering to the design, build, finance, and operate scheme was compared with one adhering to the conventional scheme. The results of the case study indicate that value for money evaluation depends to a significant extent on the viewpoint and the scope of the analysis and that the difference between evaluations can be substantial. In addition, the results demonstrate the necessity of public finance transfer between central and local governments to ensure that the project is more efficient and effective with the participation of the private sector.

Molenaar, K., et al., *Washington State Department of Transportation Design-Build Pilot Project Evaluation: A Measurement of Performance for the Process, Cost, Time, and Quality: SR500 Thurston Way Interchange*, Washington State Department of Transportation, Olympia, Jan. 2003, 44 pp.

This report is an evaluation of the Washington State DOT (WSDOT) Design-Build Program and the first DB project at the SR500 Thurston Way Interchange in Vancouver, Washington. From 1998 through 2002, WSDOT contracted with the Georgia Institute of Technology and the University of Colorado to provide an independent evaluation of the level of effectiveness achieved by the DB process for Washington State.

Molenaar, K.R. and D.D. Gransberg, "Design-Builder Selection for Small Highway Projects," *Journal of Management in Engineering*, Vol. 17, No. 4, 2001, pp. 214–223.

This paper offers six case studies of design-builder selection for small publicly funded highway projects across the United States. Arizona, Colorado, Indiana, New Jersey, South Carolina, and Washington State DOTs participated in this study. This paper offers guidance for other state transportation authorities, highway engineers, and contractors embarking on DB.

Molenaar, K., D. Gransberg, S. Scott, D. Downs, and R. Ellis, *Recommended AASHTO Design-Build Procurement Guide: Final Report*, Project No. 20-7/TASK 172, Transportation Research Board, National Research Council, Washington, D.C., Aug. 2005, 101 pp.

This *Design-Build Procurement Guide* (*Guide*) is intended to assist SHAs in the DB procurement process including the preparation of RFQs and RFPs and the selection of the successful proposer. The *Guide* includes guidelines for DB procurement, along with sample RFQ and RFP documents. The contents of this *Guide* are based on best practices from experienced SHAs and other public-sector agencies. The *Guide* is intended to be flexible for varying project types, sizes, and procurement requirements. Finally, the *Guide* promotes a common DB "vocabulary" for better dissemination of lessons learned and incorporation of continuous improvement.

Molenaar, K.R., A.D. Songer, and M. Barash "Public-Sector Design/Build Evolution and Performance," *Journal of Management in Engineering*, Vol. 15, No. 2, 1999, pp. 54–63.

DB project delivery is experiencing expansive growth in both the private and the public sectors. Owners are driving the change away from the traditional DBB method. This change and changes in federal procurement laws necessitate investigation, formalization, and development of new DB guidelines and practices. Public sector use of DB represents a fundamental departure from traditional competitive, low-bid procurement procedures. Understanding the evolution and current trends in public-sector DB provides a foundation for developing uniform guidelines and practices. This paper describes the rapid evolution of public-sector DB and analyzes results from 104 completed public-sector DB projects. The results provide insights for owners, designers, and builders into the changing public-sector procurement system. Items analyzed include owner experience, level of design completion, design/builder selection, contract type, method of award, and DB process variations. The research conclusions provide a DB benchmark for public-sector agencies.

Moore, A.T., G.F. Segal, and J. McCormally, "Infrastructure Outsourcing: Leveraging Concrete, Steel, and Asphalt with Public-

Private Partnerships," *Policy Study No. 272*, The Reason Foundation, Los Angeles, Calif., Sep. 2000.

Record economic growth has fueled a growing desire to rebuild and improve the nation's infrastructure. State and local governments traditionally have relied on public works agencies or departments for project delivery, but the growing number of vital infrastructure projects has led these agencies to seek outside help. With increased participation by the private sector, innovative outsourcing has changed the face of infrastructure delivery....

Mrawira, D., J. Rankin, and A.J. Christian, "Quality Management System for a Highway Megaproject," In *Transportation Research Record 1813*, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 275–284.

Although the concepts of quality management have been successfully applied in many industries, primarily manufacturing, and are equally applicable to the construction industry, highway megaprojects, especially those delivered through PPP arrangements, present new challenges. A documented analysis is offered of a generic implementation process that can be adopted in other projects to improve efficiency in quality information management in the highway construction industry in general and in megaprojects delivered through PPP arrangements in particular.

National Partnership for Highway Quality, "Highway Quality Awards," *Public Roads*, Vol. 65, No. 5, March/April 2002 [Online]. Available: http://www.tfhrc.gov/pubrds/02mar/06.htm [accessed Jan. 23, 2007].

The National Partnership for Highway Quality (NPHQ) recognized 26 states for their outstanding highway projects. These states received their awards at the 2001 NPHQ National Achievement Award ceremony on November 29, 2001, at the NPHQ Conference in Fort Worth, Texas.

NCHRP Synthesis of Highway Practice 38: Statistically Oriented End-Result Specifications, Transportation Research Board, National Research Council, Washington, D.C., 1976, 37 pp.

The purpose of this synthesis is to extend and amplify the concepts and findings *of Highway Research Board Special Report 118* with respect to specifications for highway materials and construction and to show how they have been applied in those instances where current information is available.

NCHRP Synthesis of Highway Practice 65: Quality Assurance, Transportation Research Board, National Research Council, Washington, D.C., 1979, 42 pp.

Overall, this synthesis emphasizes that under present circumstances there is no single, ideal QA system for all highway (buying) agencies. There appears to be a general desire to move toward end-result specifications. However, the size of the job, the skill of the contractor, and the training of inspectors vary from job to job and state to state. These differences, then, control the extent to which it is feasible to establish ultimate end-result requirements.

Nelson, R.O., "Utah's I-15 Design-Build Project," *Public Roads*, Vol. 61, No. 3, Nov./Dec. 1997, pp. 40–46.

Focuses on Utah's Interstate 15 DB project that provides for the reconstruction of Interstate mainline and the addition of new general purpose and high-occupancy vehicle lanes through the Salt Lake City metropolitan area. Construction and reconstruction of bridges, reconstruction of urban interchanges, and construction of an extensive region-wide advanced traffic management system.

Neuendorf, K.A., *The Content Analysis Guidebook*, Sage Publications, Thousand Oaks, Calif., 2002, 300 pp.

A summary of the research method of content analysis. It gives step-by-step instructions and practical advice on conducting content analysis.

Nicholson, T., "AIA Teaching Architects to Lead Design-Build Teams," *Design-Build Magazine*, McGraw–Hill Construction, May/June 2005 [Online]. Available: http://designbuild.construction.com/features/archive/2005/0506_feature2.asp [accessed Feb. 4, 2007].

As DB project delivery continues to become more popular, contractors are taking the lead on the vast majority of the work because they are used to taking on and managing risk. Architects, who generally shun construction risk and are ethically opposed to changing traditional roles, increasingly are being relegated to subcontractor roles. Now some architects are saying it is time for a change.

Nickerson, R.L. and S.A. Sabol, *NCHRP Research Results Digest 274: Quality Assurance of Structural Materials*, Transportation Research Board, National Research Council, Washington, D.C., Aug. 2003, 21 pp.

This study examines the state of the practice of QA related to critical structural materials and components: those for which failure poses a threat to public safety or to the integrity of the transportation system (e.g., bridge girders, bridge columns, and sign/signal/luminaire supports). The study focuses on conventional structural materials (e.g., steel, concrete, wood, and aluminum), which comprise the vast majority of highway structures in use or in the planning and design stages. Brief coverage of some newer materials in the highway infrastructure, such as fiber-reinforced polymers, high-performance concrete, and high-performance steel, is provided.

O'Connor, J.T., G.E. Gibson, Jr., G.C. Migliaccio, and P.P. Shrestha, *2005 Annual Interim Report on the Monitoring and Evaluation of SH 130 Project Construction,* Texas Department of Transportation Research and Technology Implementation Office, Austin, Mar. 2006, 36 pp.

This report is comprised of five chapters, including the introductory chapter. The succeeding sections of this report are structured in the following manner. Chapter 2 summarizes findings regarding Research Product No. 3, including an organizational chart that summarizes the relationships in place for the State Highway 130 (SH 130) project development. Chapter 3 lays out the key elements of the plan for benchmarking the SH 130 project extensively described in Research Product No. 5. Details on the status of Research Products 7 and 8 are offered in Chapter 4. Finally, Chapter 5 summarizes the status of the research project.

Pantazides, L., "Managing Quality on Transportation Mega Projects," *ASQ World Conference on Quality and Improvement Proceedings*, Milwaukee, Wis., Vol. 59, 2005, pp. 289–297.

With major Railway Transportation Infrastructure Projects now exceeding $1 billion, and PPPs being formed to design, build, operate, and/or maintain them over an extended period of time, the challenges for "Project Management" now go beyond just bringing the job in—"On Time" and "Within Budget." This paper describes how project quality is affected from areas previously not considered as risky.

Papernik, B. and B. Davis, "Innovation in Highway Delivery: Survey of SEP-14/SEP-15 Projects," *Design-Build Institute of America Dateline*, Washington, D.C., Apr. 2006, pp. 8–14.

This article discusses the SEP-14 and SEP-15 experiments, including a description of each program and the reasons behind them. The article focuses on how these programs have been used and the potential for further use in the future.

Parsons Brinkerhoff Quade & Douglas, Inc., *Design-Build Practice Report*, New York State Department of Transportation, Albany, Sep. 2002, 60 pp.

This report describes the major components of the DB process and summarizes the practices of the various agencies utilizing DB services. Of particular interest were the practices of each agency with regard to selection of projects for DB, legislative authorization, allocation of risk, and administering and overseeing DB contracts. Agencies were also asked to identify any particular lessons learned.

Parsons Brinkerhoff Quade & Douglas, Inc., *Design-Build Procurement Process Report*, New York State Department of Transportation, Albany, Mar. 2003, 39 pp.

Recommendations for a process to implement the DB method of project delivery. The recommended DB process of this report is based on a review of DB practices used in the United States and conforms to the pending New York State legislation and proposed FHWA rules and regulations concerning DB contracting. The report reviews the background, assumptions, and rationale leading to the recommendations, describes the steps in the selection process to obtain a DB entity, recommends changes to current NYSDOT documents, and identifies new documents necessary for a successful DB program.

Parvin, C., "Innovative Contracting Here to Stay," *Roads & Bridges*, June 1998, p. 12.

Recently, a state legislative audit of highway construction projects in Washington State found that approximately one-third of project changes were caused by inadequate field investigations, unclear specifications, plan errors, design changes, or mistakes by a construction engineer. In other words, one-third of the project changes could have been avoided.

Parvin, C., "Design-Build: Evaluation and Award," *Roads & Bridges*, Jan. 2000, p. 12.

This paper discusses problems in the DB evaluation and award process.

Parvin, C., "Design-Builders Take on the Risk," *Roads & Bridges*, Jan. 2001, p. 12.

This paper seeks to identify specific contract provisions that should concern design-builders . . . . At the outset, although some state DOTs believe harsh contract provisions attempting to shift the risk to the design-builder will avoid contract disputes, the best way a DOT can protect the public is through a complete and detailed description of the scope of work and the level of performance desired.

Pelevin, A., *Private Sector Financing in Roads Review of the Major Australian Toll Roads*, Austroads Publication No. AP-131/98, Sydney, Australia, 1998, 51 pp.

This document examines the issues, experiences, and some pitfalls associated with private-sector investment and financing in roads which, in Australia, have invariably been associated with major toll road projects.

Peters, M., "An Important Project," Canal Road Intermodal Connector Meeting, Gulfport, Miss., 2003 [Online]. Available: http://www.fhwa.dot.gov/pressroom/re031021.htm [accessed Sep. 16, 2006].

Excerpts from remarks as prepared for delivery at the Canal Road Intermodal Connector Meeting on Tuesday, October 21, 2003, in Gulfport, Mississippi.

Postma, S.E., R. Cisneros, J. Roberts, R. Wilkison, J. Clevenger, and A. Eastwood, *I-15 Corridor Reconstruction Project Design/Build Evaluation 2001 Annual Report*, Report UT-02.11, Utah Department of Transportation Research Division, Salt Lake City, Apr. 2002, 36 pp.

This report is the final report to be produced under a 4-year project of evaluation and research into the I-15 DB project. The purpose of the evaluation is to collect and evaluate information derived from the process used in this project and provide this information to other agencies or entities interested in pursuing similar DB projects in transportation. This report is the final report and summarizes all of the evaluations completed for the project. It includes reports on seven specific areas: selection/award, design, QA/QC, innovative construction methods, performance specifications, partnering, and public involvement.

Potter, J.M. and D.K. McMahon, *Selecting a Quality Control/Quality Assurance Program for a Mega Design-Build Project*, Rummel, Klepper & Kahl, LLP, Baltimore, Md., 2006, 12 pp.

The purpose of this research was to determine how other state DOT's DB programs manage their QC/QA programs during construction, identify their lessons learned, and use those findings to recommend a construction phase QC/QA program for the ICC mainline/interchange Contracts A through E.

Primer on Contracting for the Twenty-First Century, AASHTO Subcommittee on Construction—Contract Administration Task Force Report, American Association of State Highway and Transportation Officials, Washington, D.C., 2001.

An overview of different methods of contracting.

Procurement Strategy of the Finnish Road Administration, Finnish Road Administration, Helsinki, 2003, pp. 27–29.

Procurement strategies from Finland.

Qaasim, H.A., "Comprehensive Quality Assurance for Rapid Transit," *ASQ World Conference on Quality and Improvement Proceedings*, Milwaukee, Wis., Vol. 59, 2005, pp. 299–307.

For QA to be effective in design and construction, it must be part of a comprehensive strategic plan. This paper examines the principles of QA and its key role in the design and construction of a $2 billion multi-year capital construction program.

Quality Control, Quality Assurance, Independent Assurance and Independent Verification Guide for Use on Public-Private Transportation Act & Design Build Projects, Virginia Department of Transportation, Richmond, Mar. 28, 2007, 30 pp.

The Virginia DOT guide to QA and QC on DB projects.

"Quality Glossary," American Society for Quality, Milwaukee, Wis., 1998 [Online]. Available: http://www.asq.org/info/glossary/ [accessed Nov. 15, 2002].

Definitions of words and processes related to quality.

Quatman, G.W., *Design-Build for the Design Professional*, Aspen Law and Business, New York, N.Y., 2001.

A DB guide for design professionals.

Queiroz, C., "Contractual Procedures to Involve the Private Sector in Road Maintenance and Rehabilitation," Transport Sector Familiarization Program, World Bank, Washington, D.C., 1999, 18 pp.

This paper reviews options for creating an enabling environment for the construction industry, thus leading to more involvement of private contractors and consultants in improved management of road assets. Highway agencies have increased private-sector involvement in an attempt to reduce the amount of highway agency resources

required on a highway project; reallocate performance risk; increase contractor innovation; increase the quality of constructed products; and reduce life cycle costs of highway projects. A summary of recent experience in the increased involvement of the private sector in highway asset management is summarized for countries such as Australia, New Zealand, the United States, the United Kingdom, and Argentina.

Quinn, S., "Design-Build Is Coming to Transportation: Are You Ready?" *CE News*, Aug. 1999, pp. 54–57.

Nearly a decade after the FHWA's SEP-14 introduced the DB concept, DOTs and other agencies are seriously considering DB as a sound method to speed transportation project delivery. Its acceptance as an experimental method for delivering a variety of transportation projects means civil engineers need to understand when and how DB is being used, and why they should take a careful look at this "new" project delivery process.

Report to Congress on Public-Private Partnerships, U.S. Department of Transportation, Washington, D.C., Dec. 2004, 182 pp.

House Report 108-243 (2003) accompanying the FY 2004 Department of Transportation Appropriations Act requested the U.S.DOT to prepare a report identifying the impediments to the formation of large, capital-intensive highway and transit projects involving public-private partnerships (PPPs). U.S.DOT was also asked to work with states and local entities to identify and eliminate existing impediments. This report addresses both of those goals by pulling from existing literature on PPPs and by gathering comments from states, law firms, contractors, and trade associations with experience in these projects. These comments, gathered from stakeholders, do not necessarily represent the position of the U.S.DOT, but are included in response to the Committee on Appropriation's request according to the direction given by the House Report.

Rogge, D.F. and R. Pinto, *ODOT Design-Build Pilot Projects Evaluation Volume II: Special Experimental Project Evaluation for the Evans Creek–Rock Point Design-Build Pilot Project*, Oregon Department of Transportation and Federal Highway Administration, Salem, June 2001, 40 pp.

This report provides a summary of the ECRP (Evans Creek–Rock Point) project, analysis of the results, and recommendations for future Oregon DOT utilization of DB project delivery. The project is viewed as successful, primarily because a high-quality project was delivered within the established budget and 1 year ahead of the contractually allowable completion. This minimized Oregon DOT maintenance expenses and minimized traffic disruptions and associated road user costs experienced by motorists. The pavement that motorists drove on in 2000 was undoubtedly safer than it would have been if the project had not been completed until December 2000.

Rogge, D.F. and R. Pinto, *ODOT Design-Build Pilot Projects Evaluation Volume III: Evaluation—Harrisburg Bridge Design-Build Pilot Project,* Oregon Department of Transportation and Federal Highway Administration, Salem, June 2001, 43 pp.

This report provides a summary of the Harrisburg Bridge project, analysis of the results, and recommendations for future Oregon DOT utilization of DB project delivery. The project is viewed as successful, primarily because a superior quality project was delivered in advance of the established contract time with essentially no traffic disruption. The DB contractor's use of a detour bridge, at his own initiative, meant that lane closures were not required. This became particularly important when uncovering of the Bent #1 floor beam revealed severe corrosion. Without the detour bridge, repair would have required complete closure of the bridge for several days.

Russell, J.S., A.S. Hanna, S.D. Anderson, P.W. Wiseley, and R.J. Smith, "The Warranty Alternative," *Civil Engineering*, Vol. 69, No. 5, May 1999, pp. 60–63.

The number of states using warranties has continued to increase since the 1991 Intermodal Surface Transportation Efficiency Act allowed the use of warranty contracting on projects that are part of the national highway system. One major reason states are implementing warranties is to supplement their workforces and reduce the need for inspections. Most states require a warranty bond to guarantee that the contractor will remedy any problems associated with substandard performance. Contractors and SHAs say that bonding availability is the primary barrier for implementing warranty projects.

Russell, K., *Recent Advances in Road Pricing Practice*, Austroads Publication No. AP-R196/01, Sydney, Australia, 2001, 78 pp.

The purpose of this study is to provide information on recent advances in road pricing practice, both nationally and internationally. As the availability of new technologies is the most rapidly changing aspect of road pricing, a significant proportion of the report is dedicated this particular aspect. Where possible, reference is also made to the emerging sociological, political, economic, and environmental impacts of road pricing.

Saunders, M., "Bridging the Financial Gap with PPPs," *Public Roads*, Vol. 70, No. 1, July/Aug. 2006, p. 1-1.

The article focuses on private-sector involvement in highway construction and financing through PPPs in the United States. Many transportation officials think PPPs will be increasingly important in the future because traditional funding sources are not keeping pace with infrastructure investment needs and continuously growing public demand for travel.

Scheinberg, P.F., "MASS TRANSIT: Challenges in Evaluating, Overseeing, and Funding Major Transit Projects," GAO/T-RCED-00-104, Testimony Before the Subcommittee on Transportation, Committee on Appropriations, House of Representatives, U.S. General Accounting Office, Washington, D.C., Mar. 8, 2000, 26 pp.

This document presents information based on a number of completed General Accounting Office reviews, as well as ongoing work that is being conducted at the request of this Subcommittee and others on FTA's programs. Specifically, [it discusses] (1) FTA's process for evaluating proposed transit projects, (2) FTA's oversight of transit projects under construction, and (3) the ever-increasing competition for federal transit construction dollars. In addition, [it provides] information on the costs, schedules, and financing of six ongoing transit projects.

Schmidt, J., D. Perdomo, and T. Cable, *Transportation Research Circular E-C105: Factors Affecting Compaction of Asphalt Pavements,* Transportation Research Board, National Research Council, Washington, D.C., Sep. 2006.

This particular delivery method (i.e., design-build-warranty) required an integrated, performance-based, decision-making process driven by the continuous assessment of the construction quality in the context of pavement design and long-term performance. This paper focuses on some of the practical applications of statistical process control using a percent within limits specification approach and associated learning as an important component of the QC/QA/IA process in a design-build-warranty project.

Schwartz, E., "No Speed Bumps on Texas' First Design-Build Highway," *Texas Construction*, Vol. 12, No. 9, Sep. 2004, p. 28.

In its first-ever DB contract, the Texas DOT is partnering with a consortium of engineering and construction firms known as Lone Star Infrastructure to deliver the new 49-mile, $1.5 billion State Highway 130 tollway, the largest, active highway contract in the nation and the largest element of the future $3.6 billion Central Texas Turnpike Project.

Science Applications International Corporation Transportation Policy and Analysis Center, "Outsourcing of State DOT Capital

Program Delivery Functions," *NCHRP Web Document 59* (Project 20-24[18]): Contractor's Final Report, Transportation Research Board, National Research Council, Washington, D.C., Nov. 2003, 53 pp.

The outsourcing of state DOT Capital Program Delivery Functions was developed under the direction of the NCHRP for AASHTO. This document was prepared as part of the "20-24 Series" of NCHRP projects on the administration of highway and transportation agencies. The report is designed to assist state DOTs in assessing the outsourcing of their capital delivery functions.

"Selection of a Design-Builder 'A List of Principles,'" *Canadian Design-Build Institute Practice Bulletin #3*, Apr. 2001, 2 pp.

The Joint Industry–Government of Canada Design-Build Task Force has approved the following set of principles to provide guidance to the federal government and the industry for the selection of a design-builder and the proper use of DB. The principles, developed in partnership with the Association of Consulting Engineers of Canada, Canadian Construction Association, Construction Specifications Canada, and the Royal Architectural Institute of Canada, are consistent with the Canadian Design-Build Institute's Design-Build Practice Manuals (100 Series—Introduction and General, 200 Series—Procurement and Award).

SEP-15 Program—Public Private Partnerships, Federal Highway Administration, Washington, D.C., 2007 [Online]. Available: http://www.fhwa.dot.gov/PPP/sep15.htm [accessed June 3, 2007].

Description of FHWA special experimental program for PPPs.

Shammas-toma, M., D. Seymour, and L. Clark, "Obstacles to Implementing Total Quality Management in the UK Construction Industry," *Construction Management & Economics*, Vol. 16, No. 2, Mar. 1998, pp. 177–192.

Since at least the Tavistock studies, the need to improve communication and coordination in the construction process has been stressed. This paper reports from a study of 25 construction projects where QA and a number of procedures were in use that might have been expected to bring such improvement. The finding was, however, that coordination was poor. The purpose of the paper is to consider how this finding is to be explained.

Shane, J.S., *Design-Build Highway Construction: An Examination of Special Experimental Project Number 14 Performance*, Masters thesis, University of Colorado, Boulder, 2000.

Through a combined research methodology of case study, content analysis, and questionnaire procedures, this research presents a DB taxonomy for highway projects composed of four levels: project type, project size, procurement type, and design level at award. This classification system allows dissemination of project performance and experiences to aid the industry in determining the viability of DB. This report also examines 33 completed DB projects to determine the cost, schedule, and quality performance compared with similar DBB projects. The findings of this study are similar to the findings of studies in the vertical industry; projects are completed in a shorter amount of time with less cost variability.

Shane, J.S., D.D. Gransberg, K.R. Molenaar, and J.R. Gladke, "Legal Challenge to a Best-Value Procurement System," *Journal of Leadership and Management in Engineering*, Vol. 5, No. 1, Jan. 2006, pp. 1–6.

One SHA that utilized a two-step best-value procurement process received a protest from one of the firms that was not successful in passing the qualifications phase of the procurement. The court found evidence to uphold the decision of the SHA through the transparent and documented evaluation process established by the SHA. Continued exploration of new and different technologies and ideas for procurement and delivery of highway projects will result in legal challenges to the system as all parties involved work to gain an understanding of the processes. This paper is an examination of one SHA's experience with an alternative to the highway industry's typical low-bid procurement system.

Shane J.S., S. Won, and K.R. Molenaar, "Variations in State Highway Agency Design-Build Programs," 85th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 22–26, 2006, 16 pp.

A survey of 30 agencies across the United States provides insights into important program variations. According to respondents, the primary reason for choosing DB is for the advantage of time. Cost and non-cost factors are found to be equally important factors in procuring DB services. Approximately one-half of the SHAs responding to the survey use stipends to offset the proposal costs of unsuccessful proposers. Finally, SHAs are taking advantage of the ability to allocate risks differently than through the DBB methodology.

Shekharan, R., D. Frith, T. Chowdhury, C. Larson, and D. Morian, "The Effects of a Comprehensive QA/QC Plan on Pavement Management," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 14 pp.

A detailed QA process has been developed and applied to achieve the desired high-quality data. The project includes QA that has been carried out since the inception of the project, including the application of necessary adjustments in the data collection process, to ensure that quality data conforming to predefined standards is obtained. This paper quantifies the effects of a complete and comprehensive quality monitoring plan, which includes QC, QA, and an independent validation and verification, on pavement management data and the resulting budgetary estimates. Pre- and post-independent validation and verification results were analyzed to determine the effects of a comprehensive quality monitoring plan on pavement distress data collection.

Shrestha, P.P., G.C. Migliaccio, J.T. O'Connor, and G.E. Gibson, "Benchmarking of Large Design-Build Highway Projects: One-to-One Comparison and Comparison with DBB Projects," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 15 pp.

This paper analyzes a sample of four DB projects (with contract amounts ranging from $126 million to $1.4 billion) to determine how project characteristics and DB practices (inputs) affect project performance in terms of cost and schedule (outputs). Project cost and schedule performance show clear trends against 15 input factors. More data points are needed to determine correlations between these inputs and outputs. In addition, 11 DBB projects (with contract amounts ranging from $50 million to $100 million) were selected for a statistical comparison with DB projects. The authors found a statistically significant difference in cost growth between the two samples, with DBB projects having higher values.

Siebels, J.E., "Implementation of Design-Build Guidelines," Memo to Regional Transportation Directors Program Engineers, Colorado Department of Transportation, Denver, Aug. 8, 1997, 2 pp.

Memo accompanying the Colorado DOT DB guidelines.

Smith, N., "Quality Assurance Through Procurement Methodology," Memorandum, Nossaman, Guthner, Knox & Elliott, Los Angeles, Calif., May 11, 2005, 7 pp. [Online]. Available: http://www.nossaman.com/db30/cgi-bin/news/NCS_Quality%20Assurance%20Through%20Procurement%8-22-06 [accessed Aug. 22, 2006].

One of the first steps in any DB procurement is to analyze the risks associated with the project and decide how to deal with them. It is

usually possible to reduce some risks through measures such as comprehensive geotechnical and hazardous materials surveys. Most of the remaining risks must be located in the contract documents. However, one major risk—specifically the risk that transfer of control of the project to the design-builder will reduce the quality of the work product—can and should be addressed, at least in part, through use of an appropriate procurement methodology.

Smith, N.C., "Getting What You Paid for: The Quality Assurance and Acceptance Process for Transportation Projects," *Proceedings, American Bar Association Forum on the Construction Industry*, Denver, Colo., 2001, pp. 17–18.

In the transportation industry, project owners typically assure themselves regarding project quality by approving the final project design and inspecting and testing the work and materials over the course of construction. One of the most debated topics in the industry is how best to ensure quality in complex projects involving DB or other alternative delivery methodologies. Unlike "vertical" projects, owners of transportation projects cannot rely on design reviews in connection with building permit applications or on public inspections in connection with certificates of occupancy.

Songer, A.D. and K.R. Molenaar, "Selecting Design-Build: Private and Public Sector Owner Attitudes," *Journal of Engineering Management*, Vol. 12, No. 6, 1996, pp. 47–53.

This paper discusses results of research conducted to address owners' attitudes toward one specific alternative contracting method, DB. A tremendous growth in DB and limited existence of documented research on owner's attitudes toward DB necessitates a focus on this particular delivery strategy. Primary DB selection factors identified and analyzed include: establish cost, reduce cost, establish schedule, shorten duration, reduce claims, large project size/complexity, and constructability/innovation. Additionally, a comparison of private and public owner DB attitudes is documented.

State of Texas, State Bill No. 1499, Section 1, Chapter 223, Transportation Code, Subchapter E, Sep. 1, 2003.

Texas DB law.

"State of the Art Road May Be Headed South," *Albuquerque Journal*, Vol. A12, Sep. 1, 2004, p. 2.

The new way of doing business accelerated completion of the 118-mile stretch from a 27-year span to 3 years [NM 44/US 550]. The Bernalillo-to-Bloomfield route opened up and it was hailed as the smoothest-cruising roadway in the state. Less than 3 years later, the deal is looking rougher.

State of the Practice Review in Design-Build, Florida Department of Transportation and Federal Highway Administration, Tallahassee, 2002 [Online]. Available: http://www.dot.state.fl.us/construction/Design%20Build/DB%20General/State%20of%20Practice%20D-B.doc [accessed Aug. 26, 2006].

This report focuses on DB projects. The Florida DOT and other state DOTs can use the information gathered to further develop their own DB program. After researching several state transportation departments with regard to their use of DB, it was decided that visiting the South Carolina DOT and the Arizona DOT would be the most beneficial reviews for 2002. A team of FHWA Florida Division and Florida DOT personnel visited the South Carolina and Arizona DOTs in July and September 2002, respectively.

Stefani, A.M., *Managing Risk in the Federal-Aid Highway Program*, Report MH-2005-012, Federal Highway Administration, Washington, D.C., Nov. 19, 2004.

This report recommended that the FHWA require that all Division offices conduct risk assessments; issue guidance identifying major programs and program components to be evaluated and the methodology to be used for evaluating and classifying program risks; analyze the individual risk assessment results to identify program-wide issues; and follow-up with Division offices to ensure oversight attention is given to high-risk areas. FHWA concurred with the recommendations.

Stenbeck, T., "Effects of Outsourcing and Performance-Based Contracting on Innovations," 85th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 22–26, 2006, 10 pp.

This paper reports on some effects of outsourcing and performance-based contracting and in particular effects on long-term technical development. A second purpose is to list, test, and report efficient and less efficient methods to spur innovation whatever the political setting, including intermediary variants between in-house production, outsourcing, and performance-based contracting.

Strong, K., *Performance Effectiveness of Design-Build, Lane Rental, and A + B Contracting Techniques: Final Report*, Report MN/RC-2006-09, Minnesota Department of Transportation, St. Paul, Mar. 2006, 74 pp. [Online]. Available: http://www.lrrb.org/PDF/200609.pdf.

Performance and cost and value implications of A + B contracts, DB contracts, lane rental contracts, and traditional contracts were investigated. Specific performance and cost measures considered are Administration Costs, Project Costs, Management Complexity, Disruption to Third Parties, RUC, Innovation, Product/Process Quality, and Funding Flexibility. Performance parameters are compared on nine different project types; the methodology utilized a survey of national experts who rated each innovative contracting method for each performance factor on each of the project types.

Strong, K.C., J. Tometich, and N. Raadt, "Cost Effectiveness of Design-Build, Lane Rental, and A + B Contracting Techniques," *Proceedings of the 2005 Mid-Continent Transportation Research Symposium*, Iowa State University, Ames, Aug. 2005, 10 pp.

Many state DOT specifications are generally prescriptive in that they describe how contractors should conduct certain operations using minimum standards of equipment and materials. These prescriptive specifications, known as method specifications, have performed admirably in the past. Results indicate that DB and A + B contracts are the most effective methods when time is the primary driver of cost or when complex design issues require interdisciplinary coordination. Because DB appears to hold much promise for dramatically accelerating schedules, we used in-depth personal interviews of project team members involved in a DB urban corridor reconstruction project in Minnesota.

Sypsomos, M.G., "Beyond Project Controls—The Quality Improvement Approach," *AACE International Transactions*, Morgantown, W.Va., 1997, pp. 262–269.

This paper presents a proven method of quality improvement that uses existing project controls tools and methods combined with total quality management methodology. Data received from a Construction Industry Institute survey strongly showed that project success at leading companies is mainly attributed to hard measurements such as cost, schedule, and safety in addition to soft factors such as leadership, employee satisfaction, and teamwork for determining the performance of projects. However, although the trend in the construction and engineering industry is to use total quality management in the engineer-procure-construct processes, companies have yet to combine the quality improvement framework with the conventional project management and project controls performance measurements.

Tam, W.O., J.P. Bowen, K.A. Smith, and T.J. Weight, "State Highway 130 Exclusive Development Agreement Construction

Quality Assurance Program," *Asphalt Paving Technology*, Vol. 72, 2003, pp. 656–665.

This paper specifically addresses the Construction Quality Control/Quality Assurance (QC/QA) Program for the SH 130 Exclusive Development Agreement (EDA) project. The goals of this program are to ensure that the project is constructed with reasonable conformance with the requirements of the approved plans, specifications, and the EDA. The program will be consistent with the requirements set forth in the Texas DOT *Contract Administration Handbook for Construction Projects* and will comply with 23 CFR 637b. This paper describes the scope of the EDA, the parties involved in the construction QC/QA program, and their roles. It also discusses some of the checks and balances established on this project.

Tam, W.O., J.P. Bowen, P.S. Terranova, T.J. Weight, and J.E. Travis, "The State Highway 130 Exclusive Development Agreement: A Case Study in Managing Quality Assurance with Contractor Acceptance Testing and Inspection on a Design-Build Project," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 17 pp.

This paper focuses on the Texas DOT and its Program Manager's role on the project [Texas SH 130]. This includes the development of a project-specific QAP, the development of owner oversight tools and procedures, and the implementation of these procedures to oversee the Independent Construction Quality Firm and Developer's activities. Specific requirements and procedures used on the project are discussed in the paper.

Taylor, A.B., Jr., "Build-Operate-Transfer: Evaluating Efficiency During the Operation Phase," *Cost Engineering*, Vol. 40, No. 6, June 1998, pp. 23–26.

This article attempts to present a theoretical construct, the Taylor business model, which is designed to aid management in the operation phase of a BOT project. The premise for feasibility is linked to the microeconomic theory for monopolies, whereas the premise for validation is linked to the fact that BOT has become a viable option for infrastructure development. This article also attempts to qualitatively describe the integral components of the operation phase of all BOT projects to allow readers to see "the big picture" by identifying the key elements in the operation phase and relating them to the model using a systems approach.

The United States Air Force Design-Build Plus Users Guide, July 2003, 16 pp.

The purpose of this guide is to familiarize the Air Force community, Program Managers, Base Civil Engineers, Chief Engineers, Project Engineers, and Contracting Officers with the Design-Build Plus project delivery process. This *User's Guide* illustrates the process for implementing the Design-Build Plus contract vehicle.

"Third Anniversary Key to U.S. 550 'Marriage'," *Albuquerque Journal*, Vol. A14, Oct. 6, 2004, p. 14.

State transportation chief Rhonda Faught likens the relationship with the company responsible for a warranty on U.S. 550 to a marriage. With a term of 20 years, it will be longer than many. However, unlike most, there was a prenuptial contract that was very specific about certain anniversaries—like ... November 21 [2004]. That's the end of a three-year period during which the state can make claims against a professional services warranty covering design and construction problems. After that date—even if problems are attributable to design or construction—solutions come out of the limited pot of general warranty money.

Tomeh, O.A., D.C. Schnek, and R.A. Stross, "Innovative Procurement Methods in Rail Transit Projects: Baltimore's Turnkey Experience," *Transportation Research Record 1677*, Transportation Research Board, National Research Council, Washington, D.C., 1999, pp. 79–86.

As part of this evaluation, the contractual differences between the conventional contracting method used in Phase 2 and the DB, or turnkey, contracting mechanisms and incentives that were used in Phase 2 Extensions project are discussed. The focus of this discussion is on the comparative differences of the specific contracting mechanisms and incentives used by the Mass Transit Administration in the procurement phase of the two comparable projects, Central Light Rail Line Phases 1 and 2. This discussion also examines the effectiveness of the procurement approach implemented by the Mass Transit Administration as compared with other turnkey contracts.

Touran, A., L.A. Fithian, K. Ghavamifar, D.D. Gransberg, D.J. Mason, and K.R. Molenaar, *Technical Memorandum for TCRP Project G-08: A Guidebook for Evaluation of Project Delivery Methods*, Transportation Research Board, National Research Council, Washington, D.C., 2007.

The objective of this research is to develop a guidebook to help transit agencies (1) evaluate and select the most appropriate project delivery method for major capital projects and (2) evaluate the advantages and disadvantages of including operations and maintenance as a component of a contract for the project delivery system. The project delivery methods to be discussed in the guidebook are (a) DBB, (b) DB, and (c) construction manager-at-risk.

Transportation Research Circular E-C074: Glossary of Highway Quality Assurance Terms, Transportation Research Board, National Research Council, Washington, D.C., Jan. 2006, 40 pp.

TRB compendium of "official" definitions for QA terms in use in FHWA documents.

Trombly, J. and T. Luttrell, *Michigan Intelligent Transportation System Center Use of a Design/Build/Warranty Contract*, Report FHWA-OP-01-020, Federal Highway Administration, Washington, D.C., Mar. 2000, 4 pp.

Procurement of Intelligent Transportation System projects with federal-aid funds can present challenges. Conventional federal-aid construction projects are procured using a two-step project delivery approach: first, a design contract is let to design the project, and then a construction contract is let to build the project. Under federal-aid regulations, the design contractor can be selected using a qualifications-based approach, whereas the construction contractor must be selected based on low bid. In many cases, however, the requirements of Intelligent Transportation System projects cannot easily be specified at the beginning of a project. This makes it difficult to establish realistic low bids and ensure product quality.

Turochy, R.E. and F. Parker, "Comparison of Contractor and State Transportation Agency Quality Assurance Test Results on Mat Density of Hot-Mix Asphalt Concrete: Findings of a Multi-State Analysis," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 25 pp.

The results of contractor-performed tests on in-place properties of hot-mix asphalt are increasingly used in the acceptance decision in many states. Results of tests performed by contractors and state DOTs in Florida, Kansas, and North Carolina consistently indicate that differences between contractors and state DOT test results for hot-mixed asphalt concrete mat density are statistically significant. Furthermore, these comparisons consistently indicate less variable and more favorable contractor test results, relative to specification limits, that give more favorable acceptance outcomes. Details of QA processes (sampling and testing frequencies, test methods, verification procedures, and acceptance procedures) appear to have little if any effect on these comparisons. These findings provide information for state DOTs to consider in structuring their QA programs, and specifically the role of contractor-performed tests in acceptance decisions.

Turochy, R.E., J.R. Willis, and F. Parker, "Comparison of Contractor Quality Control and Georgia Department of Transportation

Data for Quality Assurance of Hot-Mix Asphalt," 85th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 22–26, 2006, 16 pp.

The Georgia Department of Transportation (GDOT) utilizes contractor-performed tests in the acceptance decision on acceptable corroboration of GDOT-performed tests. Statistical analyses have been performed to assess differences between tests conducted on hot-mix asphalt concrete by GDOT and its contractors during the 2003 construction season. Measurements of gradation and asphalt content taken by both parties were compared both across all projects and on a project-by-project basis for projects large enough to meet sample size requirements for this type of analysis. Statistically significant differences occur in some cases; these differences are much more common when comparing variability of these measurements than with the means. At the project level, on most projects in which statistically significant differences occur, the GDOT value is typically larger.

Tyborowski, T., M. Primack, and K. Matthews, "Privatization: A Closer Look," *1997 AACE International Transactions*, pp. CC.03.1–CC.03.5.

Through a review of available literature and an analysis of the results of many privatization initiatives, this paper demonstrates how competition for, and privatization of, government services can lead to increased efficiency, higher quality, and cost savings. This paper also defines privatization and discusses the economic justification for using privatization as a tool to provide government services. Based on this case study analysis, the authors also provide a discussion of the factors that, in general, lead to the successful implementation of privatization.

"Types of Public-Private Partnerships," The National Council for Public-Private Partnerships, Washington, D.C. [Online]. Available: http://ncppp.org/resources/ [accessed Mar. 6, 2007].

Definitions of different types of PPPs.

Use of Contractor Test Results in the Acceptance Decision, Recommended Quality Measures, and the Identification of Contractor/Department Risks, Technical Advisory 6120.3, Federal Highway Administration, Washington, D.C., Aug. 2004.

FHWA technical rules for using contractor QC testing in acceptance plans.

Ward, T. and D. Jackson, "Paving a New Road: Minnesota Department of Transportation Explores Best-Value Design-Build Delivery," *Design-Build Institute of America Dateline*, Washington, D.C., Nov. 2005, pp. 8–16.

Planning for ROC 52 began in the late 1980s and the Environmental Impact Statement was approved in 1996. At that time, it was estimated that it would take more than 11 years and 15 stages to finish the project corridor owing to funding limitations for MnDOT District 6. In 2000, an Economic Impact Study performed through a partnership between MnDOT District 6 and the city of Rochester analyzed four staging alternatives along with the corresponding retail transfer and business impacts within various commercial business centers. Study results prompted recommendation of a 5-year maximum construction timeline. It was clear that MnDOT needed to investigate alternative delivery methods if it were to cut the estimated schedule by more than half.

Warne, T., "Minnesota Department of Transportation Design-Build 2006 Customer Assessment," St. Paul, 2006, 99 pp.

This report is the product of MnDOT's Design-Build 2006 Customer Assessment effort. It contains inputs received through an Internet-based survey of 33 industry representatives, phone interviews, and comments received during a Design-Build Forum held on March 30, 2006. Through this process, the industry offered valuable and substantial information regarding the state's DB program that will serve as a foundation for MnDOT to further improve this project delivery method.

Warne, T., et al., *Transportation Research Circular E-C090: Design-Build: A Quality Process*, Transportation Research Board, National Research Council, Washington, D.C., Jan. 2006, 17 pp.

A document that updates the state of art in DB contracting across the United States authored by many of the nation's DOT-level experts.

Weber, R.P., *Basic Content Analysis*, Sage Publications, Beverly Hills, Calif., 1985.

A guide to performing content analysis.

Wichern, S., "Protecting Design-Build Owners Through Design Liability Coverage, Independent Construction Managers, and Quality Control Procedures," *Transportation Law Journal*, Vol. 32, No. 1, Fall 2004, pp. 35–56.

Despite the many advantages of the DB system over the traditional approach, the union of the design professional and contractor into a single entity may cause potential owners some apprehension. By demanding minimum standards in the design professional's E&O insurance, owners can protect themselves from design negligence, errors, and omissions while also securing their traditional surety guarantees under the contractor's performance bond. A second approach to securing comprehensive coverage in DB projects is for owners to require that the contractor obtain a stand-alone professional liability policy to cover the project's design exposure.

Wilson, B., "Experiment Turns to Solid Rule," *Roads & Bridges*, Jan. 2003, p. 12.

The FHWA recently approved a final rule to allow DB contracting. As of January 9 [2003], recipients in the federal-aid highway program were able to use the DB contracting method just as they would the traditional DBB contracting method.

Wilson, B., "Wheelin' and Dealin'," *Roads & Bridges*, Jan. 2000, pp. 30–32.

Innovative contracting is changing the job process of the road building industry. Some are popular, a few are not, and a fraction is currently debated. The use of warranties is creating a forum of pros and cons. It is the way of doing business for states such as Indiana, Michigan, and Wisconsin, and several more DOTs may take on the trend in the near future.

Wilson, F.J., "Public-Private Partnerships," House Transportation and Infrastructure Committee FDCH Congressional Testimony, Washington, D.C., Feb. 13, 2007.

Houston will need massive capital investment in transportation infrastructure over the next 20 years. However, more importantly over the next 5 years, the spend rate necessary to meet our short-term goals will be even more demanding. In short, federal, state, and local financial resources, although significant, will be insufficient to meet these needs. Also, the traditional public financing model results in lengthy project delivery schedules, something that Houston can no longer afford if we are to meet the binding deadlines resulting from a 2003 voter referendum and respond meaningfully to public antipathy toward excessive commute times. It is estimated that the cost of congestion in Houston alone is more than $2 billion per year. It is our belief that federal programs will not be modified in the near-term to meet these immediate needs. We also believe that private equity investments in infrastructure projects across the globe have resulted in a very sophisticated marketplace where we cannot only find investors, but also experienced and reliable private operators and managers of transportation infrastructure.

Wiss, R.A., R.T. Roberts, and S.D. Phraner, "Beyond Design-Build-Operate-Maintain New Partnership Approach Toward Fixed Guideway Transit Projects," *Transportation Research Record 1704*, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp. 13–18.

The North Jersey Rapid Rail (NJRR) proposal, as a case study, demonstrates how the bottom-up, "beyond DBOM" process is working. NJRR is an initiative of a consultant–contractor consortium working with two transit-dependent counties (Bergen and Passaic) and the New Jersey DOT. The initiative is a devolution of risk and responsibility to a more local level and a reversion to earlier private partnerships. During the first half of the 20th century, most of the rail transit infrastructure in North America was designed, built, operated, and maintained efficiently by private-sector consortia consisting of finance, transit operating, utility, and construction interests. From the vantage point of one millennium ending and a new one beginning, this research is retrospective as well as futuristic.

Yin, R.K., *Case Study Research: Design and Methods*, Sage Publications, Beverly Hills, Calif., 1994.

A guide on how to perform case study research.

Yin, R.K., "Conducting Case Studies: Collecting the Evidence," 2004 [Online]. Available: http://72.14.203.104/searchq=cache:jHb6y55UFJ8J:www.idt.mdh.se/phd/courses/fallstudie/slides%2520-%2520seminarie%25202/Yin%2520-%2520kapitel%25204%2520Rev%25203.ppt+conducting+case+studies&hl=en&gl=us&ct=clnk&cd=1 [accessed Mar. 13, 2006].

A guide on how to collect information to perform case studies.

Yuan, J., C.N. Fu, and G.W. Raba, "Implementation of a Web-Based Electronic Data Management System for the Construction Material Quality Assurance Program of a Highway Mega-Project," 85th Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 22–26, 2006, 26 pp.

This paper presents a case study of implementing a web-based electronic data management system for the construction material QA program of the State Highway 130 Turnpike project, a 49-mile DB highway mega-project in Texas. The system consists of a set of web-enabled data management and engineering analysis tools that support the independent Construction Quality Assurance Firm's (CQAF) functions in managing, reporting, and analyzing material test data. Through the electronic data management system, the quality and efficiency of the CQAF are greatly enhanced in making acceptance decisions, tracking deficiencies and corrective actions, and ensuring that materials and workmanship incorporated into the project are in compliance with requirements of project specifications.

Yuan, J., J.A. Roberts, C.N. Fu, and G.W. Raba, "The Independent Construction Quality Assurance Program of State Highway 130 Project: The Perspective of the Independent Construction Quality Assurance Firm," 86th Annual Meeting of the Transportation Research Board (CD-ROM), Washington, D.C., Jan. 21–25, 2007, 17 pp.

In recent years, mainly because of the steady growth in highway capital development programs and SHAs' continuously declining staffing levels, utilizing the construction QA services provided by private engineering entities for major transportation infrastructure projects has been a subject of increased interest to both the public and private sectors. From the perspective of the independent Construction Quality Assurance Firm (CQAF), this paper presents the construction QA program of the State Highway 130 Turnpike project (SH 130). Also discussed in this paper are the CQAF organizational structure, the Construction Quality Control and Quality Assurance Program, material testing and construction inspection functions, innovative data management techniques, and alternative QA approaches. Rooted in the principles of 23 CFR 637, the CQAF program substantially elevates the level of confidence in the complete work and seamlessly supports Texas DOT and the FHWA's construction quality oversight and verification programs.

Yusuf, J., C.Y. Wallace, and M. Hackbart, *Privatizing Transportation Through Public-Private Partnerships: Definitions, Models, and Issues*," Research Report KTC-06-09/SPR302-05-2F, Kentucky Transportation Cabinet, Frankfurt, May 2006, 56 pp.

This report serves as a primer on PPPs for the delivery of transportation infrastructure and services. It provides an overview of the concept of PPPs, presenting a broad definition of the privatization approach, comparing it with contracting out, and discussing a theoretical framework for understanding why, when, and how partnerships are appropriate as a privatization strategy. The report also reviews six PPP models—DBB, private contract fee services, DB, DBOM or BOT, DBFO, and build-own-operate—identified by the FHWA as available for use by transportation agencies considering privatizing transportation projects.

Zocher, M.A., O.H. Paananen, and C. Sohn, "Cost Engineering Considerations in Privatization," *Cost Engineering*, Vol. 39, No. 5, 1997, p. 40.

The U.S. DOE is privatizing a major, complex portion of the Tank Waste Remediation System Program at the Hanford Nuclear Reservation located in eastern Washington State. Private companies will design, permit, construct, operate, and finally deactivate waste treatment facilities that will be owned entirely by the private sector. The DOE will purchase treated waste products from the facilities after supplying the vendors with waste from the tank farms at Hanford. This effort is discussed in this article from a cost engineering standpoint and describes the basic methods used and how cost engineers can contribute to the process.

Zweig-White Research, "Is Design-Build Due for an Increase" *The Zweig Letter*, Issue 551, 2004 [Online]. Available: http://www.zweigwhite.com/trends/thezweigletter/index.asp [Feb. 18, 2007].

An analysis of the future of DB.

APPENDIX B

Example Quality Assurance Plans

ARIZONA DEPARTMENT OF TRANSPORTATION MATRIX FOR CORTARO ROAD INTERCHANGE DESIGN-BUILD PROJECT

The matrix shown in Table B1 was extracted from a request for proposal (RFP) developed by the Arizona DOT (ADOT) for the Cortaro Road Interchange Project in 1997. It provides an example of how design-build (DB) responsibilities may be communicated in an RFP.

SAMPLE QUALITY MANAGEMENT PLAN OUTLINE

This appendix contains an outline of the general requirements of a DB quality management plan. The outline was drawn from the Virginia Department of Transportation (DOT) *Quality Control, Quality Assurance, Independent Assurance and Independent Verification Guide for Use on Public-Private Transportation Act & Design Build Projects,* with additional points of emphasis included by the authors. This is not intended to be an all-inclusive list, but a starting point for DOTs to develop DB quality management requirements for RFPs or to develop an acceptable sample plan for design-builders to use in preparing a project-specific plan in response to a contract requirement.

Design Quality Management Plan

General

The Quality Assurance (QA) and Quality Control (QC) procedures shall be organized by each type of engineering discipline (such as structural, civil, and utilities). These procedures shall specify measures to be taken by the Design-Builder (1) to ensure that appropriate quality standards are specified and included in the drawings, specifications, and other design submittals and to control deviations from such standards, it being understood and agreed that no deviations from such standards shall be made unless they have been previously approved by the Department at the Department's sole discretion; and (2) for the selection of suitability of materials and elements of the Work that are included in the Project.

All QA and QC procedures proposed by the Design-Builder for the design process shall be included in the QA/QC plan. This should include an organizational chart of who will perform each task and their firm, discipline, name, qualifications, duties, responsibilities, and authorities. All subcontractors shall be included in the plan. In addition, the design QA/QC plan should identify those elements of the contract, drawings, specifications, and other design submittals, if any, requiring special construction QA and/or QC attention or emphasis, including applicable standards of quality or practice to be met, level of completeness and/or extent of detailing required, or Special Provisions to the Road and Bridge Specifications.

Quality Control

The design QC plan shall include the level, frequency, and methods of the procedures or actions necessary to accomplish the following tasks:

1. Preparing all drawings
2. Checking math and engineering computations and other aspects of drawings
3. Reviewing of the technical accuracy of the plans
4. Reviewing the specifications
5. Ensuring that the plans conform to contract requirements
6. Checking the form, content, and spelling in plans
7. Reviewing coordination with other design disciplines
8. Reviewing designs for omissions
9. Reviewing the sequence of construction
10. Ensuring there will be no utility conflicts
11. Constructability reviews.

Quality Assurance

The Design QA plan shall include the level, frequency, and methods of the procedures or actions necessary to accomplish the following tasks:

1. Evaluating whether the designer addressed problem appropriately
2. Evaluating if the correct analyses were applied
3. Evaluating whether qualified, independent personnel were assigned to the QC tasks and stamped the drawings
4. Evaluating whether solutions are practical and cost-effective
5. Evaluating whether the design is within appropriate range based on past experience
6. Levels of DOT review and/or approval
7. Final, independent review.

Construction Quality Management Plan

General

The Design-Builder shall provide an organizational chart for all employees with specific QA or QC responsibilities. The chart shall indicate, by discipline, the name, qualifications, duties, responsibilities, authorities, and number of QA/QC employees. The plan should also include how QA/QC activities will be reflected in the project progress schedule. In addition, specific QA/QC measures that must be taken for specific activities or materials should be included in the plan.

TABLE B1
ARIZONA DOT RFP QUALITY RESPONSIBILITY MATRIX

Scope Item	Design/Builder	ADOT	Others
A. Aerial Mapping			
1. Photogrammetric control and panels	N/A		
2. Aerial photography	N/A		
3. Plotter compilation	N/A		
a. Planimetric map	N/A		
b. Contour	N/A		
c. Topographic map			X
d. Drainage area map	N/A		
e. Right-of-way map	N/A		
B. Control Surveys			
1. Horizontal		X	
2. Vertical		X	
3. Topographic map		N/A	
4. Utility locations		X	
5. Right-of-way		X	
6. Roadway cross sections		X	
7. Drainage cross sections		X	
8. Structures surveys		X	
C. Environmental			
1. Environmental analysis document			X
2. Air quality technical report			X
3. Noise analysis technical report		X	
4. Cultural resources recovery	X		
5. Public meeting			
a. Advertisement		X	
b. Presentation materials		X	
c. Moderator			X
d. Technical questions		X	
e. Transcript		N/A	
f. Responses to public comments		X	
g. Liability insurance		N/A	
D. Materials Investigation			
1. Provide soil survey	X		
a. Roadway	X		
b. Lateral ditches	X		
c. Earthwork	X		
d. Retention/detention ponds	X		
2. Bridge foundation investigation	N/A		
3. Provide testing and analysis	X		
4. Provide pavement design	X		
5. Materials memorandum	X		
E. Design Traffic Data			
1. Gather statistics	N/A		
a. Two-way ADT	N/A		
b. Turning movements	N/A		
c. Cross traffic	N/A		
2. Prepare traffic data sheets		X	
3. Prepare equivalent 18 kips	X		
4. Prepare traffic analysis			X
5. LOS analysis	X		
6. Composite traffic control device plan		X	
F. Right-of-Way			
1. Develop requirements			X
2. Secure title search			X
3. Prepare RN4 plans and legal descriptions			X
4. Prepare transfer documents			X
5. Provide appraisals			X
6. Negotiate right-of-way			X
7. Condemnation proceedings			X
8. Testify in court			X
9. RN cost estimates			X
10. Relocation assistance			X
11. Property management			X
12. Clearance letter			X

(*continued on next page*)

TABLE B1
(*Continued*)

Scope Item	Design/Builder	ADOT	Others
G. Construction Plans			
1. Plot design survey	X		
2. Basic roadway plans preparation	X		
3. Drainage design	X		
4. Bridge design	N/A		
5. Roadway lighting plans	X		
6. Traffic signal plans	X		
7. Signing and pavement marking plans	X		
8. Utility adjustment plans	X	X	
9. Maintenance of traffic requirements	X		
10. Landscape architectural design	X		
H. Utility and Railroad			
1. Utilities identification	X	X	
2. Submit railroad data	X		
3. Conduct utility predesign conference	X		
4. Secure utility adjustment plans	X		
5. Secure utility relocation schedule	X		
6. Secure utility agreements	X		
7. Process relocation schedule and agreement	X		
8. Clearance letter	N/A		
K. Cost Estimates			
1. Prepare construction cost estimates	X		
2. Prepare RN cost estimates		N/A	
L. Technical Specifications			
1. Roadway construction plans	X		
2. Signing and pavement markings	X		
3. Roadway lighting plans	X		
N. Post-Design Services			
1. Respond to questions on final design		X	
2. Review and approve shop drawings		X	
3. Provide contact person		X	
4. Provide post-construction design-build		X	
P. Reviews and Submittals			
1. Roadway construction plans review			X
2. Bridge construction plans review			N/A
3. Design concept report submittal			N/A
4. Environmental reports	X		N/A
5. Initial design submittal	N/A		
6. Preliminary design submittal	X		N/A
7. Final design submittal	X		
8. Final II design submittal	N/A		
9. As-built submittal	X		

Note: ADT = average daily traffic; LOS = level of service; N/A = not available.

Quality Control

All QC activities shall include a description of the procedures, frequencies, location, methods, and personnel used to perform the task and the required documentation for each task.

1. QC inspection requirements
2. QC testing requirements including laboratory(ies) used for each test
3. QC sampling, testing, and analysis plan that includes a description of how random locations for testing and sampling are determined
4. Process for reviewing shop drawings and submittals
5. Horizontal and vertical control
6. Load testing and integrity testing required to verify adequacy of the foundation capacity, soil reinforcement elements, or adequacy of ground stabilization.

Quality Assurance

All QA activities shall include a description of the procedures, frequencies, location, methods, and personnel used to perform the task and the required documentation for each task.

1. QA inspection requirements
2. QA testing requirements
3. Verification testing requirements
4. Procedures for correcting the QA/QC plan if it does not conform to DOT standards
5. Witness and hold points that allow the DOT to perform required tests and inspections
6. Reporting and correcting nonconforming work.

(From Virginia Department of Transportation, *Quality Control, Quality Assurance, Independent Assurance and Independent Verification Guide for Use on Public-Private Transportation Act & Design Build Projects*, Richmond, Mar. 28, 2007, 30 pp.)

APPENDIX C

General Survey Questionnaire and Reponses

This appendix presents the questionnaire and a summary of the detailed responses.

NCHRP Synthesis 38-01: Quality Assurance in Design-Build Projects

INTRODUCTION/BACKGROUND: *Transportation Research Circular E-C090* expresses the motivation for this synthesis as follows: "Design-build (DB) is gaining momentum in its use by transportation agencies. Comfortable with the quality management process used in design-bid-build, many agencies are seeking assurance that the quality level of the completed project with design-build is not compromised."

Thus, the intent of this synthesis is to capture the various ways in which quality assurance is handled in DB projects. The synthesis will identify different approaches and models, and best practices recognizing the differences in each of the different delivery methods. The synthesis will also address how the core principles of quality assurance can be satisfactorily addressed in design-build projects.

The purpose of this questionnaire is to identify how state highway agencies (SHAs) that have implemented DB have implemented with quality assurance (QA) programs in their DB projects and from that baseline, identify DB QA best practices for dissemination and use by SHAs that intend to implement DB procurement on future projects.

DEFINITIONS: The synthesis 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*)

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-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 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.).

Please e-mail, fax, or post this questionnaire by one of the following means:

Dr. Doug Gransberg, PE
University of Oklahoma
Construction Science
830 Van Vleet Oval, Room 162
Norman, OK 73026

Voice: 405-325-6092
Fax: 405-325-7558
E-mail: dgransberg@ou.edu

General Information:

1. U.S. state in which the respondent is employed:

DOTs That Have Done DB	Other Public Agency	Private Industry	DOTs That Have Not Done DB
AL, AK, AZ, CO, FL, GA, HI, IN, KY, LA, ME, MD, MI, MN, MO, MS, MT, NV, NH, NM, NY, NC, OH, OR, SC, TX, UT, VA, WA, WV, WI	CA, CO, MA, NJ, OR, UT	CA, CO, OK, TX	AR, CT, IA, ID, IL, KS, NE, ND, OK, TN, VT, WY

2. What type of organization do you work for? [If you check "consulting engineering firm," "construction contractor," "integrated DB firm," or "other," move to Question 11.]

State department of transportation	52
Other public transportation agency	6
Consulting engineering firm (primarily a designer)	0
Construction contractor (primarily a builder)	1
Integrated DB firm (internal ability to do both design and construction)	2
Other	2
Total	63

3. If you answered state DOT or Other Public Agency above, what group/section do you primarily work in?

	DOT	Other Public Agency	Total
Design group/section	6	0	6
Construction group/section	19	6	25
Operations group/section	0	0	0
Maintenance group/section	1	0	1
Design-build group/section	7	1	8
Materials group/section	0	0	0
Other	4	0	4
Total	37	7	44

4. Has your agency awarded a design-build project? [If your agency has not yet awarded a DB project, but either is in the process or plans to in the future, please continue the questionnaire.]

	DOT	Other Public Agency	Total
Yes	34	6	40
Not yet, but will in the future	6	0	6
No	20	0	20
Total	60	6	66

5. In what year did or will your agency award its first DB project?

DOT	Other Public Agency
1988, 1996 (3), 1997 (4), 1998 (5), 1999, 2000 (2), 2001 (5), 2002 (3), 2003 (2), 2004 (1), 2005 (2), 2006 (2), 2007 (2), legislation pending, not sure	1992, 1998 (1), 2000 (1), 2001 (2), 2004

6. How many DB projects has your agency awarded since then?

	DOT	Other Public Agency	Total
1–5 projects	19	6	25
5–10 projects	4	0	4
Greater than 10	9	0	9
Not applicable	7	0	7
Total	39	6	45

7. About what percentage of your agency's total number of projects do DB projects make up?

	DOT	Other Public Agency	Total
Less than 1%	24	0	24
2% to 5%	10	0	10
6% to 10%	0	1	1
11% to 25%	1	5	6
26% to 50%	0	0	0
Greater than 50%	0	0	0
Not applicable	5	0	5
Total	40	6	46

8. About what percentage of your agency's total construction budget do DB projects make up?

	DOT	Other Public Agency	Total
Less than 1%	8	0	8
2% to 5%	11	0	11
6% to 10%	6	1	7
11% to 25%	8	3	11
26% to 50%	1	1	2
Greater than 50%	0	1	1
Not applicable	5	0	5
Total	39	6	45

9. Has your agency reduced the number of professional engineers it employs as a direct result of implementing DB contracting?

	DOT	Other Public Agency	Total
Yes	1	0	1
No	38	6	44

If Yes, by what average percentage, 5%?

10. Did your agency implement DB contracting as a means to augment its existing workforce?

	DOT	Other Public Agency	Total
Yes	11	1	12
No	26	4	30
Not applicable/don't know	3	1	4
Total	40	6	46

11. What are the primary reasons for your organization's decision to use DB contracting? (Check all that apply.)

	DOT	Other Public Agency	Total
Augment existing workforce	9	1	10
Reduce schedule	28	6	34
Reduce costs	8	1	9
Establish costs earlier	8	5	13
Encourage innovation	22	5	27
Share or transfer risk	16	5	21
Other	11	0	11
Total	102	23	125

Public agency respondents should now go to the next section: "Design-Build Policy Information" located after Question 16. Private industry respondents continue here at Question 12.

12. How many DB transportation projects has your organization (i.e., consulting engineering, construction, or integrated DB firm) been involved in?

	Private Industry
1–5 projects	0
5–10 projects	1
Greater than 10	3
Not applicable	0
Total	4

13. About what percentage of your organization's total number of projects do DB transportation projects make up?

	Private Industry
Less than 1%	0
2% to 5%	0
6% to 10%	2
11% to 25%	1
26% to 50%	0
Greater than 50%	1
Not applicable	0
Total	4

14. About what percentage of your organization's total volume ($ value) do DB transportation projects make up?

	Private Industry
Less than 1%	0
2% to 5%	1
6% to 10%	0
11% to 25%	1
26% to 50%	1
Greater than 50%	1
Not applicable	0
Total	4

15. In which states has your organization participated in a DB transportation project? Please list:

CA, CO, FL, ID, MN, NY, NC, NV, OR, SC, SD, TX, UT, VA, WA, and others.

Design-Build Policy Information: The following questions will break up the design-build quality management process into the following three phases: • Procurement Phase: Actions taken regarding the quality management process that are reflected in the DB solicitation documentation such as in the Request for Qualifications (RFQ) and the Request for Proposals (RFP). • Design Phase: Actions taken after 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 design-builder's design or construction deliverable and is willing to make payment for satisfactory completion of that task if asked.

Procurement Phase: Agency respondents: please answer for your agency. Industry respondents: If you have observed differences between agencies, please answer the question with what you believe to be the most prevalent practice.

16. Does either the RFQ or the RFP require the following to be submitted as part of the design-build proposal?

State DOTs

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Qualifications of the DB Quality Manager	23	0	3	5
Qualifications of the Design Quality Manager	24	0	3	4
Qualifications of the Construction Quality Manager	22	1	4	4
Design quality management plan	17	1	10	3
Design quality assurance plan	14	2	11	4
Design quality control plan	13	2	12	3
Construction quality management plan	16	0	4	1
Construction quality assurance plan	13	0	13	5
Construction quality control plan	11	0	15	4

16. Does either the RFQ or the RFP require the following to be submitted as part of the design-build proposal?

Other Public Agencies

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Qualifications of the DB Quality Manager	6	0	0	0
Qualifications of the Design Quality Manager	5	0	0	1
Qualifications of the Construction Quality Manager	5	0	0	1
Design quality management plan	2	1	1	2
Design quality assurance plan	2	0	1	3
Design quality control plan	2	0	1	3
Construction quality management plan	3	1	1	1
Construction quality assurance plan	3	1	1	1
Construction quality control plan	3	1	1	1

16. Does either the RFQ or the RFP require the following to be submitted as part of the design-build proposal?

Private Industry

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Qualifications of the DB Quality Manager	2	1	1	0
Qualifications of the Design Quality Manager	2	1	1	0
Qualifications of the Construction Quality Manager	3	0	1	0
Design quality management plan	1	1	2	0
Design quality assurance plan	0	1	3	0
Design quality control plan	0	1	3	0
Construction quality management plan	1	1	2	0
Construction quality assurance plan	0	1	3	0
Construction quality control plan	0	1	3	0

17. Does either your RFQ or your RFP contain the following?

State DOTs

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Design criteria checklists	11	5	7	7
Construction testing matrix	9	3	10	9
Quality management roles and responsibilities	22	3	2	4

17. Does either your RFQ or your RFP contain the following?

Other Public Agencies

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Design criteria checklists	4	0	0	2
Construction testing matrix	1	1	1	3
Quality management roles and responsibilities	3	1	0	2

17. Does either your RFQ or your RFP contain the following?

Private Industry

	If Yes, it is required: Is it evaluated to make the DB award decision? Yes	If Yes, it is required: Is it evaluated to make the DB award decision? No	If No, it's not required: Is it required to be submitted after contract award? Yes	If No, it's not required: Is it required to be submitted after contract award? No
Design criteria checklists	0	0	3	1
Construction testing matrix	0	0	4	0
Quality management roles and responsibilities	2	0	2	0

Design Phase

18. Who *primarily* performs the following design quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility.] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

State DOTs

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of design deliverables	16	17	1	12	0
Checking of design calculations	8	23	1	8	0
Checking of quantities	7	17	8	6	5
Acceptance of design deliverables	11	8	2	9	0
Review of specifications	19	13	4	11	0
Approval of final construction plans and other design documents	29	4	2	3	0
Approval of progress payments for design progress	29	2	0	5	0
Approval of post-award design QM/QA/QC plans	28	3	0	7	1

18. Who *primarily* performs the following design quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility.] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

Other Public Agencies

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of design deliverables	2	2	0	5	0
Checking of design calculations	0	5	0	1	0
Checking of quantities	1	4	1	0	0
Acceptance of design deliverables	5	1	0	0	0
Review of specifications	0	2	0	4	0
Approval of final construction plans and other design documents	6	0	0	0	0
Approval of progress payments for design progress	6	0	0	0	0
Approval of post-award design QM/QA/QC plans	6	0	0	0	0

18. Who *primarily* performs the following design quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility.] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

Private Industry

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of design deliverables	1	3	0	1	0
Checking of design calculations	1	3	0	0	0
Checking of quantities	0	2	2	0	1
Acceptance of design deliverables	2	2	0	0	0
Review of specifications	0	4	0	0	0
Approval of final construction plans and other design documents	2	1	0	1	0
Approval of progress payments for design progress	2	0	2	1	0
Approval of post-award design QM/QA/QC plans	3	0	0	1	0

Construction Phase

19. Who *primarily* performs the following construction quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility.] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

State DOTs

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of construction shop drawings	6	24	9	12	0
Technical review of construction material submittals	18	12	10	10	0
Checking of pay quantities	19	5	7	11	2
Routine construction inspection	11	7	21	7	0
Quality control testing	6	9	23	7	0
Establishment of horizontal and vertical control on site	4	10	24	1	0
Verification/acceptance testing	21	1	5	14	0
Approval of progress payments for construction progress	30	2	0	7	0
Approval of construction post-award QM/QA/QC plans	29	2	1	9	3
Report of nonconforming work or punch list	27	6	9	9	0

19. Who *primarily* performs the following construction quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

Other Public Agencies

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of construction shop drawings	0	4	0	2	0
Technical review of construction material submittals	0	2	0	3	0
Checking of pay quantities	2	0	0	3	1
Routine construction inspection	0	0	5	1	0
Quality control testing	0	0	6	0	0
Establishment of horizontal and vertical control on site	0	0	6	0	0
Verification/acceptance testing	1	0	0	5	0
Approval of progress payments for construction progress	6	0	0	0	0
Approval of construction post-award QM/QA/QC plans	6	0	0	0	0
Report of nonconforming work or punch list	3	0	1	2	0

19. Who *primarily* performs the following construction quality management tasks? [If the task is shared between two or more of the following entities, check the one that has primary responsibility] [Note: Because some respondents indicated more than one response for this question, the authors decided to use a point system to calculate percentages used in the paper. Four points were possible for each answer. If only one answer was marked, four points were assigned. If all four possibilities were marked, one point was given to each category. This matrix only tabulates each time a response was marked and does not use the point system. Thus, percentages in this table will not match percentages in the paper.]

Private Industry

	Agency Personnel	Design-Builder's Design Staff	Design-Builder's Construction Staff	Agency-Hired Consultant	Does Not Apply
Technical review of construction shop drawings	0	4	0	0	0
Technical review of construction material submittals	1	2	1	0	0
Checking of pay quantities	2	0	1	0	1
Routine construction inspection	0	0	3	1	0
Quality control testing	0	0	3	1	0
Establishment of horizontal and vertical control on site	0	1	3	0	0
Verification/acceptance testing	1	0	1	2	0
Approval of progress payments for construction progress	3	0	1	0	0
Approval of construction post-award QM/QA/QC plans	3	1	0	1	0
Report of nonconforming work or punch list	1	0	1	2	0

Quality Management Planning: Please answer the following questions from a general perspective based on your experience. If you are an industry practitioner and have observed differences between agencies, please answer the question with what you believe to be the most prevalent practice.

20. Is the DB DESIGN QA/QC plan significantly different from the QA/QC plan used on traditional DBB construction projects?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	12	2	3	17
No	19	4	1	24
Total	31	6	4	41

If "yes," what is the major difference?
[Various answers were received.]

21. Is the DB CONSTRUCTION QA/QC plan significantly different from the QA/QC plan used on traditional design projects?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	17	2	3	22
No	14	4	1	19
Total	31	6	4	41

If yes, what is the major difference?
[Various answers were received.]

22. Is the DB design and construction QA/QC plan significantly different from the QA/QC plan used on traditional DB projects when the project is a public-private partnership or when an extended Maintenance Agreement is included?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	2	3	3	8
No	12	2	1	15
Total	14	5	4	23

If yes, what is the major difference?
[Various answers were received.]

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

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	26	5	3	34
Only on selected projects	0	0	1	1
No, never	3	1	0	4
Total	29	6	4	39

24. Does the agency mandate the use of its own standard QA/QC plans?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	8	2	0	10
Only on selected projects	6	0	3	9
No, never	15	4	1	20
Total	29	6	4	39

25. Does the agency mandate the use of standard agency design/construction specifications?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	26	2	1	29
Only on selected projects	2	0	3	5
No, never	0	3	0	3
Total	28	5	4	37

26. Does the agency mandate the use of standard agency design/construction details?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	22	1	2	25
Only on selected projects	6	0	1	7
No, never	1	5	1	7
Total	29	6	4	39

27. Does the agency mandate the use of standard agency construction means and/or methods?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	9	0	0	9
Only on selected projects	6	0	1	7
No, never	14	5	3	22
Total	29	5	4	38

28. Does the agency mandate a specific set of qualifications for the design-builder's quality management staff?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	22	2	3	27
Only on selected projects	1	0	1	2
No, never	7	3	0	10
Total	30	5	4	39

If yes or only, what are those qualifications?
[Various answers were received.]

29. Does the agency mandate a specific set of qualifications for the design-builder's *design* quality assurance staff?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	22	2	2	26
Only on selected projects	1	0	2	3
No, never	7	4	0	11
Total	30	6	4	40

If yes or only, what are those qualifications?
[Various answers were received.]

30. Does the agency mandate a specific set of qualifications for the design-builder's *construction* quality control staff?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes, on all projects	22	2	3	27
Only on selected projects	1	0	0	1
No, never	4	4	1	9
Total	27	6	4	37

If yes or only, what are those qualifications?
[Various answers were received.]

General:

31. Do you think that the agency holds the design-builder's design staff to a higher standard of care than it sets for its internal design staff?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	4	0	1	5
No	21	1	2	24
No opinion	5	5	0	10
Total	30	6	3	39

Comments:

There can be no doubt about this at all!
DB design staff holds themselves to a higher standard of care.
We held the DB team to the same standards that we would any consultant engineering firm or an internal designer developing a project.
High standard of documented care.

32. Do you think that the agency holds the design-builder's construction quality management staff to a higher standard of care than it sets for its internal construction inspection staff?

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	6	0	1	7
No	20	1	2	23
No opinion	3	5	0	8
Total	29	6	3	38

Comments:

QC/QA team holds itself to a higher standard of care.
[No], However, it seems DBs are struggling getting Construction QA and QC staff that meet our expectations.
The DB Team was held to the same standards of a normal contractor, even with the warranty provisions in the contract.
High standard of documented care.

33. Does your organization have a document that outlines its approach to design-build quality assurance? If yes and you would be willing to share it with this research project, please contact Dr. Doug Gransberg.

	State DOTs	Other Public Agencies	Private Industry	Total
Yes	16	1	3	20
No	14	5	1	20
Total	30	6	4	40

34. Which of the below best describes your agency's approach to DB QA?

	State DOTs	Other Public Agencies	Private Industry	Total
Design-builder primarily responsible for QA—the Agency audits design-builder's program	9	1	4	14
Agency retains traditional QA roles	6	1	0	7
Agency retains an independent party to perform QA roles	2	0	0	2
Agency uses two or more of the above depending on the project	14	4	0	18
None of the above	0	0	0	0
Total	31	6	4	41

35. What are the three biggest challenges to implementing QA on DB projects?

[Various answers were received.]

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

State DOTs

	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact	N/A
Qualifications of the design-builder's staff	12	14	3	0	0	0
Design-builder's past project experience	7	12	7	3	0	0
Quality management plans	4	12	11	1	0	0
Level of agency involvement in the QA process	5	18	6	0	0	0
Use of agency specifications and/or design details	8	12	5	3	1	0
Level of detail expressed in the procurement documents (RFQ/RFP)	6	11	10	1	0	0
Use of performance criteria/specifications	6	12	8	1	0	1
Detailed design criteria	4	17	6	1	0	0
Warranty provisions	5	7	7	5	0	4
Follow-on maintenance agreement	6	4	1	3	2	12
Design-builder financing (PPP/concession)	5	4	1	1	1	16

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

Other Public Agencies

	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact	N/A
Qualifications of the design-builder's staff	3	3	0	0	0	0
Design-builder's past project experience	3	3	0	0	0	0
Quality management plans	1	3	2	0	0	0
Level of agency involvement in the QA process	1	2	3	0	0	0
Use of agency specifications and/or design details	0	0	5	1	0	0
Level of detail expressed in the procurement documents (RFQ/RFP)	3	1	2	0	0	0
Use of performance criteria/specifications	0	5	1	0	0	0
Detailed design criteria	1	2	3	0	0	0

Warranty provisions	1	5	0	0	0	0
Follow-on maintenance agreement	1	1	0	0	0	4
Design-builder financing (PPP/concession)	0	0	1	0	0	5

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

Private Industry

	Very High Impact	High Impact	Some Impact	Slight Impact	No Impact	N/A
Qualifications of the design-builder's staff	3	0	1	0	0	0
Design-builder's past project experience	2	1	1	0	0	0
Quality management plans	1	2	0	1	0	0
Level of agency involvement in the QA process	0	2	1	1	0	0
Use of agency specifications and/or design details	0	2	2	0	0	0
Level of detail expressed in the procurement documents (RFQ/RFP)	2	2	0	0	0	0
Use of performance criteria/specifications	1	2	1	0	0	0
Detailed design criteria	2	0	2	0	0	0
Warranty provisions	1	0	1	1	1	0
Follow-on maintenance agreement	1	0	1	1	0	1
Design-builder financing (PPP/concession)	2	0	1	0	1	0

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

    [Various answers were received.]

38. If you are willing, please indicate the name of a point of contact that we may contact with possible questions on your answers to this survey.

    [Various answers were received.]

39. E-mail address for survey point of contact.

    [Various answers were received.]

40. Phone number for survey point of contact.

    [Various answers were received.]

APPENDIX D

Design-Build Solicitation Document (RFP/RFQ) Content Analysis

INTRODUCTION

This appendix presents a summary of the data collected in the RFP/RFQ content analysis.
Sixty-six projects were analyzed including 15 RFQs and 59 RFPs from projects carried out in the states or other agencies listed here:

AK, AZ, CA, CO, FL, IN, LA, MD, ME, MO, MN, MS, NC, NM, NV, OH, OR, SC, SD, TX, UT, VA, WA
Alberta, Washington, D.C., U.S.DOT

The projects may not have been performed by the state DOT. In some instances a different public agency was established to manage the project.

To understand the process of content analysis and how to interpret Table D1, the following paragraph contains necessary information:

Each row contains a word, phrase, or idea that was looked for in each of the documents. When the word or idea was found, the column was marked. In the tables, the states are listed by their two-digit U.S. postal code. The anomalies are as follows: ALB = Alberta, Canada; DC = Washington, D.C.; US = U.S.DOT. The years listed are the years that the RFP or RFQ was issued, not necessarily when the project was begun.

TABLE D1
CONSOLIDATED SOLICITATION DOCUMENT CONTENT ANALYSIS OUTPUT

State	66	AK1	ALB1	AZ1	CA1	CA2	CA3	CO1	DC1	DC2	FL1	FL2	FL3	FL4	FL5	FL6	FL7	FL8	IN1	LA1	MD1	ME1	ME2
Year	Total	1997	2004	1997	1994	1991	1998	2000	2002	2001	2000	2000	2000	2000	2003	2001	2000	2006	2000	2006	1998	1997	2003
RFQ	15	x		x	x	x			x														
RFP	59		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
RFQ Required	58	x	x	x	x	x	x	x	x	x		x	x		x	x		x					x
Independent Assurance	35			x		x					x			x	x	x	x	x					x
Qualifications of Independent Quality Firm	3																	x					
Qualifications of Other Independent Quality Firms	2																						
What Design Is Required in the Proposal	38		x	x			x	x		x	x	x	x		x		x	x				x	x
Identify Deviation from Standard Design	10			x																			
Design Criteria Listed	2			x										x									
Design and Construction Schedule in Proposal	26			x			x	x		x	x			x			x					x	
Construction Specs Referenced	50			x	x	x		x		x	x			x	x	x	x	x	x	x			x
Means and Methods Scored in Proposal	10						x				x	x	x		x			x				x	
Means and Methods Required After Award	2					x		x															
Design-Builder Has Control over Means and Methods	1																						
Quality Personnel in the Proposal	24	x				x	x		x	x													x
Quality Personnel After Award	15			x		x		x		x													x
Training Required of the Contractor	1							x															
Project QM Manager	20	x				x																	
What Qualifications Required for Project QM Manager	15																						
Project QC Manager	3																			x			
On-Site Project Construction QM Manager	2																						
Design QM Manager	18					x		x	x	x													x
Required Qualifications Listed	7								x														x
Construction QM Manager	19			x		x		x	x	x													
Required Qualifications Listed	12			x					x														
Design QC/QA Manager	7						x													x			
Required Qualifications Listed	4																						
Construction QC Manager	6						x													x			

(*continued on next page*)

TABLE D1
(*continued*)

State	66	AK1	ALB1	AZ1	CA1	CA2	CA3	CO1	DC1	DC2	FL1	FL2	FL3	FL4	FL5	FL6	FL7	FL8	IN1	LA1	MD1	ME1	ME2
Year	Total	1997	2004	1997	1994	1991	1998	2000	2002	2001	2000	2000	2000	2000	2003	2001	2000	2006	2000	2006	1998	1997	2003
Required Qualifications Listed	4																			x			
Construction QA Manager	2						x																
Required Qualifications Listed	1																						
Construction QA/QC Personnel Certification	25			x			x			x							x						x
Required Qualifications Listed	9						x																
Pre-award Project QA Plan	1																						
Pre-award Project QC Plan	2	x																					
Pre-award Project QM Plan	8		x								x	x				x							
Requirements of Plan Listed	3		x																				
Pre-award QA/QC Plan Summary	30	x		x		x	x			x					x			x		x			x
Requirements of Plan Listed	13	x		x						x										x			
Post-award QM Plan	8																						
Pre-award Design Quality Plan Draft	6							x															
Pre-award Construction Quality Plan Draft	6							x															
Pre-award Design Quality Plan	8																x					x	
Requirements of Plan Listed	5																					x	
Post-award Design Quality Plan	19							x		x				x	x	x	x	x		x			x
Requirements of Plan Listed	12							x		x				x	x	x							x
Post-award Design QC Plan	4			x		x																	
Post-award Design QA Plan	1					x																	
Requirements Listed for Design QC Plan	2																						
Pre-award Construction Quality Plan	10								x		x						x						
Requirements of Plan Listed	7										x												
Pre-award Construction QC Plan	1																					x	
Requirements of Plan Listed	1																					x	
Post-award Construction Quality Plan	13							x		x				x	x	x	x			x			x
Requirements of Plan Listed	8							x		x				x		x							x
Post-award Construction QC Plan	5			x		x												x					
Requirements of Plan Listed	1			x																			

(*continued on next page*)

TABLE D1
(*continued*)

State	66	AK1	ALB1	AZ1	CA1	CA2	CA3	CO1	DC1	DC2	FL1	FL2	FL3	FL4	FL5	FL6	FL7	FL8	IN1	LA1	MD1	ME1	ME2
Year	Total	1997	2004	1997	1994	1991	1998	2000	2002	2001	2000	2000	2000	2000	2003	2001	2000	2006	2000	2006	1998	1997	2003
Post-award Construction QA Plan	1					x																	
Requirements Listed Construction QC Plan	2																						
Design Quality Audits by DOT	1			x																			
Construction QA Responsibilities	6													x		x							x
Design Criteria Checklists	1			x																			
Construction Testing Matrix (testing responsibility chart)	2			x																			
Design Responsibility Matrix	2			x																			
QM Organization/Hierarchy Chart (quality responsibility chart)	27		x			x	x	x		x										x			x
Change in Key Personnel Must Be Approved by DOT	23			x				x		x				x	x	x	x	x					x
Owner Review/Approval of Post-award QM Plan	25					x		x		x					x	x	x						x
Design Phase	0																						
Technical Review of Design Deliverables	37		x	x	x	x		x		x	x			x	x	x	x	x		x			x
Checking of Design Calculations	29		x	x		x		x		x	x			x	x	x	x	x		x			x
Checking of Quantities	23		x	x		x		x		x	x			x	x	x		x					x
Levels of DOT Design Submittal Reviews	42			x		x		x		x	x			x	x	x		x		x			x
Acceptance of Design Deliverables	13			x				x			x												
Review of Specifications	24		x	x	x					x				x	x		x	x		x			x
Approval of Final Construction Plans and Other Design Documents	43			x		x		x		x	x			x	x	x	x	x		x			x
Approval of Progress Payments for Design Progress	7																						
Quality Report Necessary for Progress PMT	3																						
Approval of Post-award Design QM/QA/QC Plans	4					x																	
Construction Phase	0																						
Technical Review of Construction Shop Drawings	26			x	x	x		x		x	x			x	x	x	x	x					
Technical Review of Construction Material Submittals	5					x																	
Checking of Pay Quantities	3																						x

(*continued on next page*)

TABLE D1
(*continued*)

State	66	AK1	ALB1	AZ1	CA1	CA2	CA3	CO1	DC1	DC2	FL1	FL2	FL3	FL4	FL5	FL6	FL7	FL8	IN1	LA1	MD1	ME1	ME2
Year	Total	1997	2004	1997	1994	1991	1998	2000	2002	2001	2000	2000	2000	2000	2003	2001	2000	2006	2000	2006	1998	1997	2003
Routine Construction Inspection	40	x		x	x	x	x	x		x	x						x	x		x			x
Quality Control Testing	40	x		x		x	x	x		x	x			x	x	x	x			x			x
Establishment Horizontal and Vertical Control	42			x		x				x	x			x	x		x	x			x		x
Verification/Acceptance Testing	40	x		x	x	x		x		x				x	x	x	x	x					x
Approval of Progress Payments for Construction Progress	31					x				x	x			x									x
Quality Report Necessary for Progress Performance Management Team	5																	x					
Approval of Construction Post-award QM/QA/QC Plans	7									x													
Report of Nonconforming Work or Punch List	25					x		x												x			x
General	0																						
Design Company Had Past Experience with Specific Project Type	22	x		x					x		x										x		
Design Personnel Had Past Experience with Specific Project Type	18	x							x		x					x							
Contractor Company Had Past Experience with Specific Project Type	27	x		x	x	x			x		x					x			x		x		
Contractor Personnel Had Past Experience with Specific Project Type	23	x			x	x			x		x					x			x				
Design QA/QC Personnel with Experience	11	x				x				x													
Construction QA/QC Personnel with Experience	16	x		x		x																	
Follow Owner's Standard Design Specs (for road and bridge projects)	39			x	x					x	x			x	x	x	x	x					
Design QM Requirements Listed by Owner	4																						
Construction QM Requirements Listed by Owner	3																						
Extra Warranties = Extra Points	9														x	x							x
Warranties Required	39				x	x		x		x	x				x	x	x					x	x
Follow-on Maintenance	9	x			x																		
Design-Builder Financing	7		x		x														x				
Scoring Criteria	47	x		x				x	x	x	x	x			x	x	x	x					x

(*continued on next page*)

TABLE D1
(*continued*)

State	MO1	MN1	MN2	MN3	MS1	MS2	NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8	NM1	NV1	OH1	OH2	OH3	OH4	OH5	OR1	OR2
Year	2006	2001	2001	2001	2005	2005	2002	2002	2005	2006	2004	2006	2005	2005	2001	2001	2001	2001	2001	2001	2001	2002	2006
RFQ		x	x												x								x
RFP	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	
RFQ Required	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
Independent Assurance	x	x	x	x	x	x	x	x	x	x		x	x	x	x								x
Qualifications of Independent Quality Firm														x									
Qualifications of Other Independent Quality Firms														x									
What Design Is Required in the Proposal	x				x	x	x	x	x	x	x	x	x	x									
Identify Deviation from Standard Design							x	x	x	x			x										
Design Criteria Listed																							
Design and Construction Schedule in Proposal					x	x				x	x	x	x	x									
Construction Specs Referenced	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x		
Means and Methods Scored in Proposal																							
Means and Methods Required After Award																							
Design-Builder Has Control over Means and Methods																							
Quality Personnel in the Proposal	x		x		x	x									x	x							x
Quality Personnel After Award		x	x																				
Training Required of the Contractor																							
Project QM Manager	x						x	x	x	x	x	x	x	x									x
What Qualifications Required for Project QM Manager	x						x	x	x	x	x	x	x	x									x
Project QC Manager					x	x																	
On-Site Project Construction QM Manager																							
Design QM Manager		x	x	x												x							
Required Qualifications Listed			x																				
Construction QM Manager		x	x	x												x							
Required Qualifications Listed			x	x																			
Design QC/QA Manager					x	x																	
Required Qualifications Listed					x	x																	
Construction QC Manager					x	x																	

(*continued on next page*)

TABLE D1
(*continued*)

State	MO1	MN1	MN2	MN3	MS1	MS2	NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8	NM1	NV1	OH1	OH2	OH3	OH4	OH5	OR1	OR2
Year	2006	2001	2001	2001	2005	2005	2002	2002	2005	2006	2004	2006	2005	2005	2001	2001	2001	2001	2001	2001	2001	2002	2006
Required Qualifications Listed					x	x																	
Construction QA Manager																							
Required Qualifications Listed																							
Construction QA/QC Personnel Certification	x	x		x	x	x		x	x	x	x	x	x	x									
Required Qualifications Listed					x	x					x	x	x	x									
Pre-award Project QA Plan																							
Pre-award Project QC Plan																							
Pre-award Project QM Plan																							
Requirements of Plan Listed																							
Pre-award QA/QC Plan Summary					x	x	x	x	x	x	x	x	x	x									
Requirements of Plan Listed							x	x	x	x	x	x	x	x									
Post-award QM Plan	x																						x
Pre-award Design Quality Plan Draft			x																				
Pre-award Construction Quality Plan Draft			x																				
Pre-award Design Quality Plan				x																			
Requirements of Plan Listed				x																			
Post-award Design Quality Plan		x	x												x								
Requirements of Plan Listed		x	x																				
Post-award Design QC Plan					x	x																	
Post-award Design QA Plan																							
Requirements Listed for Design QC Plan					x	x																	
Pre-award Construction Quality Plan		x		x																			
Requirements of Plan Listed		x		x																			
Pre-award Construction QC Plan																							
Requirements of Plan Listed																							
Post-award Construction Quality Plan			x												x								
Requirements of Plan Listed			x																				
Post-award Construction QC Plan					x	x																	
Requirements of Plan Listed																							

(*continued on next page*)

TABLE D1
(*continued*)

State	MO1	MN1	MN2	MN3	MS1	MS2	NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8	NM1	NV1	OH1	OH2	OH3	OH4	OH5	OR1	OR2
Year	2006	2001	2001	2001	2005	2005	2002	2002	2005	2006	2004	2006	2005	2005	2001	2001	2001	2001	2001	2001	2001	2002	2006
Post-award Construction QA Plan																							
Requirements Listed Construction QC Plan					x	x																	
Design Quality Audits by DOT																							
Construction QA Responsibilities					x	x																	
Design Criteria Checklists																							
Construction Testing Matrix (testing responsibility chart)																							
Design Responsibility Matrix																							
QM Organization/Hierarchy Chart (quality responsibility chart)		x	x	x	x	x									x								x
Change in Key Personnel Must Be Approved by DOT	x	x			x	x	x	x	x	x	x	x	x	x									
Owner Review/Approval of Post-award QM Plan	x	x	x	x											x								x
Design Phase																							
Technical Review of Design Deliverables	x	x	x		x	x											x	x	x	x	x		x
Checking of Design Calculations	x	x	x		x	x																	x
Checking of Quantities	x				x	x																	x
Levels of DOT Design Submittal Reviews		x	x		x	x	x	x	x	x	x	x	x	x			x	x	x	x	x		
Acceptance of Design Deliverables		x			x	x																	
Review of Specifications		x	x		x	x																	
Approval of Final Construction Plans and Other Design Documents	x	x	x		x	x	x	x	x	x		x	x	x			x	x	x	x	x		
Approval of Progress Payments for Design Progress					x	x																	
Quality Report Necessary for Progress PMT					x	x																	
Approval of Post-award Design QM/QA/QC Plans					x	x																	
Construction Phase																							
Technical Review of Construction Shop Drawings		x	x														x	x			x		
Technical Review of Construction Material Submittals					x	x																	
Checking of Pay Quantities					x	x																	

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TABLE D1
(*continued*)

State	MO1	MN1	MN2	MN3	MS1	MS2	NC1	NC2	NC3	NC4	NC5	NC6	NC7	NC8	NM1	NV1	OH1	OH2	OH3	OH4	OH5	OR1	OR2
Year	2006	2001	2001	2001	2005	2005	2002	2002	2005	2006	2004	2006	2005	2005	2001	2001	2001	2001	2001	2001	2001	2002	2006
Routine Construction Inspection	x	x	x		x	x	x	x	x	x	x	x	x	x									x
Quality Control Testing	x	x	x		x	x	x	x	x	x	x	x	x	x									
Establishment Horizontal and Vertical Control			x		x	x	x	x	x	x	x	x	x	x			x	x	x	x	x		
Verification/Acceptance Testing	x	x	x		x	x	x	x	x	x	x	x	x	x									x
Approval of Progress Payments for Construction Progress	x		x		x	x	x	x	x	x	x	x	x	x					x	x	x		
Quality Report Necessary for Progress Performance Management Team					x	x																	
Approval of Construction Post-award QM/QA/QC Plans			x		x	x																	
Report of Nonconforming Work or Punch List	x		x		x	x	x	x	x	x	x	x	x	x									
General																							
Design Company Had Past Experience with Specific Project Type		x	x												x	x						x	x
Design Personnel Had Past Experience with Specific Project Type	x	x	x												x	x						x	
Contractor Company Had Past Experience with Specific Project Type		x	x												x	x						x	x
Contractor Personnel Had Past Experience with Specific Project Type	x	x	x				x								x	x						x	
Design QA/QC Personnel with Experience		x			x	x										x							
Construction QA/QC Personnel with Experience	x	x			x	x										x							
Follow Owner's Standard Design Specs (for road and bridge projects)	x	x	x	x	x	x	x	x	x	x	x	x	x	x									
Design QM Requirements Listed by Owner		x																					
Construction QM Requirements Listed by Owner		x													x								
Extra Warranties = Extra Points									x	x	x	x	x	x									
Warranties Required	x	x	x	x	x	x		x	x	x	x	x	x	x			x	x		x	x		
Follow-on Maintenance									x														
Design-Builder Financing																							
Scoring Criteria	x	x	x		x	x	x	x	x	x	x	x	x	x		x						x	x

(*continued on next page*)

TABLE D1
(*continued*)

State	SC1	SD1	TX1	TX2	TX3	TX4	US1	UT1	UT2	UT3	UT4	UT5	VA1	VA2	VA3	VA4	VA5	WA1	WA2	WA3	WA4		
Year	1997	2000	2001	2007	2006	2007	2001	1997	2004	2004	2004	2005	2000	2002	2006	2006	2006	2000	2004	2002	2004		
RFQ	x			x	x	x							x	x									
RFP	x	x	x	x			x	x	x	x	x	x		x	x	x	x	x	x	x	x		
RFQ Required	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Independent Assurance		x	x	x				x			x			x	x	x	x	x	x				
Qualifications of Independent Quality Firm				x																			
Qualifications of Other Independent Quality Firms								x															
What Design Is Required in the Proposal	x	x	x	x			x	x	x		x	x			x	x	x	x	x				
Identify Deviation from Standard Design		x					x				x								x				
Design Criteria Listed																							
Design and Construction Schedule in Proposal	x	x		x			x	x				x		x	x	x	x				x		
Construction Specs Referenced	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Means and Methods Scored in Proposal		x							x					x									
Means and Methods Required After Award																							
Design-Builder Has Control over Means and Methods												x											
Quality Personnel in the Proposal			x	x				x	x	x	x		x		x	x	x				x		
Quality Personnel After Award		x	x				x	x	x		x							x	x				
Training Required of the Contractor																							
Project QM Manager				x			x				x				x	x	x	x			x		
What Qualifications Required for Project QM Manager															x	x	x	x			x		
Project QC Manager																							
On-Site Project Construction QM Manager								x						x									
Design QM Manager							x	x	x	x		x		x				x	x		x		
Required Qualifications Listed								x										x	x		x		
Construction QM Manager			x				x	x	x		x		x	x				x	x		x		
Required Qualifications Listed			x					x	x				x	x				x	x		x		
Design QC/QA Manager		x	x																x				
Required Qualifications Listed		x	x																				
Construction QC Manager		x	x																				

(*continued on next page*)

TABLE D1
(*continued*)

State	SC1	SD1	TX1	TX2	TX3	TX4	US1	UT1	UT2	UT3	UT4	UT5	VA1	VA2	VA3	VA4	VA5	WA1	WA2	WA3	WA4		
Year	1997	2000	2001	2007	2006	2007	2001	1997	2004	2004	2004	2005	2000	2002	2006	2006	2006	2000	2004	2002	2004		
Required Qualifications Listed			x																				
Construction QA Manager			x																				
Required Qualifications Listed			x																				
Construction QA/QC Personnel Certification			x					x			x			x	x	x	x		x				
Required Qualifications Listed			x					x															
Pre-award Project QA Plan														x									
Pre-award Project QC Plan														x									
Pre-award Project QM Plan								x			x							x	x				
Requirements of Plan Listed											x							x					
Pre-award QA/QC Plan Summary	x			x			x	x	x				x	x	x	x	x				x		
Requirements of Plan Listed				x																			
Post-award QM Plan								x	x						x	x	x				x		
Pre-award Design Quality Plan Draft			x												x	x	x						
Pre-award Construction Quality Plan Draft			x												x	x	x						
Pre-award Design Quality Plan	x	x										x						x	x				
Requirements of Plan Listed		x																x	x				
Post-award Design Quality Plan			x				x	x		x					x	x	x						
Requirements of Plan Listed			x				x	x		x													
Post-award Design QC Plan																							
Post-award Design QA Plan																							
Requirements Listed for Design QC Plan																							
Pre-award Construction Quality Plan	x	x								x								x	x				
Requirements of Plan Listed		x								x								x	x				
Pre-award Construction QC Plan																							
Requirements of Plan Listed																							
Post-award Construction Quality Plan			x				x	x															
Requirements of Plan Listed							x	x															
Post-award Construction QC Plan																							
Requirements of Plan Listed																							

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TABLE D1
(*continued*)

State	SC1	SD1	TX1	TX2	TX3	TX4	US1	UT1	UT2	UT3	UT4	UT5	VA1	VA2	VA3	VA4	VA5	WA1	WA2	WA3	WA4		
Year	1997	2000	2001	2007	2006	2007	2001	1997	2004	2004	2004	2005	2000	2002	2006	2006	2006	2000	2004	2002	2004		
Post-award Construction QA Plan																							
Requirements Listed Construction QC Plan																							
Design Quality Audits by DOT																							
Construction QA Responsibilities														x									
Design Criteria Checklists																							
Construction Testing Matrix (testing responsibility chart)														x									
Design Responsibility Matrix														x									
QM Organization/Hierarchy Chart (quality responsibility chart)		x	x	x			x	x	x		x			x	x	x	x	x	x				
Change in Key Personnel Must Be Approved by DOT						x										x							
Owner Review/Approval of Post-award QM Plan		x					x	x	x	x				x	x	x	x	x	x		x		
Design Phase																							
Technical Review of Design Deliverables		x	x				x	x	x	x	x	x		x				x	x		x		
Checking of Design Calculations		x	x				x	x	x	x	x	x						x	x				
Checking of Quantities		x	x				x	x	x	x								x	x				
Levels of DOT Design Submittal Reviews		x	x				x	x	x	x	x	x			x	x	x	x	x		x		
Acceptance of Design Deliverables			x								x	x		x	x	x	x						
Review of Specifications		x	x				x	x	x	x	x	x						x	x				
Approval of Final Construction Plans and Other Design Documents		x	x				x	x	x	x	x	x		x	x	x	x	x	x				
Approval of Progress Payments for Design Progress								x				x			x	x	x						
Quality Report Necessary for Progress PMT											x												
Approval of Post-award Design QM/QA/QC Plans			x																				
Construction Phase																							
Technical Review of Construction Shop Drawings		x	x				x	x	x		x	x		x					x		x		
Technical Review of Construction Material Submittals														x				x					

(*continued on next page*)

TABLE D1
(*continued*)

State	SC1	SD1	TX1	TX2	TX3	TX4	US1	UT1	UT2	UT3	UT4	UT5	VA1	VA2	VA3	VA4	VA5	WA1	WA2	WA3	WA4		
Year	1997	2000	2001	2007	2006	2007	2001	1997	2004	2004	2004	2005	2000	2002	2006	2006	2006	2000	2004	2002	2004		
Checking of Pay Quantities																							
Routine Construction Inspection		x	x				x	x	x	x	x	x		x	x	x	x	x	x				
Quality Control Testing		x	x				x	x	x	x	x	x		x	x	x	x	x	x				
Establishment Horizontal and Vertical Control		x	x				x	x	x	x	x	x		x	x	x	x	x	x	x	x		
Verification/Acceptance Testing		x	x				x	x	x	x	x	x		x	x	x	x	x	x				
Approval of Progress Payments for Construction Progress			x				x	x		x	x	x		x	x	x	x	x					
Quality Report Necessary for Progress PMT								x											x				
Approval of Construction Post-award QM/QA/QC Plans			x				x												x				
Report of Nonconforming Work or Punch List			x					x		x	x				x	x	x		x		x		
General																							
Design Company Had Past Experience with Specific Project Type	x	x		x	x	x							x	x		x	x			x	x		
Design Personnel Had Past Experience with Specific Project Type	x				x								x	x		x	x	x		x			
Contractor Company Had Past Experience with Specific Project Type	x	x		x	x	x							x	x	x	x	x			x	x		
Contractor Personnel Had Past Experience with Specific Project Type	x				x								x	x	x	x	x	x		x			
Design QA/QC Personnel with Experience								x			x							x	x				
Construction QA/QC Personnel with Experience		x					x	x	x		x			x				x	x				
Follow Owner's Standard Design Specs (for road and bridge projects)	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x				
Design QM Requirements Listed by Owner		x										x							x				
Construction QM Requirements Listed by Owner																			x				
Extra Warranties = Extra Points																							
Warranties Required		x					x		x	x	x	x		x	x	x	x	x	x				
Follow-on Maintenance			x	x	x	x		x													x		
Design-Builder Financing			x	x	x																x		
Scoring Criteria	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		

APPENDIX E

Department of Transportation Design-Build Policy Document Content Analysis

INTRODUCTION

This appendix presents a summary of the data collected in the DOT DB guideline content analysis. Each row contains a phrase or idea that was looked for in each of the documents. When the word or idea was found, the column was marked.

DESIGN-BUILD POLICY DOCUMENT CONTENT ANALYSIS

The DB guideline content analysis is the combination of 17 DB guidelines shown in Table E1 from the DOTs as follows: AK, AR, AZ, CO, FL, KS, MA, MN, MT, NC, NY, OH, SD, TX, UT, VA, and WA.

This content analysis identified specific quality control/quality assurance criteria mentioned in the DB guidelines. It was performed as the RFP/RFQ content analysis outlined in Appendix D, except that it was not as detailed. For the most part, the DB guidelines are not comprehensive documents but general rules to be followed for DB projects in the specific states.

It is interesting to note that two of the states, Arkansas and Kansas, from which guidelines were found, reported that they did not use DB in the general survey. New York reported that it would be using it in the future. Therefore, these guidelines were treated as untested during the final analysis.

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Virginia Department of Transportation Innovative Project Delivery Division, *Design-Build Procurement Manual*, Nov. 12, 2004, revised June 30, 2006 (draft format), Richmond, 2006.

Washington State Department of Transportation, *Guidebook for Design-Build Highway Project Development*, Olympia, June 20, 2004.

TABLE E1
DESIGN-BUILD POLICY DOCUMENT CONTENT ANALYSIS RESULTS

Criteria	No.	States That Included Design-Build Guidelines
Design in RFP (DOT furnished design)	13	AR, AZ, CO, FL, MA, MT, NY, NC, OH, SD, UT, VA, WA
What Design Is Required in the Proposal (proposal design submittal) (design-builder furnished design)	14	AR, AZ, CO, FL, KS, MA, MT, NY, NC, SD, TX, UT, VA, WA
Bridge Project Requirements	8	CO, FL, KS, MT, NY, OH, UT, WA
Roadway Project	8	CO, FL, KS, MT, NY, OH, UT, WA
Traffic Control	11	AR, CO, FL, MT, NY, NC, OH, SD, TX, VA, WA
Railroad	9	AZ, FL, KS, MT, NY, NC, OH, UT, WA
Utilities As-Builts	9	AR, AZ, CO, FL, MT, NY, NC, OH, WA
Permits	10	AR, AZ, CO, FL, MT, NY, NC, OH, VA, WA
Survey Requirements	13	AR, AZ, CO, FL, MA, MT, NY, NC, OH, SD, TX, UT, WA
Design Plans and Engineering Calculations Verification of Contract Compliance	10	AR, AZ, FL, MN, MT, NY, NC, TX, UT, WA
Design Plans and Engineering Calculations Approval	0	
Design/Construction Standard Specifications	12	AR, AZ, CO, FL, KS, MA, MT, NY, NC, TX, VA, WA
Design Review (DB, DOT, or 3rd party)	13	AR, AZ, FL, KS, MA, MN, MT, NY, SD, TX, UT, VA, WA
Request For Qualification (RFQ)	16	AR, AZ, CO, FL, KS, MA, MN, MT, NY, NC, OH, SD, TX, UT, VA, WA
QA/QC Plan Included in Proposal	11	AR, AZ, CO, FL, MA, MN, NY, TX, UT, VA, WA
After Award of Contract	0	
Construction QC Responsibility	6	CO, FL, KS, NC, TX, WA
Construction QA Responsibility	7	CO, FL, KS, NY, NC, TX, WA
Quality Construction	4	MN, NY, UT, VA
Design QC Responsibility	2	CO, WA
Design QA Responsibility	3	CO, NY, WA
Quality Design	5	AZ, MA, MN, UT, VA
Quality Assurance (QA)	7	AR, MA, MN, MT, UT, VA, WA
Quality Control (QC)	6	AR, AZ, MA, MN, NY, UT
Independent Assurance	10	AR, AZ, FL, MA, MN, MT, NY, NC, TX, WA
Verification/Acceptance	11	AR, AZ, FL, KS, MA, MN, MT, NC, UT, VA, WA
Quality Personnel Required	8	AZ, CO, MA, MN, NY, TX, VA, WA
Qualifications Listed	4	MA, MN, TX, WA
Progress Payments	14	AR, AZ, CO, FL, KS, MA, MN, MT, NY, NC, OH, UT, VA, WA
Consulting Firm	10	AZ, CO, FL, KS, MA, MT, NY, OH, VA, WA
Warranties	9	AR, CO, FL, MT, NY, TX, UT, VA, WA

APPENDIX F

Design-Build Perceptions Survey

Objective: The objective of this survey is to measure the *perceived* impact of implementing design-build contracting on Quality Assurance activities performed by the public workforce. The results will be compared with measured impacts gained from another survey of state DOTs that have implemented design-build contracting. Perceptions are important in public procurement policy implementation as they often form a motivation for implementation or a major barrier to change.

Please answer the following questions based on how you perceive the impact of implementing design-build project delivery on project quality.

In what U.S. state are you employed? AK, CA, CO, DC, IA, IL, MA, MD, MN, NC, NV, OK, PA, TX, UT, VA, WA.

What is your job ☐ Public employee ☐ Private industry? (If responding from the private industry perspective, please answer the following questions based on your perception of what is happening to a typical public agency with which you are familiar.)

1. Did implementing design-build cause your agency to reduce the number of professional engineers employed by your agency?
   ☐ Yes ☐ No ☐ Not applicable

   Responses

Yes	No	Not Applicable
8.7%	65.2%	26.1%

2. Do you feel that implementing design-build project delivery would cause your agency to change the number of professional engineers it requires?
   ☐ Yes, we will need more ☐ Yes, we will need less ☐ No change is expected

   Responses

Yes/More	Yes/Less	No Change
21.7%	30.4%	43.5%

3. Do you feel that implementing design-build project delivery will change the roles that professional engineers employed by your agency would play? Check all that apply.

   ☐ Yes, we will do less in-house design and more design review
   ☐ Yes, we will do less construction inspection and more construction oversight
   ☐ No change is expected
   ☐ No opinion

   Responses

Yes/Design	Yes/Construction	No Change	No Opinion
60.9%	60.9%	26.1%	4.3%

4. Do you believe that design-build project delivery has an impact on the quality of the project?
   ☐ Yes, its better ☐ Yes, its worse ☐ No change ☐ Don't know

   Responses

Yes/better	Yes/worse	No Change	Don't Know
47.8%	4.3%	30.4%	17.4%

5. Who should have the majority of the responsibility for quality assurance in a design-build project?
   ☐ The public agency ☐ The design-builder
   ☐ No opinion ☐ It should be shared by the agency and the design-builder

   Responses

Agency	Design-Builder	No Opinion	Shared
21.7%	30.4%	0%	47.8%

6. Please write any comments that you feel would be helpful to this research.

Various responses were received, including the following:

- DB contractors are successful if best value selection is used regardless of who undertakes QA.
- Need DB contractor buy-in.
- DB changes roles and level of owner QA involvement is not yet clear.
- Skill set of agency engineers needs to change to manage DB effectively.
- DB reduces amount of conventional design done in-house.
- GEC in DB needs more senior staff for oversight.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation