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IMPLEMENTATION OF QUALITY CONTROL PLANS FOR ALTERNATIVE CONTRACTING METHODS IN HIGHWAY PROJECTS

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ABSTRACT: Quality control (QC) is an essential component of quality assurance (QA) programs used to manage the quality of highway construction projects. As state departments of transportation (DOTs) are increasingly implementing alternative contracting methods (ACMs), including design-build, construction manager/general contractor, and public-private partnerships, it is important to consider the impact of shifting more responsibility to the contractor on quality management activities, including developing and monitoring QC plans throughout the project development. The objective of this paper is to investigate the implementation of QC plans for administering QA specifications in highway infrastructure projects delivered using ACMs. The data collected from a survey questionnaire of 50 state DOTs in the U.S. was employed to investigate this research's objective. The result of this study shows that most state DOTs confirmed there was no difference in requirements for QC plans between ACMs and the traditional design-bid-build delivery method in terms of certifications/qualifications for QC personnel, and process control. However, the roles and responsibilities between contractors and agencies regarding QC plans and acceptance decisions in ACM projects were not clearly defined. This paper contributes to the body of knowledge by providing current practices of the highway agency's use of QC plans for administering their QA specifications in ACM projects. This paper sheds light on the consideration of the optimal roles and responsibilities of agencies and contractors to manage QA activities and QC plans in ACM projects to help state DOTs allocate risk to ensure quality work is performed.

1. INTRODUCTION

State departments of transportation (DOTs) are responsible for managing the quality of completed transportation projects as a measurement of the DOT's performance in investing tax revenue in improving the state's infrastructure (Tran et al. 2022). Therefore, state DOTs have devoted major attention and resources to construction quality management, including quality assurance (QA) measures designed to control and verify construction, material, and product quality. The Title 23 Code of Federal Regulations Part 637 Subpart B – Quality Assurance Procedures for Construction (CFR 2007) requires all state DOTs to have a QA program to ensure that the materials and workmanship incorporated into each federal-aid highway-construction project on the National Highway System (NHS) conform to the requirements of the approved plans and specifications, including approved changes. As a result, QA programs have been developed and implemented by state DOTs and federal transportation agencies across the country (FHWA 2016). A QA program consists of planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service or make sure the quality of a product is what it should

be (TR Circular 2018). The development of QA programs is an evolutionary process, and the form and elements of QA programs vary among state DOTs. A generic QA program often includes six core elements: contractor quality control (QC), agency acceptance, independent assurance, dispute resolution, personnel qualification, and laboratory accreditation/qualification (Hughes 2005).

The QC process is specified by the agency for a contractor to monitor, assess and adjust their production or placement processes to ensure that the final product will meet the specified level of quality (TR Circular 2018). To comply with the QC process, contractors prepare a project-specific document, namely QC plan, which identifies all QC personnel and procedures that will be used to maintain all production and placement processes under control and meet the agency specification requirements. The document also addresses actions to be taken in the event that a process goes out of control (TR Circular 2018).

In the past two decades, the growing use of alternative contracting methods (ACMs), including design-build (DB), construction manager/general contractor (CM/GC), and public-private partnerships (P3), has created a new environment for state DOTs to manage the quality of transportation projects (Tran et al. 2022). The roles of state DOTs and contractors in quality-management systems are changing (Molenaar et al. 2015a). For example, under the traditional design-bid-build (DBB) delivery method or a CM/GC agreement, the agency-dominated system is mainly responsible for quality management. Under DB or P3 agreements, the responsibility for quality management is shared to varying degrees between the contractor and the state DOT (Caltrans 2015; FHWA 2012). The implementation of ACMs challenged the traditional quality-management approach where the contractor performed QC while the state DOT conducted QA (Scott et al. 2017). This challenge affects the efficiency of conducting the QA program and the development of QC plans in highway construction projects. A research gap exists regarding the consideration of the impact of shifting more responsibility to the contractor on quality management activities, including developing and monitoring QC plans throughout the project development. The objective of this paper is to investigate the implementation of QC plans for administering QA specifications in highway infrastructure projects delivered using ACMs.

2. BACKGROUND

This section summarizes the overview of QA programs in highway construction projects that implemented ACMs, including DB, CM/GC, and P3.

2.1 Overview of QA for DB Projects

One of the main characteristics of DB project delivery is that the design and construction are performed under one contract by the same entity (i.e., the design-builder) (AASHTO 2008). This single source of responsibility for both design and construction in DB projects is the key difference to quality management between DB and DBB projects. The management of quality in the DB project is of utmost importance and requires that a DOT contemplating the use of a DB project delivery prepare a thorough and thoughtful approach to communicate 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 (Gransberg et al. 2008). The DB project delivery system offers several documented benefits over the traditional DBB method on certain projects. While DB offers the design-builder more control over design, materials, and construction methods than DBB, the agency still has an important role in assuring quality (Tran et al. 2022). As agencies develop DB procurement documents, it is important that roles and responsibilities for design-builder QC and agency acceptance be clearly defined (Gransberg et al. 2008). The responsibility for acceptance by the agency (or their designated agent) is applicable regardless of the project delivery method used (FHWA 2012). FHWA (2012) also indicated that, in DB projects, the responsibilities of the design-builder and the contracting agency must be clearly defined when preparing the request for proposal (RFP). There are several QA models for DB projects, including assurance QA, variable QA, and oversight QA models (Molenaar et al. 2015b). Kraft et al. (2015) found that the oversight QA model is the most feasible for DB projects. In the oversight QA model, the agency's role is to ensure that both the designer and contractor QA plans are effective at meeting the agency's quality requirements and that the plans are being

implemented (Kraft et al. 2015). Accordingly, the design-builder is responsible for all QC and acceptance of the project (Molenaar et al. 2015b).

Several state DOTs have developed QA guidance for their DB projects (TxDOT 2017; CDOT 2020). For example, Texas DOT (TxDOT) has used its QA program to provide statewide consistency, and a programmatic approach to QA for DB projects where the design-builder (i.e., DB contractor) test results are used in the acceptance decision regardless of how the project is funded (TxDOT 2017). TxDOT noted that the design-builder in DB projects establishes a systematic QC plan to define processes, methods, and documentation for the delivery of QC. The plan clearly defines the authority and responsibility for the administration of QC to ensure that the work is delivered in accordance with the contract documents (TxDOT 2017). Recently, Colorado DOT (CDOT) has developed a QA program for its DB projects. CDOT's QA program consists of a QC program, an owner-acceptance program, and an independent assurance program (CDOT 2020). CDOT noted that project management and quality management require some adjustment to address the shift in responsibility from the owner to the design-builder, but the fundamental principles of QA must remain in DB projects (CDOT 2020). CDOT's QA program for DB projects allows for the use of the contractor's performed test results, referred to as independent contractor quality control, as part of an acceptance decision if those results are validated by the owner verification testing results performed by a representative for CDOT (CDOT 2020).

2.2 Overview of QA for CM/GC Projects

Through an analysis of federal projects, Uhlik et al. (1999) showed that CM/GC project delivery provides two main features that help enhance the project quality: (1) a system of checks and balances exists between design and construction, and (2) input on quality is provided during design by a construction expert. The FHWA Every-Day-Counts (EDC-2) report indicated that one of the main benefits of CM/GC project delivery is improved design quality (FHWA 2014). Specifically, in CM/GC construction projects, the contractor is able to review the designs and provide feedback, provide answers to designer questions, and make changes accordingly. The contractor's review and feedback can support the designer in producing better designs, reduce issues during the construction process, and prevent any change orders that can lead to cost and schedule overruns (FHWA 2014).

The construction quality management of CM/GC projects does not differ greatly from traditional DBB projects because the owner still occupies the same contractual position with respect to the designer and builder (Molenaar et al. 2015b). Several state DOTs have directly applied their QA program for DBB projects to CM/GC projects with little alteration. For example, California DOT (Caltrans) developed its construction QA program manual that is applied to both DBB and CM/GC projects (Caltrans 2015). The Caltrans manual highlighted the role of the QA program, in DBB projects and projects under a CM/GC agreement, in providing confidence that the quality of the materials and workmanship incorporated into highway construction projects conforms to the requirements of the plans and specifications (Caltrans 2015). Similarly, CDOT's Construction Manager/General Contractor Manual indicated that the QA program in CM/GC projects can be performed as it would be for a DBB project. Specifically, typical activities, such as construction management, testing and inspection, are performed by CDOT or a Consultant Project Engineer and staff. CDOT also requires the contractor to develop a QC plan during the Preconstruction Phase that should be referenced during the Construction Phase (CDOT 2015).

2.3 Overview of QA for P3 Projects

A report from FHWA indicated that the traditional means of QA is not an option for P3 projects (FHWA 2019). Most transportation P3 projects in the United States have used a best-value procurement approach. QA and QC organization and approach and the quality of past performance are among the key technical evaluation factors for P3 best-value selection. According to FHWA (2019), the agency needs to concentrate on the quality of the contractor teams and their proposals and rely on the P3 structure, contract terms, and conditions to provide the contractor incentives to construct a high-quality project with satisfied operations that meet public needs. In P3 projects, the concessionaire often has a significant role in QA and QC. The Virginia DOT (VDOT) requires the QA plan to be separated and distinct from the QC plan for both design and construction (VDOT 2018). The concessionaire in P3 projects prepares the Quality Management

System Plan (QMSP) that includes an acceptable QA plan and an acceptable QC plan. The QMSP defines a uniform process approach to design and construction quality management, quality procedures, records keeping, and document management/control that the concessionaire shall adhere to throughout the duration of the project (VDOT 2018). The minimum requirement for the design of QMSP includes the following (VDOT 2018):

- Written documentation and definition of the project's design criteria, standards, and processes.
- Procedures for the performance of experienced senior engineers' detailed checks of all design reports, calculations, drawings, and specifications.
- Directions for interdisciplinary reviews by technical and management staff to provide coordination and uniformity among section designs.
- Procedures for constructability reviews to facilitate the timely planning of construction activities.
- Procedures for maintainability reviews to ensure feasibility of future maintenance and operation.
- QA audit checklists.

The minimum requirements for the construction of QMSP include staffing plan, inspection plan, testing plan, and construction inspection checklists (VDOT 2018). Kraft et al. (2015) found that the acceptance QA model is the most feasible for P3 projects. In the acceptance QA model, the agency is responsible only for verification testing and final acceptance, and the concessionaire is responsible for all other quality roles and responsibilities. The acceptance QA officer provides the agency with the least amount of direct control over QA of a project. The main agency's focus in the acceptance QA model is to perform oversight of the design and construction quality-management efforts to satisfy the legal responsibilities. As long as the QC plans meet the requirements of the contract, the agency approves them (Molenaar et al. 2015b).

3. METHODOLOGY

This study aims to investigate the current state of practices of using QC plans for highway construction projects delivered using ACMs. The research methodology of this study was designed with the mixed use of a systematic literature review, a survey of 50 state DOTs, and content analysis of QA/QC documents, guidelines, and manuals related to ACMs.

3.1 Literature Review

A comprehensive literature review was conducted to synthesize the relevant information regarding the requirements and implementation of QA programs and QC plans in ACM highway construction projects. The search included current industry publications, academic literature, state DOT websites, and government reports to find the most current trends and practices of QA programs and QC inspection and testing activities in ACM-delivered highway projects. This study attempted to seek both the most current information and archival documents so that the change over time, if any, in QA programs and requirements for QC plans for ACM highway projects could be identified and related to the current state of the practice.

3.2 Data Sampling

A web-based survey questionnaire and its paper-based forms were developed and distributed to the members of the AASHTO Committee on Materials and Pavements (COMP), including members representing all 50 state DOTs and the District of Columbia DOT. The AASHTO COMP member at each DOT was requested to either complete the survey or forward it to the person or people best qualified to respond. The purpose of the survey was to collect information on current nationwide practices, uses, and implementation of QC plans for administering QA specifications and to identify state DOTs with knowledge and experience that warrant additional investigation. In addition, the questionnaire allowed state DOT respondents to provide document links, references to websites, or attachments that offered specific DOT information on the use of QC plans. As a result, 43 responses were received at an 84% response rate. Out of 43 responses, 37 state DOTs reported that they require contractors to submit QC plans; two state DOTs are considering requiring contractors to submit QC plans; and four state DOTs do not require contractors to submit QC plans. The responses were tabulated, evaluated, and analyzed to identify the

current state of practice of agency use of QC plans for administering QA specifications. The analysis of the information was gathered from state DOT construction manuals, QA manuals, specifications, QC guidelines, and relevant QA and QC documents. It is important to note that the 43 state DOT respondents were not required to respond to all questions in the survey. As a result, the sample size (n) of each question varies.

4. FINDINGS AND DISCUSSION

The ACM has an impact on the development and monitoring of QC plans. Figure 1 shows the current use of ACMs across the nation. Out of 37 responses, 34 state DOTs (92%) have used DB and its variation; 13 state DOTs (35%) have used P3; and 11 state DOTs (30%) have used CM/GC delivery methods for their highway-construction projects. Only three state DOTs: Illinois, Iowa, and North Dakota have not used any ACMs (e.g., DB, CM/GC, or P3). The survey respondents were asked if the state DOTs hold the contractor's QC staff to a higher standard of care for a project delivered using ACMs. The standard of care is typically defined as the reasonable degree of care required of a prudent professional under the circumstance. The standard of care for a contractor or a construction manager is measured at the level of competence exercised by members of that profession in a similar situation (Banik et al. 2006). The following sections present the results of the contractor QC staff standard of care and QC plan requirements for ACMs, including CM/GC, DB, and P3, in comparison to traditional DBB delivery.

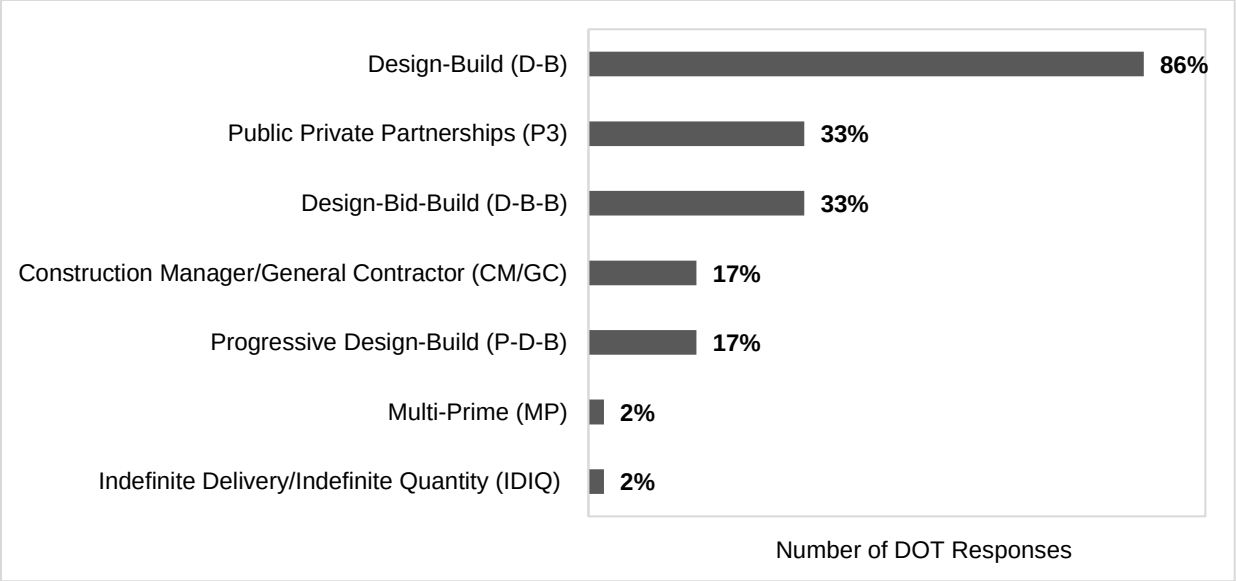

Figure 1: Frequency of using ACMs in highway construction projects (n = 37)

4.1 QC Requirements for CM/GC Projects

Out of 11 state DOTs that use CM/GC delivery, seven state DOTs (64%) reported that they do not hold the contractor QC staff to a higher standard of care, typically for two reasons: (1) the sample policies and procedures of QC are conducted for both DBB and CM/GC projects; and (2) contractors must meet current agency minimum requirements. CDOT pointed out that CM/GC is a design collaboration process, and construction is handled similarly to the DBB projects in that the agency conducts QA testing, and the contractor conducts QC testing. Utah DOT (UDOT) mentioned that the goal is consistent project delivery with similar care for all kinds of projects. However, UDOT recognizes a risk-based allocation of testing, and effort depends more on the items of work than the delivery method. In reality, the speed of construction for these types of projects, with a project-specific organization, sometimes raises quality concerns.

The results also show that three state DOTs (27%) indicated that they hold the contractor QC staff to a higher standard of care for CM/GC projects. For example, Maryland DOT pointed out that more responsibility is passed to the contractor to meet requirements. Similarly, Delaware DOT (DelDOT) indicated that there is no official document stating that QC staff for CM/GC is held to a higher standard of care. However, there is an unofficial understanding that the contractor QC staff needs to be held accountable for their QC. As a result, the contractor typically performs a much higher level of QC. State DOTs were asked if they evaluate the typical elements of QC plans for CM/GC projects differently from DBB projects using a four-point scale: 0 = No Different; 1 = Slightly Different; 2 = Moderately Different; and 3 = Very Different. Table 1 summarizes the results of this question. It is noted that the weighted score is calculated by dividing the sum of the product between the rating and the associated number of responses by the total responses. Table 1 shows that out of 11 state DOTs using CM/GC, seven or more state DOTs (64%) indicated that there is no difference in QC requirements between CM/GC and DBB projects across eight elements: (1) Certifications/qualifications for QC personnel; (2) Process control; (3) Random sampling schemes; (4) QC testing and inspection plan; (5) Control of material provider; (6) Correction plan; (7) QC Documentation (reporting and correcting nonconforming work); and (8) Approval of QC plans. No state DOT used the "Very Different" category to rate these eight elements. The highest weighted score of 0.4, which is below the "Slightly Different" rating, is for QC documentation.

Table 1: QC requirements for CM/GC in comparison to DBB projects (n = 11)

Typical Elements of QC Plans	No Different (0)	Slightly Different (1)	Moderately Different (2)	Very Different (3)	Score
Certifications/qualifications for QC personnel	9	0	1	0	0.2
Process control	7	3	0	0	0.3
Random sampling schemes	8	1	1	0	0.3
QC testing and inspection plan	8	2	0	0	0.2
Control of material provider	9	1	0	0	0.1
Correction plan	9	1	0	0	0.1
QC documentation (reporting nonconforming work)	7	2	1	0	0.4
Approval of QC plans	8	1	1	0	0.3

4.2 QC Requirements for DB Projects

Out of 34 state DOTs using DB delivery, 17 state DOTs (50%) reported that they do not hold the contractor QC staff to a higher standard of care for DB projects. The typical reasons for not holding the contractor QC staff to a higher standard of care for DB projects are: (1) the sample policies and procedures of QC are conducted for both DB and DBB projects, and (2) contractors must meet current agency minimum requirements. For example, Georgia DOT pointed out that a similar sampling, testing, and inspection guide is used for both DB and DBB projects. UDOT mentioned that the goal is consistent project delivery with similar care for all projects. However, the speed of construction with DB projects sometimes raises quality concerns.

The result also shows that 10 state DOTs (30%) indicated that they hold the contractor QC staff to a higher standard of care for DB projects. The typical reasons for holding the contractor QC staff to a higher standard of care for DB projects are: (1) more items of work require QC testing requirements; (2) contractors perform much higher levels of QC; and (3) more responsibility is passed to the DB team to meet QC requirements. For example, CDOT pointed out that they implement a three-step process: owner acceptance, independent contractor QC, and contractor QC on some DB projects. The independent contractor QC is utilized for payment on some of the projects provided the results from the variance (F) and means test (t) analysis are within tolerance.

Table 2 summarizes the results of evaluating typical elements of QC plans for DB projects in comparison to DBB projects. The four-point scale was used to rate the level of difference between DB and DBB projects across eight main elements of QC plans. Table 2 shows that most state DOTs indicate that there is no difference in QC requirements between DB and DBB projects. For example, 27 state DOTs pointed out that there is no difference in certifications/qualifications for QC personnel between DB and DBB projects. For the process control, 17 state DOTs responded that there is no difference; 8 state DOTs mentioned it is slightly different; and three state DOTs indicated that it is moderately different. More than five state DOTs showed that it is moderately different between DB and DBB projects regarding the QC testing and inspection plan, correction plan, and QC documentation. Two state DOTs indicated that it is very different in the approval of QC plans between DB and DBB projects. Table 2 shows 5 QC plan elements that have a weighted average score greater than or equal to 0.5, including process control, QC testing and inspection plan, correction plan, QC documentation, and approval of QC plans. Like CM/GC delivery, QC documentation was rated with the highest combined score (0.8) out of 8 QC plan elements.

Table 2: QC requirements for DB in comparison to DBB projects (n = 34)

Typical Elements of QC Plans	No Different (0)	Slightly Different (1)	Moderately Different (2)	Very Different (3)	Score
Certifications/qualifications for QC personnel	27	0	1	0	0.1
Process control	17	8	3	0	0.5
Random sampling schemes	22	4	1	0	0.2
QC testing and inspection plan	20	1	7	0	0.5
Control of material provider	24	3	1	0	0.2
Correction plan	17	5	6	0	0.6
QC documentation (reporting nonconforming work)	13	9	6	0	0.8
Approval of QC plans	20	3	3	2	0.5

4.3 QC Requirements for P3 Projects

Out of 13 state DOTs using P3 delivery, six state DOTs (47%) reported that they do not hold the contractor QC staff to a higher standard of care. Like CM/GC and DB delivery methods, the typical reasons for not holding the contractor QC staff to a higher standard of care for P3 projects are: (1) the sample policies and procedures of QC are conducted for both P3 and DBB projects, and (2) contractors must meet current agency minimum requirements. The result also shows that five state DOTs (38%) hold the contractor QC staff to a higher standard of care for P3 projects. Like DB delivery, the typical reasons for holding the contractor QC staff to a higher standard of care for P3 projects are: (1) QC for P3 projects is defined in greater detail with more QC and less QA, and (2) more responsibility is passed to the DB team to meet the QC requirements.

Table 3 summarizes the results of evaluating typical elements of QC plans for P3 projects in comparison to DBB projects. The four-point scale was used to rate the level of difference between P3 and DBB projects across eight main elements of QC plans. Table 3 shows that QC plans for P3 projects are relatively different from DBB projects. For example, most state DOTs indicated that it is moderately different between P3 and DBB projects in regard to QC testing and inspection plan, correction plan, and QC documentation. For the process control element of QC plans, four state DOTs rated No Different; two state DOTs rated Slightly Different; four state DOTs rated Moderately Different; and two state DOTs rated Very Different. Table 3 shows that 5 QC plan elements that have a weighted average score greater than or equal to 1.2 include the process control, QC testing and inspection plan, correction plan, QC documentation, and approval of QC plans. The QC testing and inspection plan and QC documentation were rated with the highest combined score (1.4) out of 8 QC plan elements.

Table 3: QC requirements for P3 in comparison to DBB projects (n = 13)

Typical Elements of QC Plans	No Different (0)	Slightly Different (1)	Moderately Different (2)	Very Different (3)	Score
Certifications/qualifications for QC personnel	10	0	2	0	0.3
Process control	4	2	4	2	0.3
Random sampling schemes	8	0	2	2	0.8
QC testing and inspection plan	4	0	7	1	0.4
Control of material provider	8	1	3	0	0.6
Correction plan	4	1	6	1	0.3
QC documentation (reporting nonconforming work)	3	2	6	1	0.4
Approval of QC plans	6	1	2	3	0.2

4.4 Practical Implications

The findings of this study show that most state DOTs confirmed there was no difference in requirements for QC plans between ACMs and the traditional DBB delivery method in terms of certifications/qualifications for QC personnel, and process control. However, the roles and responsibilities between contractors and agencies regarding QC plans and acceptance decisions in ACM projects were not clearly defined. The use of ACMs also has a critical impact on the development and monitoring of QC plans for highway projects to ensure effective project execution and quality. For instance, Florida DOT has shifted more responsibility regarding professional quality, technical accuracy, and coordination of all surveys, designs, drawings, specifications, geotechnical, and other services to contractors. The Idaho Transportation Department indicates specific QC requirements in their DB highway projects using DB quality management and DB construction administration special provisions. Nevada DOT requires all QA and quality-oversight-related tasks to be performed by an independent quality company to ensure that there are clear lines of independence and authority to stop work in ACM-delivered highway projects.

Another major impact of QC plans on ACM highway projects is the improvement of accountability across all involved parties. A well-documented QC process ensures both the agency and contractor understand their role in upholding construction quality. For example, North Carolina DOT requests that contractors need to develop and implement QA and QC plans for ACM projects to verify that all deliverables and work products meet the agency's standards and expectations. As a result, QC processes in ACM projects create a transparent roadmap that improves communication and limits confusion, ultimately helping project stakeholders stay on track.

The implementation of QC plans can also enhance risk management in ACM highway projects which often include high capital investment, strict regulatory frameworks, and unpredictable environmental and geotechnical conditions. Although ACMs offer advantages in terms of cost savings and timely completion, the project delivery process involves high potential for design errors and construction defects. A well-developed, proactive QC plan incorporates continuous inspections, quality benchmarks, and clear documentation protocols, which can provide preventive measures early in the process and allow for timely corrections to improve ACM highway project quality.

5. CONCLUSIONS

For years, state DOTs were solely responsible for QC and performed testing and inspection to verify construction quality. However, since the 1970s, many state DOTs have transferred the responsibility for QC processes of their highway-construction projects to contractors and continued performing tests for acceptance or verification purposes. Modern QA specifications promoted by the FHWA recognize that the state DOT is responsible for monitoring the contractor's QC activities, conducting detailed inspections, and

performing material-acceptance sampling and testing. With the increasing use of ACMs (e.g., DB, CM/GC, and P3) in highway construction projects, the agency has shifted more responsibility to the contractor on quality management activities. This study aims to investigate the current practices of implementing QC plans for administering QA specifications in ACM highway construction projects.

The findings of this study identified the knowledge gap in implementing ACMs and suggestions for future research to improve the QC activities in highway construction projects. Specifically, this study found that most state DOTs confirmed there was no difference in requirements for QC plans between ACMs and the traditional DBB delivery method in terms of certifications/qualifications for QC personnel and process control. The results of this study also show that the agency-dominated system is mainly responsible for quality management for traditional DBB or CM/GC projects. Under DB or P3 agreements, the responsibility for quality management is shared to varying degrees between the contractor and the state DOT. However, the six core elements of a QA program—contractor QC, agency acceptance, independent assurance, dispute resolution, personnel qualification, and laboratory accreditation—apply regardless of project delivery methods. The results from the content analysis show that the roles and responsibilities between contractors and agencies regarding QC plans and acceptance decisions in ACM projects were not clearly defined. Therefore, contractors are required to meet the DOT minimum requirements regardless of the project delivery methods used. Future research may investigate the optimal roles and responsibilities of contractors and agencies to manage QC and QA activities to help state DOTs allocate risk to ensure quality work is performed while recognizing the shortage of agency inspection staff. The results of this study are limited to implementing QC plans in highway projects delivered using DB, CM/GC, and P3. Future studies may include investigations of using QC plans in other ACMs and their variations, such as Progressive Design-Build, Design-Build-Finance, Design-Build-Operate-Maintain, and Integrated Project Delivery, to help state DOTs improve their QC processes.

This study makes several contributions. First, it provides a systematic review and investigation of the current practices of the highway agency's use of QC plans for administering their QA specifications in ACM projects. Second, this study sheds light on the consideration of the optimal roles and responsibilities of agencies and contractors to manage QA activities and QC plans in ACM projects to help state DOTs allocate risk to ensure quality work is performed.

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