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Current Practices of Implementing Quality Control Plans in Managing Quality Assurance Programs in Highway Construction Projects

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Abstract

Question: How are contractor quality control (QC) plans currently required, developed, reviewed, accepted, and overseen by U.S. state DOTs when administering quality assurance (QA) specifications in highway construction?

Purpose: The main objective of this paper is to investigate the current practices of implementing QA and QC activities in highway construction projects in terms of roles and responsibilities of agency and contractor personnel, requirements, review and acceptance processes, monitoring and inspection of contractor's QC plan implementation and innovative efforts and technologies in QA and QC processes.

Research Method: The data collected from a national survey questionnaire of 50 state departments of transportation (DOTs) in the U.S. were used to perform content analysis and verify the use of QC plans for QA.

Findings: As a result, 80% of the agencies studied in this paper used operation-specific QC plans or a combination of operation-specific and generic QC plans for administering QA specifications. State DOTs also indicated the substantial benefits of utilizing advanced technologies, including unmanned aircraft systems, digital delivery models, field inspection tools, and e-Ticketing, for their QA and QC activities.

Limitations: Heterogeneity in DOT practices and terminology complicates direct comparison. The content analysis depended on the currency and completeness of publicly available manuals/templates.

Implications: This paper contributes to the body of knowledge by advancing the understanding on the current implementation of QC plans for administering QA specifications in highway construction projects. State DOTs are recommended to provide more guidance and templates for administering effective QC plans.

Value for authors: This paper provides nationwide visibility into how QC plans are used in highway construction and where enforcement and guidance gaps persist. A snapshot

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of QC plan practices with a Lean lens, pinpointing variability drivers (staffing, communication, subcontractor integration). A pathway to Lean-based QC, helping teams reduce waste, stabilize flow, and improve acceptance outcomes.

Keywords: Quality assurance, quality control plans, highway construction, transportation agency, contractor oversight, acceptance & verification

Paper type: Full Paper

Introduction

The quality of completed transportation projects plays a pivotal role in the success of a state department of transportation (DOT) (Burati et al. 2003). These projects represent tangible products by which the public can measure the DOT's performance in investing tax revenue in improving the state's infrastructure. Accordingly, inspection activities throughout the construction phase are critical to the success of a construction project (Tran & Hoyne, 2022). State DOTs have provided major resources to construction quality management, including quality assurance (QA) measures designed to control and verify construction, material, and product quality (Hughes 2005). According to the Title 23 Code of Federal Regulations Part 637 Subpart B – Quality Assurance Procedures for Construction (CFR 2007), state DOTs are required 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, specifications, and changes.

For years, state DOTs have specified quality standards, including detailed instructions describing the required materials and construction methods and solely performed testing and inspection to verify construction quality (TR Circular 2018). During those years, there was no formal quality control (QC) requirements (Hughes 2005). State DOTs were solely responsible for QC by stipulating how the contractor performed the work and monitoring the construction operations to decide if the work was in compliance and if full payment should be made (Tran & Hoyne, 2022). Many state DOTs have recently transferred the responsibility for QC processes to contractors while they continued performing tests for acceptance or verification (Tran & Hoyne,. 2022). There were several reasons for the shift of QC responsibility from the state DOT to the contractor. First, if the state DOT controls the contractor's process, the state DOT implicitly accepts responsibility for the product (Hughes 2005). Second, the contractor's production equipment and personnel are used to produce the material and work; thus, the best entity to control these items is the contractor (Caltrans 2015).

An essential component of QC is to develop a QC plan which typically is written by the contractor based on DOT requirements and specifications and approved by the state DOT (CFR 2007). Well-developed QC plans can help contractors reduce process variability, prevent rework, and aid in delivering projects on schedule and within budget (Shekharan et al. 2007). However, QC plans are often developed with the sole purpose of meeting agency specification requirements rather than producing a well-reasoned and proactive plan to prevent potential problems (Tran & Hoyne, 2022). In fact, some DOTs have even stopped requiring QC plans due to the quality of QC plans being submitted (Clifford 2020). The existing literature indicates a lack of research and training on reviewing the contractor's QC plan and the appropriate methods of DOT oversight of QC inspection and testing activities. The objective of this paper is to investigate the current practices of implementing QC plans in highway construction, including how QC plans are reviewed, accepted, and monitored to achieve project specifications and what actions are being taken by an agency when QC plans are not being followed.

Literature Review

This section provides an overview of QA/QC programs in highway construction projects and describes the potential of lean production principles in improving QA/QC practices. Then, the research motivation of this study is discussed.

QA/QC Programs in Highway Construction

QA programs are developed and implemented by state DOTs and federal transportation agencies across the country (TR Circular 2019). All federal-aid projects on the NHS are required to comply with 23 CFR 637 (CFR 2007). For projects off the NHS, the established QA procedures that are approved by state DOTs and satisfy the federal requirements can be used for material acceptance (FHWA 2016). The development of QA programs is an evolutionary process, and the form and elements of QA programs vary among state DOTs (FDOT 2024; ITD 2022; KDOT 2018). The Transportation Research E-Circular E-C249 (TR Circular 2019) report indicated that a good QA program aims to balance the cost of testing and inspection for a construction project. The Title 23 Code of Federal Regulations Part 637 (CFR 2007) indicates six core elements: (1) contractor QC, (2) agency acceptance, (3) independent assurance, (4) dispute resolution, (5) personnel qualification, and (6) laboratory accreditation/qualification, for a comprehensive construction QA program. The contractor QC demonstrates the agency's requirement to have the contractor perform QC sampling and testing that may result in reducing variability and increasing long-term performance (TR Circular 2019). The agency acceptance aims to evaluate the quality of the product (e.g., the degree of compliance with contract requirements) and establish payment when appropriate (CFR 2007). There are several factors involved in the acceptance process, including agency responsibilities; quality measures; validation of QC data when contractor test results are used; inspection; and risks to the agency and the contractor (Hughes 2005; FHWA 2012). Independent assurance is used to ensure the reliability of all data used in the agency's acceptance decision, including both the agency's verification test results and the contractor's QC testing (FHWA 2004; 2016). The purpose of a dispute resolution system is to resolve possible discrepancies between the QC data and the agency's acceptance data if QC testing data will be included in the agency acceptance (CFR 2007). The personnel qualification is required in order to perform sampling and testing for QC used in the acceptance decision, verification, and independent assurance (CFR 2007). The laboratory accreditation/qualification is required for all contractor, vendor, and state DOT testing used in the acceptance decision. These six core elements of QA apply regardless of the project-delivery method (FHWA 2012).

A QC plan is an essential component of managing quality (Clifford 2020). Because the QC function is the responsibility of the contractor, it is critical to the success of a highway construction project that the contractor has a functional and responsive QC plan (Scott et al. 2017). The Federal Lands Highway Construction Manual emphasized that an effective QC plan does not depend on the oversight and interaction of agency inspectors to control quality (Federal Lands Highway Division 2009). To develop a QC plan, each contractor has unique means, methods, and strategies to achieve the quality that meets the agency's needs and expectations (Tran & Hoyne, 2022).

The purpose of the QC plan is to provide a framework or procedures that clearly describe how the contractor intends to address various quality requirements, given the project requirements and contractor resources, preferences, and risk tolerance (Shekharan et al. 2007). The QC plan is developed to measure the quality characteristics and inspect construction activities when corrective actions can be taken to prevent nonconforming materials from being incorporated into the project (Burati et al. 2003). Typically, there are two types of QC plans: generic QC plan and contractor-specific QC plan (Tran & Hoyne, 2022). The purpose of using a generic QC plan is to create a common approach for all contractors. The purpose of an operation-specific QC plan is to hold a contractor accountable for their QC activities because the contractor is in the best position to know the type of tests and the testing frequencies in a QC plan. The QC plan is typically reviewed by state DOTs before any construction work can begin (Federal Lands Highway Division 2009). The review process often involves evaluating the contractor plan associated with each category of work, along with the preparatory, start-up, and production phases (Federal Lands Highway Division 2009). The QC plan should avoid paraphrasing of requirements or simply promising to comply with the contract. There are several approaches to implementing a QC plan (Tran & Hoyne, 2022). For example, the QC plan can be stipulated by the state DOT, chosen by the contractor, or a combination of both (FHWA 2004). Each approach to developing QC plans has advantages and disadvantages. For instance, if a DOT specifies the minimum requirements for a QC plan, the contractor may view these requirements as all necessary for developing the QC plan (FHWA 2014). On the other hand, if a DOT specifies all the requirements and properties for a QC plan, the contractor may view the QC plan as the agency's plan rather than the contractor's plan, which may result in less contractor innovation (FHWA 2016).

Lean Production Foundations for Construction QA/QC Management

Lean Construction originated from the transfer of modern production theory to the built environment by reframing projects as production systems where value is created by reliably converting and flowing work (Uddin, 2020; Idrissi et al. 2023). Lean's emphasis on make-ready planning, transparent commitments (Ibrahim et al. 2025), and rapid feedback loops complement formal quality systems by attacking root causes of variability that precipitate nonconformance (Heet et al. 2020). From a lean standpoint, a well-designed QC plan operationalizes process control in which it names qualified people, defines sampling/testing frequencies, identifies action limits, prescribes corrective actions, and standardizes documentation (Willar et al. 2022). On the same note, complementary guidance from TRB (E-C249) emphasizes the value in the basics of QA and the importance of checks and balances when contractor test results feed acceptance decisions—points (Tran & Hoyne, 2022), which is consistent with lean's insistence on trustworthy data and visible standards (Liu et al. 2024). Lean production depends on timely, accurate information to expose constraints, manage commitments, and enable rapid learning (Chung & Mutis, 2020; Salem et al. 2005). Recent transportation practice has advanced digital workflows that directly reinforce these lean requirements. For instance, the e-Construction process replaces paper with secure digital submission, routing, e-signatures, and mobile access, aiming at shortening feedback cycles, increasing transparency, and reducing administrative waste. FHWA's EDC initiatives and state programs document time, cost, and dispute reductions from digitized documentation, which in turn strengthen QA traceability and QCP enforcement. e-Ticketing digitizes materials delivery records (mix design, truck/plant data, temperatures, quantities, timestamps, GPS), enabling safer contactless operations, real-time reconciliation with acceptance tests, and analytics that support production control and pay processes.

Research Motivation

In summary, most state DOTs have used QC plans in varying manners with varying degrees of success. However, little research has explored and documented effective practices for the areas of contractor QC, including effective agency oversight of the QC plan. The research motivation of this study was to (1) identify requirements of contractors regarding QC plans in transportation projects, (2) synthesize guidance and templates provided by DOTs for QC plans, (3) document minimum certifications/qualifications for QC personnel required by agencies, (4) identify QC plan's review and approval/acceptance processes used by DOTs, and (5) determine DOT compliance monitoring and inspection of contractor implementation of QC plans. In addition, the results of this study also include recommendations of effective QC plans and innovative efforts in construction QC. The findings of this study are expected to support state DOTs and transportation agencies to affirm the effectiveness of practices being used, adopt new practices, and develop an effective strategy for using QC plans for administering QA specifications.

Research Methods

The research method of this study is designed as a combination of (a) a systematic literature review, (b) a content analysis of state DOT documents and manuals, and (c) a survey of state DOTs using a web-based questionnaire. Specifically, a comprehensive literature review of agency use of QC plans and QA specifications was conducted using a search of current academic literature, industry publications, state DOT websites, and government reports. The content analysis aimed to identify the most current trends and practices for reviewing the contractor's QC plan and appropriate methods of DOT oversight of QC inspection and testing activities. Then, a survey questionnaire was established and sent out to state DOTs. 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.

The survey questionnaire was distributed in web-based and paper-based forms to the members of the American Association of State Highway and Transportation Officials (AASHTO) Committee on Materials and Pavements, which includes members representing all 50 state DOTs and the District of Columbia DOT as shown in Figure 1. After sending several requests to participate in the survey, 43 completed questionnaires were obtained, providing an 84% response rate. The responses were then tabulated, evaluated, and supplemented with follow-up telephone calls and emails as needed for clarification. The survey respondents primarily worked in managerial and engineering roles in multiple highway divisions and groups, including materials (n=39), construction (n=13), maintenance (n=1), operations (n=2), and alternative project delivery (n=1). Next, the research team analyzed information gathered from state DOT construction manuals, QA specifications, reports, guidelines, and templates related to QC plans. 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.

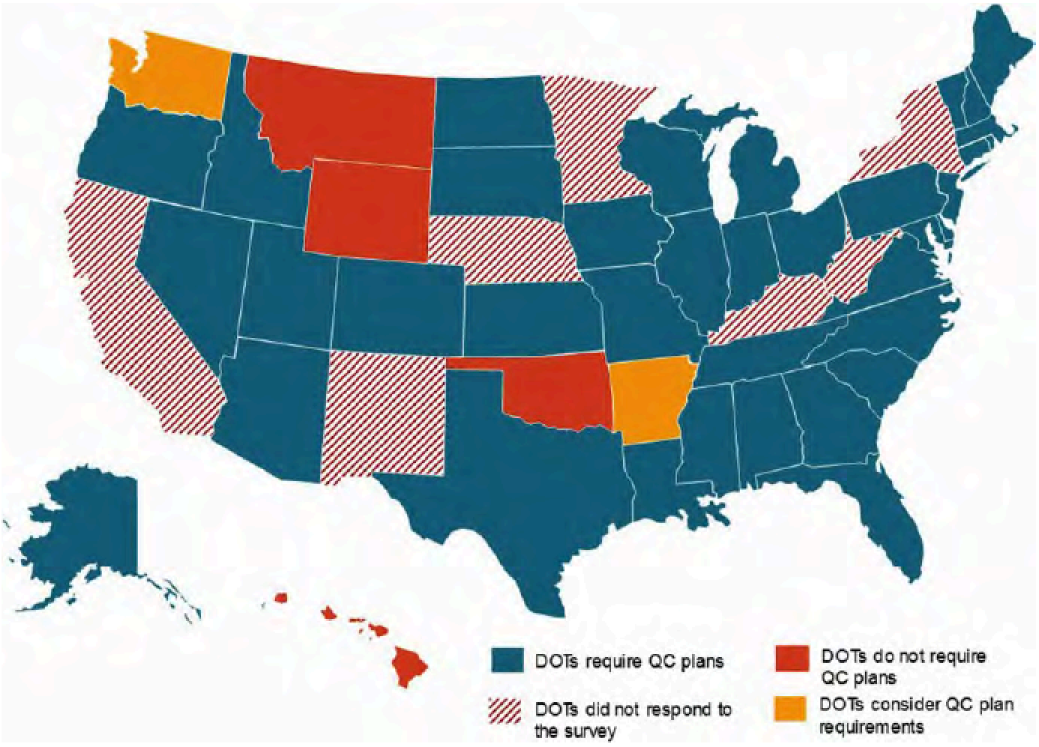

Figure 1. Map of agency use of QC plans for QA specifications (n = 43)

Results

This section provides results from the survey questionnaire focusing on (1) the development of QC plans for highway construction projects, (2) review and acceptance of QC plans, (3) the implementation and oversights of QC plans, and (4) effective construction QC plans. Based on the current practices of using QC plans for administering QA specifications, this study provides recommendations for future QA and QC research in the highway construction domain.

Development of QC Plans for Highway Construction Projects

The requirement of contractors to submit QC plans varies among state DOTs. Out of 43 responses, 37 state DOTs (86%) reported that they require contractors to submit QC plans, and two state DOTs, Washington and Arkansas, are considering requiring contractors to submit QC plans. Four state DOTs that do not require contractors to submit QC plans are Hawaii, Montana, Oklahoma, and Wyoming. Seven state DOTs did not respond to the survey: California, Kentucky, Minnesota, Nebraska, New Mexico, New York, and West Virginia.

Successfully addressing the QC requirements provides the contractor with the necessary information related to material, construction means and methods, staffing, and laboratory equipment. State DOTs typically have a different approach to specifying what must be included in contractor QC plans. As a result, out of 39 state DOTs that require or consider requiring a contractor to submit QC plans, 21 state DOTs (54%) reported that they specify required elements in QC plans only for selected projects or items of work. Furthermore, 6 state DOTs (15%) indicated that they specify required elements in QC plans only for selected items of work on selected projects. Additionally, nine state DOTs (23%) reported that they specify required elements in QC plans for all projects, and three state DOTs (8%) mentioned that they never specify what must be included in contractor QC plans.

The results of this study also identified the project elements and work types for which they require contractors to be included in QC plans. Figure 2 shows that most state DOTs (82%) require a contractor QC plan for asphalt pavement. More than half of the 38 responses (55%) reported that they require a contractor QC plan for structural concrete and Portland cement concrete pavement. Almost half of the 38 DOT responses (47%) require a QC plan for precast concrete. Approximately one-third of the 38 valid responses (26%) indicated that they required a contractor QC plan for earthwork and embarkment, aggregate-based and subbase, and special provision items of work. Some state DOTs also require QC plans for drainage structures (6 responses, 16%) and work-zone traffic control and safety (2 responses, 5%).

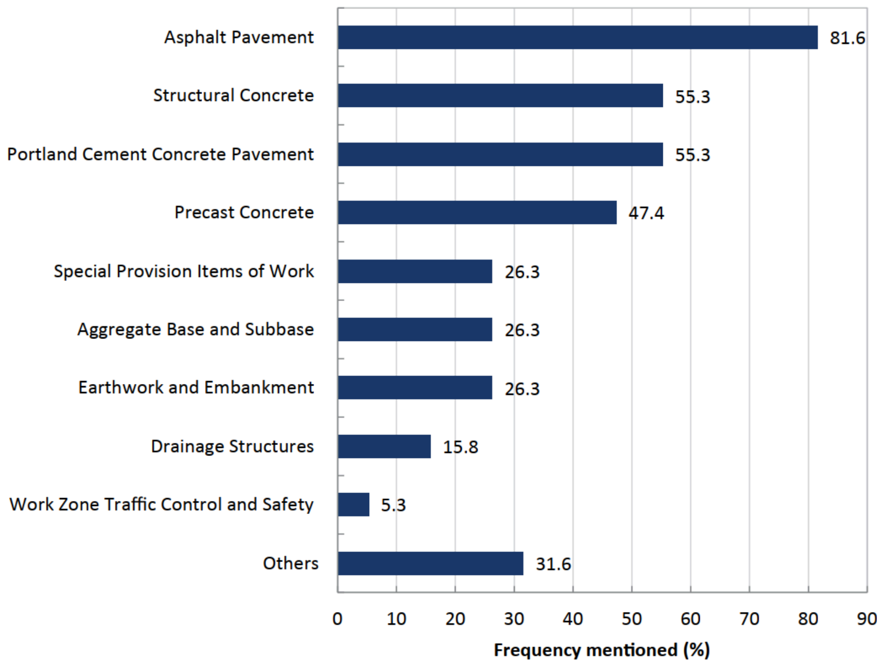

Figure 2. Required elements of QC plans specified by state DOTs (n = 39)

The survey results also found all responded state DOTs agreed that the contractors' roles and responsibilities are to develop, submit, and maintain the QC plan. Accordingly, the main roles and responsibilities of contractors for QC plans consist of (1) providing personnel and equipment capable of performing the specified QC tests, (2) providing sampling and testing materials according to the QC plan, (3) maintaining complete records of all QC tests and inspections, and (4) submitting QC test results to state DOTs. Furthermore, a list of typical certifications and qualifications that are required for contractors and agency personnel for developing and monitoring QC plans was combined, as shown in Table 1. As a result, the American Concrete Institute and agency-specific qualification standards were highly required for contractors, agency QA personnel, and agency-hired consultant personnel.

Table 1: Personnel certifications and qualifications for QC plans (n = 37)

Certificate/Qualification	Contractor QC Personnel	Agency QA Personnel	Agency-hired Consultant Personnel
NICET	4	1	4
The AASHTO resource and the Cement and Concrete Reference Laboratory	13	20	16
Regional programs	13	13	13
American Concrete Institute	23	22	22
Agency-specific qualification standards	27	29	26

Review and Acceptance of QC Plans

The findings of this study found that the QC plan often requires agency review and approval, and state DOTs typically establish a process of reviewing QC plans. However, the process of review varies from state to state. Most of the state DOTs (76%) reported that they review QC plans based on conformance to specification requirements. Approximately 40% of 38 state DOTs indicated that they employ a QA audit process and checklists to review and verify QC procedures in QC plans. Five state DOTs (13%) stated that they employ independent technical review for their QC plans. The independent technical review focuses on reviewing the main project deliverables and documents, including construction plans, specifications, and estimates of probable QC cost. Some other approaches to the QC plan review and approval include (a) using district offices for review (e.g., districts determine the review and approval process), (b) conducting an informal review, and (c) checking the plan for approved material sources (e.g., plant/pit), mix designs, qualified personnel, and qualified labs.

The survey results indicated some other current practices of reviewing QC plans. QC plans are typically reviewed and accepted on a project-specific basis. QC plans must be reviewed and approved before construction begins. QC plans are reviewed based on risk. They become contract documents once approved. Typically, one team in each district reviews QC plans by checking against the list of minimum requirements. QC plans are reviewed based on the contract and QC items. To achieve consistency in reviewing QC plans, the area engineer, project manager, engineer on record, and regional materials engineer are often involved in the review process. Out of 37 responses, more than one-third of state DOTs indicated that the typical members included in the review team for QPs are: a project resident engineer, a QA engineer, and a construction engineer. Twelve state DOTs (32%) indicated that they include the project manager in the review of QC plans. Three state DOTs (8%) also include an FHWA representative in the QC plan review process. Other typical personnel included in the review of QC plans consist of the area engineer and engineer on record, asphalt materials manager, central materials personnel for qualified supplier's quality management plan, central office aggregate staff for the aggregate supplier program QC plans, paving engineer, district materials engineer, specific materials engineer, and regional materials engineer.

The findings of this study also summarize particular reasons that state DOTs found a QC plan was not compliant with specification requirements, including (1) missing key information related to work items, (2) simple repetition of agency QC minimum requirements, (3) having little or no useful information or lack of innovative efforts on the contractor's quality process, (4) including simple promise or statement to comply with the contract, and (5) using a boilerplate template without providing necessary description related to the QC process. The survey also shows that most state DOTs do not have a template, guidance, or document that describes and provides guidance on the evaluation of QC plans. Specifically, out of 35 state DOTs, only 13 state DOTs (37%) reported that they have some type of guidance to help agency staff evaluate contractors' QC plans. For example, Arizona DOT mentioned that they have standard specification language that includes the QC reporting requirements used as guidance for evaluating QC plans. In some cases, Arizona DOT provides an internal checklist to the contractor to help them develop a QC plan. Similarly, Florida DOT provides a checklist to help with the review of QC plans.

Implementation and Oversight of QC Plans

The content analysis found that once a QC plan is approved, the construction operation can begin. Thus, it is necessary that state DOTs monitor the QC plan implementation process throughout construction. In fact, deficient work is an indication of a failure of the QC plan. In addition, when the agency is compelled to increase its inspection levels to compensate for poor contractor QC, it is evidence that the QC plan is not effective. Out of 35 state DOTs, only three state DOTs (9%), including Georgia, Rhode Island, and South Dakota, reported that contractors in their state follow the QC plans every time. Most of the state DOTs (77%) indicated that contractors usually follow their QC plans. Michigan DOT mentioned that contractors rarely follow their QC plan. Louisiana DOT indicated that contractors occasionally follow QC plans. Three state DOTs: Alaska, Connecticut, and Ohio, reported that contractors in their state frequently follow the QC plans. There are several causes for contractors not following their QC plans. Out of 36 responses, most state DOTs (67%) reported that inadequate QC personnel is the main reason that contractors did not follow their QC plans. Half of state DOTs (50%) indicated that miscommunication is also a main reason that contractors do not follow their QC plans. More than one-third of state DOTs indicated that the main causes for contractors not following their QC plans include: subcontractor mishandling (42%), challenges to control QC testing and inspection (36%), material supplier and vendor failure (33%), and related cost of performing QC (33%). Six state DOTs (17%) mentioned contractors' overconfidence as one of the main reasons leading to a QC plan not being followed.

Regarding how often QC plans are reviewed and monitored during the construction process, out of 37 responses, more than half of state DOTs reported that they review QC plans only at the beginning of the project or items of work or conduct periodic reviews during the course of construction. Fifteen state DOTs (41%) mentioned that they only review the QC plan when nonconformance or failing test results occur. Four state DOTs (11%) stated that QC plans are reviewed and monitored based on project schedule milestones. Some state DOTs have a unique approach to reviewing and monitoring the QC plans during construction. For example, the Idaho DOT mentioned that the QC plan is intended as a working document of how the contractor will ensure quality throughout the project. Texas DOT indicated their practice is to review the QC plans throughout the project, and QC test results are often reviewed daily. Tennessee DOT pointed out that QC plans are reviewed annually for asphalt plants, and they maintain an agency representative on-site during construction.

Approximately 60% of the agencies that responded to the survey do not have a formal policy or procedure to deal with a contractor when QC plans are not followed. Rather, state DOTs often use their specification requirements and/or specific points in the contract documents or resolve the issues on a case-by-case basis. Out of 37 state DOTs, only 9 (24%) reported that they have some type of formal policy or procedure if the contractor is not following their QC plan. For example, Alabama DOT mentioned that the work is halted, except for erosion and sediment control work, until compliance is achieved. Continuous and repetitive noncompliance events may result in contractor disqualification or removal from future projects. Florida DOT indicated that failing materials, materials produced at unapproved sources, and materials tested by unapproved labs or technicians must be resolved on each affected project. Georgia DOT mentioned that the noncompliance issues in QC plans are documented and resolved through the noncompliance-report process. These issues must be resolved in a timely manner. Maryland DOT pointed out that when QC plans are not followed, the work is stopped, and the contractor is required to fulfill the approved QC plan before work can resume.

Effective Construction QC Plans

The Federal Lands Highway emphasizes that an effective QC plan does not depend on the oversight and interaction of the agency inspector to control construction quality (Federal Lands Highway Division 2009). Paraphrasing contract requirements or simply promising to comply with the contract add little value to the QC plan. Effective QC plans go beyond the contract requirements and address the process for consistently delivering these requirements. As a result, some benefits of requiring a contractor to submit effective QC plans include (a) holding contractors accountable for their work, (b) increasing quality improvement, (c) enhancing contractor's effort on QC, (d) enhancing communication with contractors, and (e) providing better dispute resolution. Additionally, approximately one-third of 35 state DOTs indicate that effective QC plans help to overcome the reduction of inspection staff and improve productivity and safety. Some state DOTs also provided additional benefits of having effective QC plans. Vermont DOT (VTrans) highlighted that an effective QC plan is a necessary component of any QA specifications. Delaware DOT pointed out that effective QC plans help reduce risk to its agencies.

Contractors are increasingly using innovative efforts and technologies for developing and implementing their QC plans throughout the construction process. Some innovative efforts include (1) electronic submission, (2) increased use of mobile devices such as tablets, iPads, or smartphones, (3) enhancing automation of document review and approval, (4) e-Construction, and (5) use of sensor technologies. Out of 35 responses, more than half of state DOTs (24 responses, 69%) indicated that electronic-submission technology is used in their state DOTs for QC plans. In addition, more than 50% of DOTs mentioned that mobile technologies, including tablets, iPads, or other smart devices, are increasingly used in their state DOTs for QC plans.

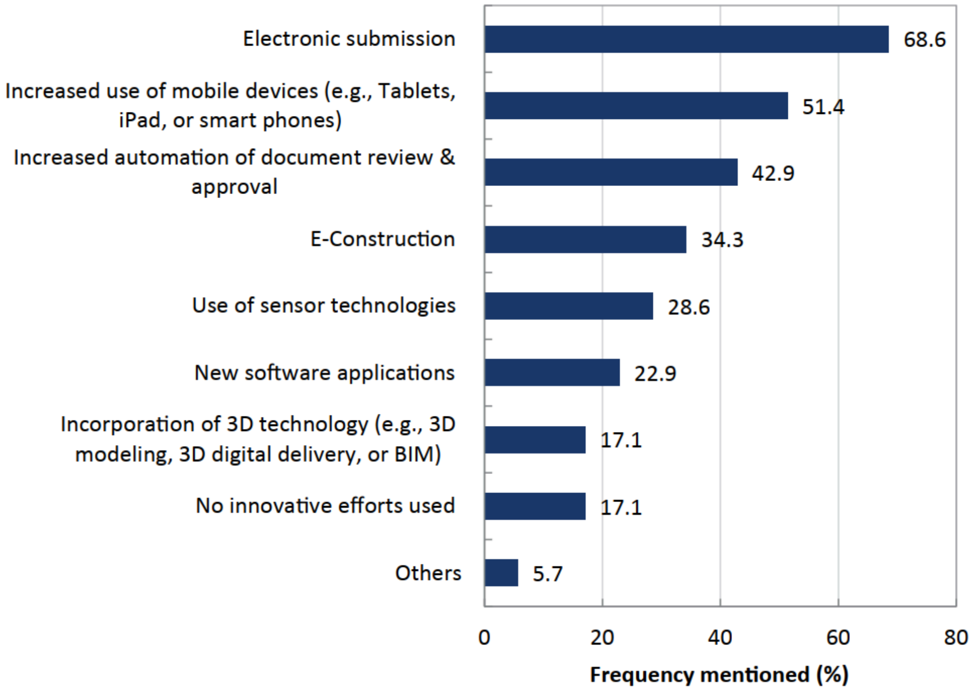

Figure 3. Innovative efforts for QC plan (n = 35)

Figure 3 also shows that one-third of 35 state DOTs increasingly use automation of document review and approval (43%) and e-Construction (34%) for developing and implementing QC plans. Further, sensor technologies (10 responses, 29%), new software applications (8 responses, 23%), and the incorporation of 3-D modeling (6 responses, 17%) are among innovative efforts for QC plans and activities. Six state DOTs (17%) also indicated that there are no innovative efforts used for QC plans. VTrans highlighted that both the agency and contractors are struggling to hire qualified QC/acceptance testing staff because there simply are not enough qualified personnel. Finally, some state DOTs indicated that technologies and innovative approaches are being implemented but are not directly tied to QC plans.

Discussion

The synthesis of U.S. DOT practices shows that QC plans are widely required, especially for high-risk work such as asphalt, PCC pavement, and structural concrete, yet too often devolve into boilerplate promises to comply rather than actionable process controls (e.g., sampling plans, action limits, corrective actions, and documentation standards). This section provides recommendations for future QC research together with lean-based practices for administrating QA programs for transportation agencies.

Recommendations for Future QC Research for Administering QA Programs

The current use of QC plans for administering QA specifications varies widely among state DOTs. While state DOTs emphasize the importance of having an effective QC plan to improve process reliability, prevent rework, and generate potential savings in both cost and time, there is not enough guidance about what constitutes an effective QC plan, how they are developed, and how to review the plan. Future research may need to explore a framework that helps state DOTs provide guidance and templates for developing and administering effective QC plans. The survey results indicated that most state DOTs do not use incentive/disincentive clauses to encourage contractors to develop and follow their innovative QC plans. Contractors' QC plans typically reflect their own resources and risk tolerances to meet the quality requirements. If state DOTs believe in the process of using QC plans for administering QA specifications but contractors are not following the spirit and intent of a QC plan, then the process can be ineffective. Future research that investigates how to determine the optimal allocation of incentive/disincentive clauses to encourage contractors to develop a better QC plan and then follow the QC plan would be helpful.

Some state DOTs, including Florida, Kansas, Nevada, North Carolina, Utah, and Virginia, already observe the substantial benefits of using innovative efforts and technologies, such as UAS, digital-delivery models, field-inspection tools, and e-Ticketing, for their QA and QC processes. For instance, Florida DOT utilizes e-Construction and mobile devices to create a paperless environment by transmitting construction documents electronically. Nevada DOT implements the use of Intelligent Compaction (IC) technology to ensure real-time smoothness in the construction QC. Utah DOT indicates that technological advancements offer many benefits to improve QA and QC processes, including real-time and more-accurate data to make informed decisions. The findings of this study also show that more than 50% of the responded DOTs mentioned the need to utilize mobile technologies, such as tablets, iPads, and other smart devices for implementing QC plans. However, there is limited guidance on how these innovative efforts can be integrated with the development, review, monitoring, and administering of QC and QA processes. Exploring this knowledge gap can add significant value to state DOTs in terms of selecting appropriate methods for oversight of QC inspection and testing activities. The roles and responsibilities between contractors and agencies regarding QC plans and acceptance decisions in various project delivery methods are not clearly defined. Therefore, 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.

Aligning Construction QA/QC with Lean Practices

The results of this paper show a widespread use of checklists and criteria for QC plan review, periodic audits, and clear team roles (resident engineer, QA engineer, construction engineer). Lean practices can strengthen these routines by pairing them with the Last Planner System (LPS) processes focusing on collaborative phase scheduling to define handoffs, make-ready planning to remove constraints, weekly work planning with commitment tracking, and percent-plan-complete measurement to expose systemic causes of plan failure. Extending LPS across project- and production-levels raises planning reliability and, by extension, the reliability of acceptance sampling and pay decision. Transportation agencies seeking higher confidence in acceptance data can leverage the takt control's cadence to reduce variability upstream, thereby lowering the risk that verification tests and dispute resolution will be driven by unstable processes rather than true product differences. e-Construction and e-Ticketing provide the time-stamped, structured data streams that lean needs for rapid learning. As a result, mainstreaming these technologies reduces administrative waste and safety risks while improving data quality for QA/QC acceptance. As agencies scale e-Ticketing and sensor integration, lean-for-highway-related research should explore how to stitch these data into takt/LPS dashboards and acceptance decision logic by reducing latency, improving validation, and enabling predictive quality control; for example, digitally triggered corrective actions before nonconformance occurs. Lean methods supply the operating system that makes those frameworks deliver should aim at reliable planning and handoffs, rapid learning from trustworthy data, and collaborative behaviors aligned by project delivery models and incentives.

This study found a recurring pattern that QC plans are rejected or later found ineffective because they lack operation-specific detail, rely on generic promise-to-comply language, list expired or unqualified personnel/laboratories, offer vague corrective-action procedures, and fail to coordinate subcontractors at handoffs as shown in Table 2. These deficiencies manifest in more nonconforming reports, delayed corrective actions, and lower verification agreement rates between contractor QC and agency acceptance tests. Lean construction can reframe QC plans as production-control systems (standard work, visual controls, rapid feedback) where QCPs are designed that way and supported by digital workflows (e-Construction, e-Ticketing), agencies report faster cycles, clearer accountability, and fewer disputes. In summary, transportation agencies can reduce rejections and field failures by requiring operation-specific content, visual procedures and action limits, credential gates, takt handoffs with hold-points, and digital validation. On the other hand, contractors can respond by treating the QC plan as their production system where LPS for planning reliability, takt for flow, percent-complete tests for early warning, and A3 for fast learning. When these lean-based features are embedded, QC plans can start operating as quality-creating systems, delivering higher agreement rates, fewer nonconforming reports, and more predictable acceptance and payment.

Table 2: Typical QC noncompliance causes and lean-based preventive design features

QC noncompliance causes	Lean-based Preventive Feature in QC Plans	Recommendations	
		Agency	Contractor
Missing work-item specifics	Operation-specific templates Checklists in e-Construction	Issue item-level checklist	Pre-fill frequencies and limits from specs
Boilerplate promise-to-comply	Standard work with action limits and triggers Visual control charts	Return submittals that lack procedures	Add flowchart and check-sheet for each operation
Unqualified personnel/labs	Live registry check and alerts QA scope linked to plan	Require certification upload	Weekly credential checks
Weak corrective-action detail	Predefined countermeasure playbook (A3) Nonconforming report workflow	Set closure time targets	Nonconforming report each morning until closure
Poor subcontractor coordination	Takt sequenced handoffs Make-ready across subs	Hold big-room phase planning	Run weekly constraint removal

Conclusions

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. Well-developed, proactive QC plans should be used to increase process reliability and produce quality work, which will aid in delivering projects on schedule, within budget, and achieving the target design life. However, QC plans are often developed with the sole purpose of meeting agency specification requirements rather than producing a well-reasoned and proactive plan to prevent potential problems. The objective of this paper is to document the various QC requirements used by state DOTs, including how QC plans are reviewed, accepted, and monitored to achieve project specifications and what actions are being taken by an agency when QC plans are not being followed. The research methods of this study included a systematic literature review, content analysis of information gathered from state DOT construction manuals, reports, and guidelines, and a national survey of state DOTs.

As a result, contractors are required to meet the DOT minimum requirements for QC plans regardless of the project-delivery methods used. QC personnel certification or qualification requirements vary from agency to agency. The QC personnel often include QC manager, inspectors, testers, and other personnel directly involved with inspection and testing. The typical certifications and qualifications required for all personnel include agency-specific qualification standards, regional programs, American Concrete Institute, AASHTO resources and the Cement and Concrete Reference Laboratory. Most state DOTs require contractors to submit QC plans only for selected items of work or selected projects. The most common types of work or project types that state DOTs require contractors to submit their QC plans include asphalt pavement, Portland cement concrete pavement, structural concrete, and precast concrete. State DOTs review and approve the QC plan before any construction work can begin. The team members included in the QC plan's review process vary from state to state, which typically consists of the resident engineer, construction engineer, project manager, and QA engineer. Particular innovative efforts and technologies, such as electronic submission, increased use of mobile devices such as tablets and smartphones, enhancing automation of document review and approval, e-Construction, and the use of sensor technologies, have been used by contractors to develop their QC plans. State DOTs also indicated the substantial benefits of utilizing advanced technologies, including unmanned aircraft systems, digital delivery models, field inspection tools, and e-Ticketing, for their QA and QC activities.

This study contributes to the body of knowledge by advancing the understanding on the current implementation of QC plans for administering QA specifications in highway construction projects. The findings of this study are expected to help state DOTs and transportation agencies affirm the effectiveness of practices being used, adopt new practices, or develop an effective strategy for using QC plans for administering QA specifications. State DOTs are recommended to provide more guidance and templates for developing and administering effective QC plans and use incentive/disincentive clauses to encourage contractors to develop and follow their innovative QC activities. Embedding LPS/takt artifacts (phase schedules, make-ready lists, reasons-for-variance) inside QC plans creates the closed-loop learning cycle (plan–observe–adjust) that produces built-in quality on public works.

Future lean-for-highway research should focus on specifying the essential artifacts, data signals, and decision cadence that integrate LPS/takt, e-Construction/e-Ticketing, and QA/IA/dispute resolution into one system under project delivery methods. The lean community can also utilize e-Ticketing and sensor data to build predictive models that trigger corrective actions before nonconformance occurs and study how these models should feed acceptance logic and pay processes without compromising checks-and-balances. It can be beneficial to transportation agencies by developing visual management templates that tie takt trains, percent-plan-complete, and reasons-for-variance to QC plan action limits and acceptance milestones. The opportunity for the lean construction community is to integrate these elements into a single, practice-ready system so that built-in quality becomes the everyday reality of capital construction projects.

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