ENHANCING ORGANIZATIONAL TRANSFORMATION FOR DESIGN-BUILD INFRASTRUCTURE PROJECTS: DESIGN LIABILITY, CONSTRUCTION QUALITY ASSURANCE, AND NEW ENGINEERING LEADERSHIP REQUIREMENTS

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To my father, Seokjun Lee, and my mother, Myungsook Jeong,

Your dreams, my dreams, and unconditional love.

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SUMMARY

Major transportation infrastructure projects have used alternative project delivery, such as design-build (DB), to streamline and expedite project delivery, transferring many roles and responsibilities from state departments of transportation (DOTs) to private actors. One challenge that state DOTs face in their major DB projects is ensuring that the DB team upholds the highest standards of design and construction quality in the integrated design and construction environment. The overarching objectives of this study are to support decision-makers in streamlining project delivery by identifying challenges related to understanding gaps between public owners' expectations and the industry's perception and suggesting recommendations to mitigate the gaps. Most specifically, this study addresses issues found in DB transportation infrastructure projects and recommends innovative solutions to overcome those issues in the following areas: (1) design liability, (2) construction quality assurance, and (3) a new engineering leadership requirement on the DB team. This study utilizes a mixed-method research methodology, combining quantitative and qualitative techniques to identify key areas of variances in the integrated DB infrastructure projects. The data in this study come from a survey and semi-structured interviews. Because of the interdisciplinary nature of the research, it is necessary to capture several viewpoints from a wide range of subject-matter experts (SMEs) from multiple domains, including design consultants, highway contractors, public owners, owner representatives, insurance and legal advisors, and construction engineering and inspection (CEI) specialists. The results show that SMEs had considerably different perceptions regarding the frequency and severity of design claim sources in the DB environment.

Inconsistencies between CEI perceptions and DOT requirements for quality assurance roles and responsibilities are identified. The results also highlight that a new engineering leadership requirement on the DB team will add value to large and complex projects. This study contributes to the body of knowledge in proactive design and construction quality management by providing decision-makers insights into design liability issues and opportunities to reduce them, providing guidance on reinforcing the quality assurance program for current and future DB projects, and mitigating gaps between the DOT's expectations and the industry's perceptions. The findings of this study have important implications for future practice and offer constructive guidance on streamlining project delivery in the DB transportation infrastructure market.

1. INTRODUCTION

1.1 Background

1.1.1 Increasing Needs for Infrastructure Investment

The construction industry in the U.S. has been growing steadily. According to the survey conducted by the Associated General Contractors of America (AGC) and the FMI Corporation in 2020, total annual nonresidential megaproject spending as a percent of nonresidential construction put in place will increase by about 28 percent by 2023, comparing 6.2 percent in 2018 (Howsam and Hoover 2020; Strawberry 2019). Figure 1 describes estimated construction spending, indicating that spending on highway and street construction put in place, depicted in the blue circle, is expected to grow by about four to seven percent from 2020 to 2025 (Bowman et al. 2021).

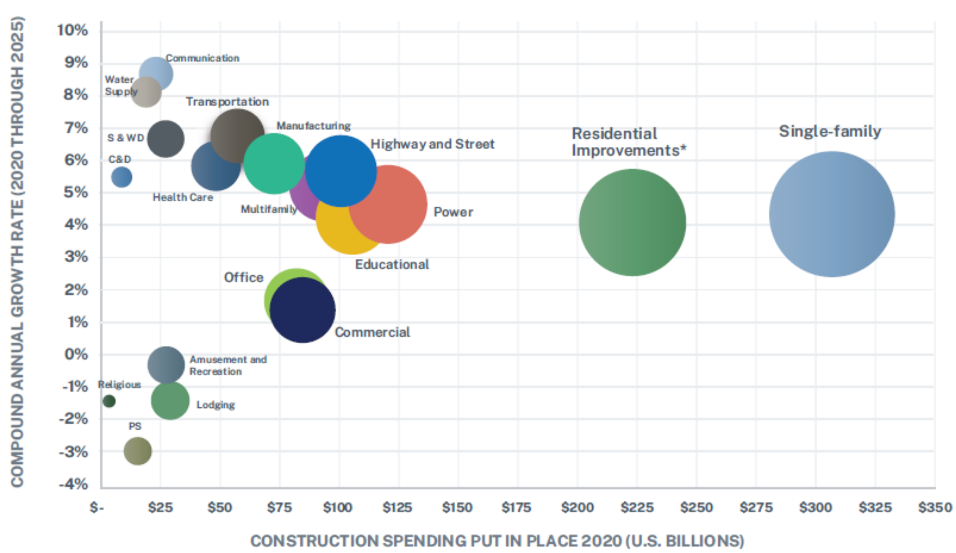


Figure 1 – Total U.S. Construction Spending Forecast (Bowman et al. 2021)

The need for more and better infrastructure is accurate. The US Council of Economic Advisers estimated that every $1 billion in transportation infrastructure investment would support 13,000 jobs annually (Federal Highway Administration (FHWA) 2021). Employment in highway construction has increased since the recession began in late 2007 (see Figure 2). Beyond the employment rates, infrastructure closely interacts with the health and well-being of people living in this country; It is said that “the United States could not function without the roads, bridges, sewers, clean water, and airports previous generations paid for” (Katseff et al. 2020).

Source: Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey (National).

Note: Data for 2020 are through January.

Figure 2 – Employment in Highway, Street, and Bridge Construction (Mallett 2020)

While most infrastructure remains critical to the national interests, a surprising amount is obsolete. According to the American Society of Civil Engineers (ASCE) Infrastructure Report Card published every four years, US infrastructure gets C- in 2021, which was an improved grade compared to the D+ in 2017(ASCE 2021). The physical infrastructure systems are aging, needing attention and ongoing costs to monitor and maintain. The ASCE estimates the US needs to spend more than $1.2 trillion by 2029 and more than $2.4 trillion by 2039 to fill the investment gaps in surface transportation projects (EBP 2021). In response to these crying needs, the Bipartisan Infrastructure Bill—the Infrastructure Investment and Jobs Act (IIJA)—allocates $110 billion to be invested in roads and bridges over the next eight years (The White House 2021). It is critical to streamline project delivery and ensure the increasing level of project support promised by the government.

1.1.2 Increasing Use of Alternative Project Delivery

To fulfill a continually rising demand for project development and maintenance, the state departments of transportation (DOTs) across the nation attempted to experiment with alternative processes to expedite highway project delivery (US DOT 2006). The Federal Highway Administration (FHWA) decided to approve Special Experimental Project No. 14 (SEP 14) to enable state transportation agencies (STAs) to test and evaluate various alternative project contracting methods that provided the potential to expedite highway projects cost-effectively (US DOT 2006). The SEP 14 program showed the benefits of alternative project delivery methods such as design-build (DB) in terms of schedule and cost (Gatti et al. 2014). As a result, in 1998, Transportation Equity Act for the 21st Century (TEA-21) allowed alternative project delivery methods for selected federally funded projects (Alleman et al. 2018; Tran and Molenaar 2014). In 2002, FHWA issued a final rule for design-build (DB) project delivery systems that allows DB to be applied to qualified projects without SEP-14 approval (Federal Highway Administration (FHWA) 2002). Since then, the DB delivery method was moved from experimental status and became mainstream use on federally-funded projects (Tran and Molenaar 2014).

Consequently, many DOTs are moving toward alternative methods of project delivery to increase the efficiency and effectiveness of infrastructure development (Ashuri and Kashani 2012). More federal projects use an alternative delivery method if state legislation allows design-build (Smith et al. 2009). The DB delivery method is continuing to gain momentum in the transportation industry. Figure 3 presents the status of design-build authorization in the transportation market. The DB delivery method is used at varying authorization capacities in transportation programs. Compared to the map of 2005 presented on the left, as of January 2022, according to the Design-Build Institute of America (DBIA), DB had been fully authorized in 30 states and the District of Columbia, widely permitted in another 5 states, and authorized with certain limitations in 11 additional states; only four states do not authorize the use of design-build in transportation ((DBIA) 2022). This clearly shows that design-build in the transportation market keeps growing.

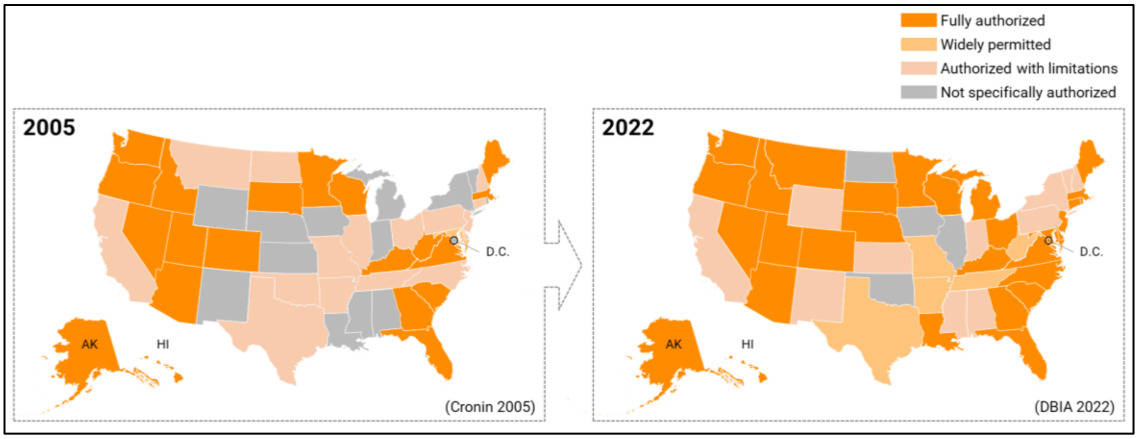


Figure 3 – Design-Build Authorization for Transportation ((DBIA) 2022; Cronin 2005)

In addition to the increasing number of state governments authorized design-build, the dollar value put in the design-build construction projects is increasing. In 2018, the FMI Corporation prospected a bright outlook for a DB delivery system, indicating about 13 percent increased design-build spending in the highway and transportation markets from 2018 to 2021 (FMI Corporation 2018). According to the recent design-build market research conducted by the FMI corporation, construction spending for design-build is estimated to yield $405 billion in 2025 (See Figure 4).

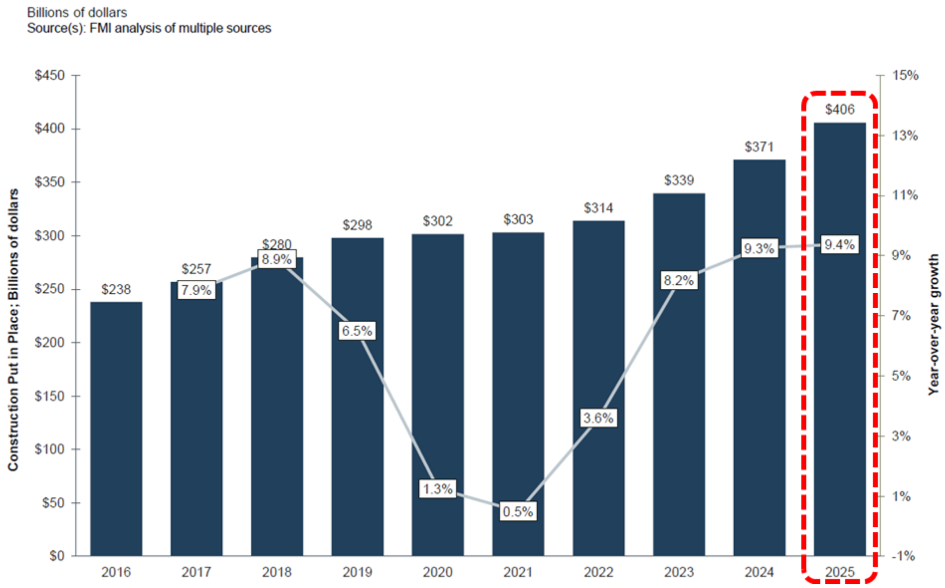


Figure 4 – Design-Build Outlook (FMI Corporation 2018)

Considering the marketwise amount, Figure 5 presents that highways and streets account for one of the most significant volumes of design-build construction spending. In addition, I would like to highlight the recent passing of the infrastructure bill known as the Infrastructure Investment and Jobs Act (IIJA) last December. The Federal Highway Administration appointed the $52.5 billion funding for the Fiscal Year 2022, which represents an increase of more than 20% compared to the Fiscal Year 2021 for the Federal-aid Highway Program ($43.2B). Significant funding coming to state and local governments is expected to promote alternative project delivery methods such as DB to streamline the influx of transportation infrastructure projects. This shows that design-build has grown in prominence.

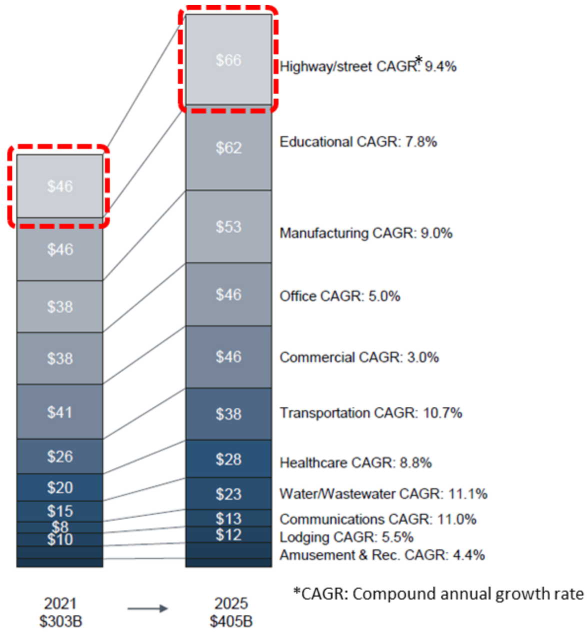


Figure 5 – Distribution of Forecast Spending by Market (FMI Corporation 2018)

Increasing the use of a DB delivery system relates to its benefits. The DB environment is designed to lessen the administrative burden (Gad et al. 2015). Projects with a DB delivery system are delivered faster, with lower cost and shorter schedule growth than traditional design–bid–build (DBB) systems (Amekudzi-kennedy et al. 2016; Ashuri and Kashani 2012; Franz et al. 2020; Gad et al. 2015; Gransberg and Molenaar 2019). Further, public-private partnership (P3) project delivery systems, such as design-build–finance (DBF) and design-build-finance-operate-maintain (DBFOM), offer numerous benefits, as well (Mostaan and Ashuri 2015). These systems generate mutually beneficial, long-term contracts where private-sector entities provide operating and maintenance services for the public sector (Garvin et al. 2011). They make it possible to achieve broader objectives, reduce prices, and make schedules shorter and more consistent (Brown 2009).

These increasing needs for alternative project delivery methods are also derived from a flush with large and complex projects in the transportation infrastructure market. Project complexity increases due to rapid changes in the environment, increased product complexity, and increased time pressure (Williams 1999). In recent years, the construction industry has witnessed rapid growth in increasing the size and complexity of projects (Luo et al. 2017). According to the FMI Corporation, the total annual megaproject is expected to increase from 4.0% in 2018 to over 20% by 2023 (Hoover 2019). Megaproject size is expected to increase 37%, from $2.1 billion in 2018 to $2.9 billion by 2023 (Hoover 2019). The FMI Corporation also identified that 473 U.S. megaprojects, representing $1.3 trillion, are planned from 2019 to 2023 (Strawberry 2019). A growing need to replace aging infrastructure has become a leading driver of megaprojects in the transportation market (Knapschaefer 2019). Megaprojects need to be managed effectively to achieve budget and schedule objectives. Understanding the increasing complexity of the megaprojects is key to successfully delivering transportation infrastructure projects (Garemo et al. 2015; Williams 1999).

1.2 Research Motivation and Impacts

Compared to the traditional design-bid-build, presented on the left of the organizational structure, shown in Figure 6, a key feature of the DB contract is a single point of responsibility, which brings several benefits over the traditional DBB contract. In the DB environment, a design-builder can overlap design and construction activities and even initiate construction work before the design phase is completed. It clearly shows more roles and responsibilities have shifted from owners to design-builders. The organizational transition with alternative project delivery changes the fundamental way of key stakeholders in the infrastructure construction industry compete and cooperate.

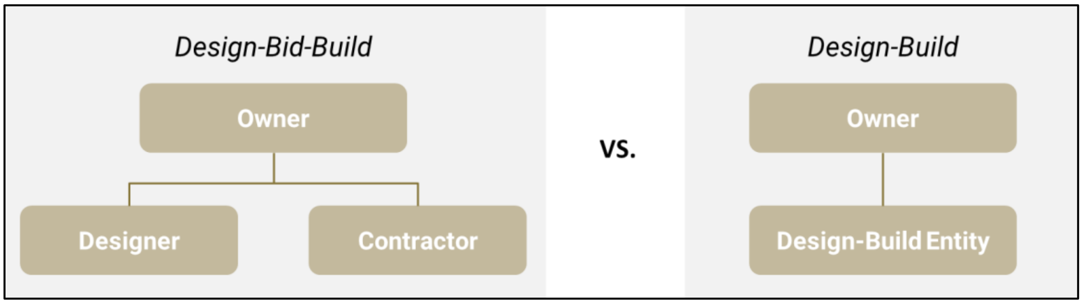


Figure 6 – Changes in Organizational Structure

The Federal Highway Administration (FHWA) and several state DOTs have defined best practices to enhance the utilization of alternative project delivery in the U.S. Identified best practices to implement alternative project delivery systems effectively were highlighted in several research studies (Ashuri et al. 2018a). Still, there is little known about how DB industry professionals understand the institutional norms and new organizational expectations in design and construction quality management for the DB infrastructure projects. The existing literature emphasizes design liability transfer in DB projects and significant differences in standard of care between designers and contractors. In addition to extra responsibilities for the design liability, the design-builder also accepts the duty of quality acceptance, hiring an independent quality firm. In the integrated design and construction processes, it is imperative that non-designers should not influence engineering decisions.

Questions remain over whether these alternative delivery methods improve all areas of project delivery and whether adequate checks and balances are provided to ensure the design and construction quality of the projects. While the quality of DB projects is required to be at least as high as that of commensurate DBB projects (Gransberg and Molenaar 2008), concerns persist over whether project quality remains at the same level (Ernzen and Feeney 2002). There is a gap in the knowledge needed to understand better how different industry stakeholder groups perceive the risk of increased design claims and expanded responsibilities for design and construction quality management in the alternative delivery environment. These concerns demand an in-depth investigation of how the DB team needs to uphold the highest level of diligence in ensuring the high-quality standards of DOT infrastructure development in the DB environment.

1.3 Research Objectives and Questions

Design and construction quality management are usually performed under the owner's direct control in the traditional design-bid-build setting. In the transition toward alternative project delivery, these tasks can be transferred to the private actors, which requires the construction industry to have a different mindset than when implementing the traditional DBB. The construction industry should embrace new norms, expectations, and requirements in the alternative project delivery environment to achieve the owner's interests, project goals, and public interests. Thus, it is imperative to measure the perception of the construction industry to identify their level of understanding of alternative project delivery. If there is any misalignment among industry practitioners, this should be addressed, and additional educational guidance should be developed to understand better and implement alternative project delivery.

The overarching purpose of this study is to support decision-makers in streamlining project delivery by identifying challenges related to understanding gaps between public owner's expectations and the industry's perceptions and suggesting recommendations to mitigate the gaps. The ultimate goals of this study are to attract more industry firms to the DB infrastructure projects and encourage healthy competition by mitigating understanding gaps among industry practitioners. An in-depth investigation of various viewpoints from a wide range of SMEs should be analyzed. Three research objectives are devised to address the research questions and achieve the primary research objectives as follows:

1. To identify and analyze important challenges related to design professional liability issues in the transportation DB industry;
2. To identify and analyze understanding gaps in alternative QAP between public owner's expectations and the industry's perceptions; and
3. To determine the engineering decision-making practices in the design-build environment by exploring opportunities offered by a new leadership position in the design-build team.

This study identifies three research questions to achieve the research objectives and address the challenges that the infrastructure construction industry is experiencing. The following chapters will discuss each question further as research thrusts 1, 2, and 3.

1. What are the emerging challenges in transferring design liability in the design-build environment?

2. What are the gaps between the industry perception and public owner's requirements regarding the roles and responsibilities of the construction quality assurance in the design-build environment?
3. Would the new engineering leadership requirement on the DB team add value to large and complex design-build projects?

2. LITERATURE REVIEW

This chapter reviews previous research on challenges in the infrastructure alternative delivery environment. Corresponding to three research questions presented in the previous section, this chapter consists of three overarching issues: design liability, construction quality assurance, and rising complexity in transportation megaprojects.

2.1 Design Liability

2.1.1 Transferring Design Liability from the Owner to the Design-Builder

Many researchers have documented a trend of transferring the risk of design liability from the owner to the DB team for errors and omissions in DB projects. (Molenaar and Gransberg 2001) examined six case studies of DB projects and discussed how the risk of errors and omissions was transferred to the design-builder. (Gransberg et al. 2006) affirmed that, compared with DBB contracts, the owner vests the design-builder responsible for design details. The Federal Highway Administration published a report stating that the DB agreement may indicate that the design-builder takes the risk. At the same time, the design documents provided are regarded as complete and free from error (Federal Highway Administration (FHWA) 2006). One of the main risks that DOTs need to consider when using the DB method is this shift of design liability (Tran and Molenaar 2014).

2.1.2 Standard of Care

Transferring design liability from the owner to the design-builder may result in a situation in which designers are held to an elevated standard of care. Common law states that design professionals are held to a "standard of care," which is defined as what reasonably prudent professionals would do "in the same community, in the same time frame, given the same or similar circumstances" (Demkin and American Institute of Architects 2008). The Design-Build Institute of America (DBIA) standard agreement states: "The standard of care for all design professional services performed to execute the Work shall be the care and skill ordinarily used by members of the design profession practicing under similar conditions at the same time and locality of the Project" (Design-Build Institute of America (DBIA) 2010). Many believe that this standard of professional design liability does not guarantee a satisfactory outcome. Contractors, however, usually warrant that the result of their services will be satisfactory. Design-builders are generally held to the same warranty standards as contractors with respect to both construction and design services. This often leads to a situation where the design professionals are held to a stricter standard in a DB contract than when there is a separate contract for design services in a traditional DBB contract (Friedlander 1998).

(Ahmadifar 2013) explained the difference between design liability in the DBB and that in the DB. In DBB, the design professionals design the project to fit the required specifications, and the contractors fully comply with the plans and specifications. Thus, the design professional's standard of liability is limited to professional negligence. However, under the DB contract, the standard of care of the design-builder is often "fitness for the intended purpose." Thus, it might be perceived that the design professional is potentially subject to a higher standard of care, such as “an express warranty,” “an implied warranty,” and “strict liability in tort.”

(Loulakis et al. 2015) noted that the DB contract is based on the principle of a “single point of responsibility” that applies to both design and construction services. This vital principle transfers significant risks from the owner to the design-build team, which is required to assume all potential liabilities related to design performance and construction quality. This added liability should be considered carefully by the designer of record on the design-build team. (Vinet and Zhedanov 2011) stated that, under the DB approach, the design consultant could be assigned to perform some construction-related professional services on behalf of the design-builder. However, this additional assignment of responsibility usually cannot stand the standard-of-care test. (Gransberg and Molenaar 2019) also concluded that, depending on the preliminary design portion, design liability allocation could vary in the DB contract. Design liability can be fully transferred to the DB team if the design-builder is assigned to complete the entire design effort.

2.1.3 Design Professional Liability Insurance

It is known as professional negligence when a design professional fails to meet the professional standard of care. To protect the design professional against liability claims and lawsuits that arise from negligence, errors, and omissions in providing professional services, design professional liability insurance (DPLI), commonly known as an errors and omissions (E&O) policy, is required by the owner (Beard et al. 2001). The DPLI coverage responds to professional negligence. One of the critical characteristics of DPLI is that this policy only covers the common law standard of care. (Chan and Yu 2005) identified two common perceptions in the DB industry related to the design liability: (1) fitness for purpose and (2) reasonable skill and care. Meanwhile, the main practical problem is that common DPLI policies do not cover design liability for "fitness for purpose." These policies cover professional negligence only when a design professional fails to provide reasonable skill and care.

(Tran et al. 2013) found that design professional liability insurance becomes an issue in management that influences the design-build delivery selection. They noted that insurance could be high risk due to onerous or unobtainable insurance requirements. There is no coverage problem if the contract standard of care is consistent with the common law standard of care. (Hickman 2013) affirmed that the policy might exclude coverage for failure to meet a heightened standard of care. Thus, it is vital to obtain advice on the DPLI policy and contract documents from legal and insurance experts before executing the contract.

The owners may like the design-build contract because of this stricter language of a standard of care. (Levin 2016), however, states that this heightened standard of care can result in a potentially uncovered gap when a breach of contract falls within the heightened standard of care that is above the common law standard of care. The typical DPLI policies generally do not cover the claims and lawsuits arising out of contractual agreements that need to meet a higher standard of care than required by law (Hickman 2013). There is no standard and uniform DPLI policy. Each insurance company offers its distinctive policy form. Thus, it is crucial to be aware of contract language, and the design professional should determine how to handle the unique project requirements and risks they assume (Hickman 2013).

The existing literature emphasizes significant differences in design professional liability between DB and DBB. However, it does not determine what subject-matter experts from different professional backgrounds think about design claims in the transportation infrastructure DB environment. There is a gap in the knowledge needed to understand better how different industry stakeholder groups perceive the risk of increased design claims in the transportation DB environment. Notably, there is little known about what industry groups think about the increased number of design claims due to the heightened standard-of-care terms typically found in transportation DB contracts. Also, the relative significance of design claim sources is not discussed in the current DB literature. There is also a need to identify potential sources of design claims and assess their relative importance from the viewpoints of different industry stakeholders.

2.2 Construction Quality Assurance

2.2.1 Quality Assurance Program in Alternative Delivery

One of the essential criteria to achieve project success is ensuring quality assurance (Chan et al. 2002). If the material and workmanship lack quality, it may fail to comply with specifications and contract requirements, leading to project failures such as cost overruns and delayed schedules on a highway project. Title 23, Part 637 of the Code of Federal Regulations (23 CFR 637) defines quality assurance (QA) as "all those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality" and requires each state department of transportation (DOT) to develop its own QA program (Federal Highway Administration (FHWA) 2017).

Transportation agencies have historically applied quality control/quality assurance (QC/QA) (or QA/QC), indicating that QC represents the contractor's responsibility and QA is the agency's responsibility. However, the transportation industry has moved away from the term QC/QA to refer to a quality assurance program because quality control is not a separate function from quality assurance (Federal Highway Administration (FHWA) 2008, 2012). Instead, QC is one of the core elements of a quality assurance program. Thus, QA refers to an overall system for assuring project quality (QAP).

The DB environment presents many unique challenges for ensuring project quality. Contractors are familiar and comfortable with the conventional QA process, especially when they know that the liability is transferred to the owner once the work is accepted (Transportation Research Board (TRB) 2006). Since the engineer-of-record works directly for the design-builder, the liability of design remains with the design-build team and, therefore, the contractor needs to be more cautious than earlier so that it can deliver the total project with the anticipated level of performance as outlined in the design developed by the design-build team (Gransberg et al. 2008; Transportation Research Board (TRB) 2006). To clarify roles, responsibilities, and quality-related activities when DOTs use DB contracting, the FHWA published the TechBreif, titled "Construction Quality Assurance for Design-Build Highway Projects," which recommends that DOTs use synthesized quality management programs by implementing quality assurance as an umbrella term with six core elements (Federal Highway Administration (FHWA) 2012): (1) quality control; (2) quality acceptance; (3) independent assurance (IA); (4) personnel qualification; (5) laboratory accreditation; and (6) dispute resolution.

An appropriate quality management approach for alternative delivery needs to be developed, even when the detailed designs and actual quantities are unavailable (Gransberg and Molenaar 2004). Design-build contracts are lump-sum contracts based on partially completed designs. Detailed designs and quantities of major line items are unavailable when the design-builder comes on board (Beard et al. 2001). The design-builder develops the cost estimate based on estimated quantities of different line items that may change throughout the detailed design development. The lack of detailed information about design elements and the actual quantities of different line items makes it challenging for state DOTs and design-build contractors to define a quality management program (Federal Highway Administration (FHWA) 2006).

QA practices for alternative delivery methods are not generally applied in traditional DBB projects (Harman and Sillars 2013). DB delivery methods are often used on large-scale, fast-paced development projects. This creates challenging constraints for QA personnel as they oversee extensive amounts of work on a rapid schedule. In DB projects, quality planners need to evaluate their risks (Ashuri et al. 2015). While major DB projects often carry large amounts of risk as high-budget, heavily used infrastructure, the rapidity of delivery tasks in the DB environment places additional stress on the QA process.

Additionally, the flexibility inherent to DB operations makes it difficult to predict exactly what a project's final designs will entail, generating uncertainty that must be accounted for when conducting QA and requiring post-construction quality management. It is critical for the DOTs to understand the unique requirements of projects because the state DOTs can tailor their approach to the DB environment (Gransberg and Molenaar 2004). These newer QA practices, primarily used for alternative project delivery methods such as DB, may be a key factor for project managers to consider when developing a whole quality assurance system (Harman and Sillars 2013).

2.2.2 Emerging Challenges in Quality Assurance Program

These unique environmental constraints are accompanied by structural changes governing the responsibilities of the owner and design-builder of projects (Ashuri et al. 2013). The highway agency does not retain the authority of the checks and balances found in DBB when the engineer-of-record is involved in the DB (Gransberg and Molenaar 2008, 2004; Lee and Arditi 2006). As the design-builder takes on additional responsibility over the project and assumes liability for design (Ashuri et al. 2019, 2021; Gransberg and Molenaar 2008), it also takes charge of the QC and quality acceptance of the project. In DBB projects, the contractor was only responsible for quality control, whereas the owner was responsible for quality assurance, acceptance, and independent assurance (Gransberg et al. 2008). In the design-build landscape, reporting lines have changed, and the roles and responsibilities have transcended from one stakeholder to another. The project owner (typically a DOT) minimizes its involvement in quality management and moves to an oversight role, leaving the design-builder in charge of quality control (QC) and quality acceptance.

The design-builder takes on an increasing role in the acceptance process. The owner relinquishes some of the responsibility and implicitly some liability to the design-build team. While in the DB environment, the project owner transfers quality acceptance responsibilities to the contractor (Gransberg et al. 2008b), the level of transfer and precise form of these steps in the QA process varies between state DOTs (Scott and Molenaar 2017). Some state DOTs still do QA in-house for DB projects, but most lack the staff and resources to take on this process and outsource it (Lee et al. 2020a). DB contractors take on the responsibility of QC themselves. Still, they need to hire an independent quality acceptance firm—a CQAF or an IQF—to fulfill other quality acceptance roles on the project (Ashuri et al. 2018).

The organizational structure of DOTs for quality management needs to adapt to the DB environment because several stakeholders are involved in the project (TRB 2006). (Kraft and Molenaar 2013) identified five different types of quality assurance organization (QAO) processes based on the magnitude of assignments of roles and responsibilities in project specifications. They found two distinct approaches to QAO: reactive and proactive. In a continuation of their work in 2015, project delivery methods are one of the factors that influenced the selection of QAO (Kraft and Molenaar 2015).

Other P3 methods in the DB environment come with their unique requirements. In DBF projects, the design-builder takes over project financing, allowing the project owner to defer payments until delivery (Federal Highway Administration (FHWA) 2020). This creates additional risk for the design-builder as they face new financial considerations and uncertainty associated with the project owner's future budgetary appropriations (Ashuri and Mostaan 2015). Similarly, DBFOM projects allow the design-builder to assume both the project's financing and responsibility for its long-term operation and maintenance (Ashuri and Mostaan 2014). This system comes with risks similar to DBF, but it also gives the design-builder a vested interest in the long-term quality of the project (Federal Highway Administration (FHWA) 2020). DBFOM incentives to maximize project performance, in the long run, can encourage design–builders to ensure high-quality QC and quality acceptance.

This added incentive to produce high-quality products can help ensure successful project QA, but P3 projects that do not have operations and maintenance components, such as DBF and standard DB projects, often lack adequate incentives for project quality in the QA process (Mostaan and Ashuri 2017). While the structural requirements of DB and other P3 delivery methods create many differences in how they must approach quality management, a deeper understanding of how QA functions for each alternative delivery method is needed.

2.2.3 Heterogeneous Quality Assurance Program

Finally, heterogeneous QA standards at different state DOTs give rise to additional ambiguity over the expectations for agents working on DB projects in multiple states. While state differences allow DOTs to be flexible and cater their QA processes to unique project requirements (Gransberg and Molenaar 2004), the lack of uniformity can make QA roles, responsibilities, and standards more difficult to follow for design–builders and CQAF personnel if DOTs fail to communicate their expectations explicitly.

Previous research identified that the requirement for quality management plans (QMPs) vary by the project owner and often look very different between different DOTs (Scott and Molenaar 2017). In the DB environment, state DOTs tend toward a different approach in which they request the DB team to propose a quality management plan for the

DB project and then evaluate the plan during the selection phase. (Scott and Molenaar 2017) further note that the practice for one DOT might not be acceptable for other DOTs, so design-builders are often required to submit QA plans for the DOT to review, as is suggested by (Federal Highway Administration (FHWA) 2012) and (Gransberg et al. 2008). Recent work by (Lee et al. 2020a) identified ten factors most commonly considered by state DOT personnel for selecting prospective DB teams through structured interviews with 12 different state DOTs. Those ten factors mentioned by DOT personnel included a quality manager as key personnel and a narrative form of quality management approach during the RFQ phase. Still, a systematic understanding of the QAP requirements explicitly specified in DB and P3 contract documents is lacking.

2.3 Rising Complexity of Transportation Megaprojects

2.3.1 Megaprojects

Transportation projects continued to increase in size and complexity. Many designers, engineers, and contractors have participated in the project delivery, and various multifunctional activities impact the project construction schedule (Mudholkar 2008). (Gharaibeh 2014) asserted that megaprojects are challenging, complex, and risky, inherent with many personnel and interfaces. A significant challenge for megaprojects is a lack of leadership and supervision in engineering and construction organizations (Gharaibeh 2014). (Zhu et al. 2020) also stated that megaprojects face a high degree of technical complexity, and their risks far exceed that of general projects.

2.3.2 *Increasing Needs for a New Leadership*

Since large and complex projects involve multidisciplinary parties on board, the projects devote trustworthy leadership to handle issues arising from the multidiscipline nature. Hollenbeck and Trott (2008) studied the lessons learned for a successful megaproject in the suggestion of hiring an engineering firm with a hands-on project manager supported by a technically competent and well-organized project engineer. Fischer et al. (2011) analyzed four case studies and found that success correlates with engineering. The authors emphasized that the industry needs competent, thoughtful, and well-educated engineers to ensure that field decision is made using the required level of technical analysis (Fischer et al. 2011).

Since multiple parties are involved in the engineering decision-making process, especially for large projects, there is a need for a position responsible for the overall integration of work and can handle multiple engineering disciplines and resolve engineering issues during the construction phase. This study noticed that some state DOTs have extensively adopted a new position as key personnel in their DB projects. The Virginia DOT (VDOT) Alternative Project Delivery Division recently started asking for a role titled entrusted engineer-in-charge (EIC), as key personnel on complex DB and P3 projects over $100M (VDOT 2018). As a registered professional engineer, the EIC should make engineering decisions as needed for the project and ensure that a professional engineer licensed in Virginia makes complex engineering decisions involving multidisciplinary work (VDOT 2019). Another critical responsibility is that the EIC should ensure that non-engineers do not make any engineering decisions (VDOT 2019).

Texas DOT (TxDOT), as part of its new quality organization, has defined a new professional service quality assurance manager (PSQAM) role. Requiring a professional engineer license, this position is in charge of all professional services, including design, environmental, utilities, right-of-way (ROW), and survey, for the DB corporate management team. During construction, the PSQAM should certify that the design change has been checked per the contract documents and review any design changes in the design package. The PSQAM works closely with an independent quality firm (IQF) manager to oversee all professional services in DB projects. The PSQAM and IQF manager have a dual reporting responsibility to both the design-builder corporate management team and the TxDOT project manager.

The Georgia DOT (GDOT) recently requested a new project chief engineer (PCE) position. According to a recently published request for qualification, this individual should verify that qualified discipline engineers sign and seal the work products and supervise all decisions throughout design and construction related to an engineering aspect. Also, the PCE is responsible for rejecting or approving the design work and resolving disputes regarding engineering work. The new position differs from the engineer of record, who is ultimately responsible for the design and certifies and stamps each drawing for the discipline in charge. It is also a different role than the design manager, who considers both design and construction simultaneously and manages the flow of information between different design disciplines and construction trades to satisfy the owner's performance objectives and meet the design-build contractor's goals. GDOT intends that this new position will ensure an appropriate standard of care is exercised in the engineering decision-making process on the design-build team through developing an integrative plan by stages and disciplines.

There has been no detailed investigation of a new leadership position in the DB team for large DB and P3 projects. Elevating the state of engineering decision-making practices in the design-build environment needs to be better understood by exploring opportunities offered by the new position in the design-build team. An urgent need exists to identify what specific qualifications and skillsets are critical for the success of the new position as key personnel in the dynamic design-build project delivery environment.

3. DESIGN LIABILITY

3.1 Introduction

In the DB environment, a single point of responsibility, a key feature of the DB contract, brings several benefits over the traditional DBB contract (Beard et al. 2001). To save time and costs, a design-builder can overlap design and construction activities and even initiate construction work before the design phase is complete (Ashuri et al. 2013). In DB, more roles and responsibilities have shifted from owners to design-builders (Loulakis et al. 2015). One critical risk factor in highway DB projects is design liability because responsibility for the design is transferred to the DB team (Ashuri et al. 2015, 2017a, b, 2018; Garvin et al. 2011; Gatti et al. 2014; Lee et al. 2020; Tran et al. 2013). This change can create problems determining who needs to bear responsibility when a dispute arises between the owner and the design-builder or between the design-builder and the design professional (Loulakis et al. 2015).

The (Design-Build Institute of America (DBIA) 2010) standard contract states, "[…] the Work shall be the care and skill ordinarily used by members of the design profession practicing under similar conditions at the same time and locality of the Project." On the other hand, it is precisely specified that the contractor's work has to be free of defects: "Construction that is of good quality, in conformance with the contract documents, and free of defects in materials and workmanship (Loulakis et al. 2015)". Because contractors and designers are held to different standards of care in the integrated environment of DB, the line between the liability of the professional design services and the liability of the construction work is often blurred (Allensworth et al. 2009). When utilizing design-build, the owner frequently includes the contractor's standard of care for both construction and design services. In this case, a design professional has to meet this heightened standard of care, which is above the designer's standard of care required by common law.

The existing literature addressed that design-build contracts can elevate design liability by including a heightened standard of care, which can cause a design liability insurance coverage gap in design-build. Problems that remain unsolved include how the industry practitioners understand the impacts of a heightened standard of care and the severity and frequency of the challenges related to design liability in the design-build transportation infrastructure industry (Lee et al. 2020b). It addressed the need to analyze the viewpoints of subject-matter experts from different professional disciplines regarding design claims in the transportation DB industry. Also, the relative significance of design claim sources is not discussed in the current DB literature. There is also a need to identify potential sources of design claims and assess their relative importance from the viewpoints of different industry stakeholders. Regarding heightened standard-of-care terms and conditions in transportation DB projects, the similarities and differences were investigated among opinions of SMEs from various industry groups. This chapter addresses the first research thrust and aims to identify the emerging challenges in transferring design liability in the design-build environment with the research question, “What are the emerging challenges in transferring design liability in the design-build environment?”

3.2 Research Methodology

Because of the interdisciplinary nature of the research, it was necessary to reach out to a wide range of subject-matter experts (SMEs) from multiple domains. Data collection from a questionnaire was used because it is a cost-effective and reliable means of gathering qualitative and quantitative data. A survey allowed this study to collect data across the U.S to capture several viewpoints from various professional groups. Figure 7 describes the overview of the research process. The methodology consisted of developing questionnaires for data collection and conducting statistical analysis.

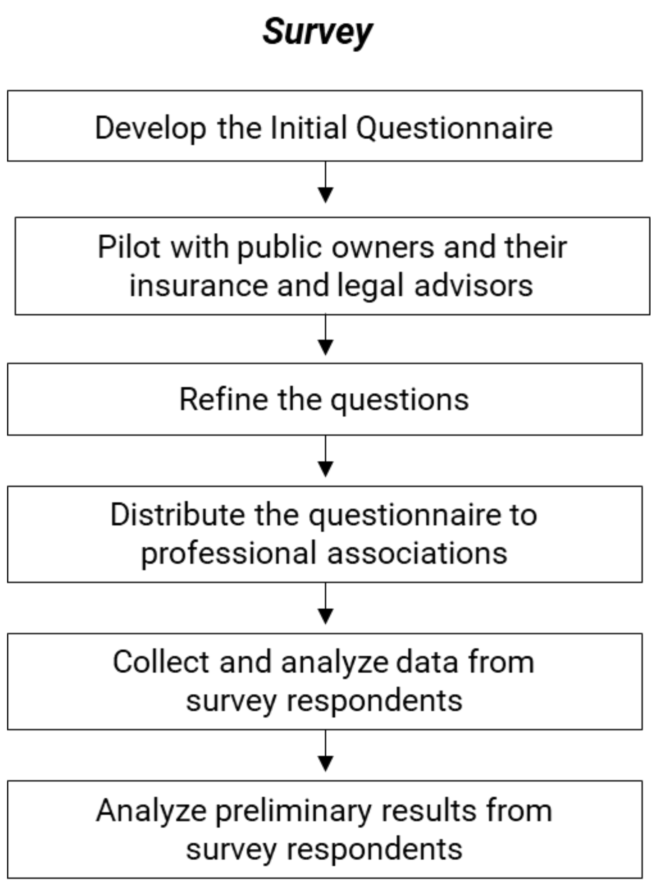


Figure 7 – Overview of Research Process – Design Liability

3.2.1 Questionnaire

This study developed the survey questionnaire to determine the challenges in design liability in the transportation DB environment. A literature review of previous studies was helpful in the creation of the questionnaires for this study. The initial questionnaire was piloted with several public owners and their insurance and legal advisors considered SMEs in the transportation design-build industry. The public-sector SMEs were heads of innovative program delivery in state DOTs in design-build. All SMEs have many years of experience developing transportation DB projects and are familiar with the fundamental challenges of professional design liability in the integrated delivery environment. The SMEs expressed great interest in the research and accepted the invitation of this study to review survey questions before the survey was widely disseminated. Those included in the pilot survey also participated in the final survey.

Overall, the feedback from the SMEs was positive. The SMEs confirmed that this study looked into the right areas of concern in the DB environment's professional design liability and insurance. A pilot survey ensured that these SMEs understood the questionnaire as this study intended. A few comments were made to enhance the readability of some questions. For example, one potential design claim source described in the initial survey was a *recovery of loss because of Spearin Doctrine*. To avoid any challenges in understanding this legal language, the SMEs suggested changing this source to a *recovery of losses due to defective owner-furnished documents*. Also, suggestions were made to add questions to the survey. For instance, several SMEs expressed their concerns about a coverage gap due to the heightened standard of care in the DB environment. This study added the following survey question to explore the scope of design professional liability insurance (DPLI) coverage: “Does a typical DPLI Policy of the engineering consulting firm cover design claims arising from failure to meet the clauses regarding the Heightened Standard of Care in the DB project?”

In addition to the question above, the survey participants were asked a specific question about design claims: “In your opinion, on average, is the number of design claims greater in DB projects compared to those in design-bid-build projects?” This survey question was added to identify their relative significance: “In your opinion, what is the relative importance of the following factors as the source of design claims against the engineering consulting firm in DB projects?” To rate the relative significance, the survey question used a four-point scale. Coming to the issue related to the standard of care, the survey participants were asked a question: “How often have you seen the following heightened standard of care in your design-bid-build (DBB) and design-build (DB) projects?” The four-point scale was used to measure the frequency. Another survey question regarding the challenges stemming from heightened-standard-of-care language investigated its impact on the number of design claims by asking, “In your opinion, has the heightened standard of care in DB contracts resulted in more design claims?” Following the SMEs’ suggestion to the initial questionnaire, the last question was added to determine the coverage issue regarding professional liability insurance: “Does a typical design professional liability insurance (DPLI) policy of the engineering consulting firm cover design claims arising from failure to meet the clauses regarding the heightened standard of care?”

3.2.2 Data Collection

This study made every effort to reach out to as many SMEs in the transportation industry as possible. The survey was distributed to the members of six professional associations and professional communities: (1) Design-Build Institute of America (DBIA) Transportation and Aviation Markets Committee; (2) American Society of Highway Engineers (ASHE); (3) American Society of Civil Engineers (ASCE) Construction Institute (CI); (4) International Risk Management Institute (IRMI); (5) Association for the Improvement of American Infrastructure (AIAI); and (6) American Council of Engineering Companies of Georgia (ACEC-GA). The distribution of the survey was done directly by these organizations. However, due to member privacy policies, these organizations did not share their email lists with the author. Therefore, this study was unsure how many professionals this survey had actually been sent to. Considering the large size of the membership in these organizations, it was confident that the survey had been distributed to a significantly large number of SMEs in the transportation industry. This study received 85 responses to the survey for further analysis.

3.2.3 Overview of Survey Participants

The questionnaire was distributed on the SurveyMonkey platform. Data collection was made from July 2018 to March 2019. A total of 85 respondents represented five professions: design consultants, highway contractors, public owners, owner representatives, and insurance and legal advisors. The nature of this research topic led to more attentive participation in the survey from the designer group than from the other groups. Figure 8 shows the response distribution: 63.53% are the design consultant group. Highway contractors and insurance and legal advisors each represented 10.59%. Public owners and owner representatives represented 9.41% and 5.88%, respectively.

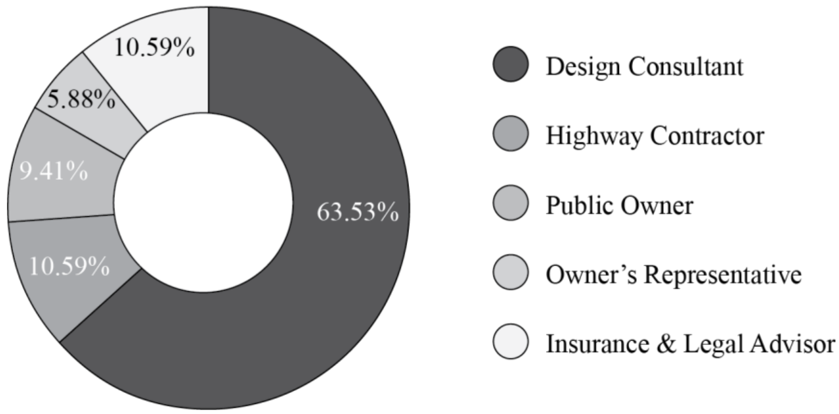


Figure 8 – Distribution of Respondents' Profession

It was necessary to obtain insights from SMEs with sufficient work experience in the transportation DB industry. Table 1 shows that almost half of the respondents from all professional groups had more than 10 years of experience in the DB method: 48.15% of design consultants, 44.45% of highway contractors, 62.5% of public owners, 80% of owner representatives, and 66.67% of insurance and legal advisors.

Table 1 – Survey Respondents' DB Work Experience by Professions

	More than 20 years	Less than 20 years	Less than 15 years	Less than 10 years	Less than 5 years
Design consultants	22.22%	18.52%	7.41%	24.07%	27.78%
Highway Contractors	44.45%	-	-	33.33%	22.22%
Public Owners	12.50%	-	50.00%	37.50%	-
Owner's Representatives	20.00%	40.00%	20.00%	-	20.00%
Insurance and Legal Advisors	44.45%	-	22.22%	11.11%	22.22%

3.2.4 Data Analysis Methods

This study only considered responses that were sufficiently complete for further analysis. Therefore, the first criterion for a high-quality answer was completeness in responding to all survey questions. Table 2 presents the data analysis methods that were used for assessing the statistical difference in perceptions regarding design liability across the professional groups, including (1) descriptive statistics; (2) relative important index (RII); and (3) the Mann-Whitney U test (U test).

Table 2 – Data Analysis Methods

Issue	Survey Question	Research Methodology
Design claim	In your opinion, on average, is the number of design claims greater in DB projects compared to those in design-bid-build projects?	Descriptive Statistics
	In your opinion, what is the relative importance of the following factors as the source of design claims against the engineering consulting firm in DB projects?	RII & U test
Standard of care	How often have you seen the following heightened standard of care in your design-bid-build (DBB) and design-build (DB) projects?	Descriptive Statistics
	In your opinion, has the heightened standard of care in DB contracts resulted in more design claims?	Descriptive Statistics
	Does a typical design professional liability insurance (DPLI) policy of the engineering consulting firm cover design claims arising from failure to meet the clauses regarding the heightened standard of care?	Descriptive Statistics

Regarding the design claim sources, this study used the relative importance index (RII) to identify the importance of claims sources collected through the survey. The RII method (Amarasekara et al. 2018; Awwad et al. 2016) was used to determine the overall importance of each claim source from the perspective of the survey respondents in each industry group. This index is calculated using Equation 1, where W is the weight given to each observable variable by the participants in the survey based on the Likert scale, A is the highest weight (4 in this survey), and N is the total number of participants.

$$RII = \sum W/A \times N$$

The greater the RII value for a claim source, the more important the claim source is from the perspective of that stakeholder group. The values were calculated for claim sources across the different professional groups and ranked from the highest to the lowest.

Nonparametric testing—the Mann-Whitney-Wilcoxon (MWW) test—was used to compare individual design claim sources in the different groups and determine if there was a statistically significant difference between each design claim source for each professional group. Nonparametric tests are typically used when the underlying survey data are not normally distributed or show significant skewness among respondents from different groups (Magdy et al. 2019). This study used the Mann-Whitney test, also known as the Wilcoxon rank-sum test, to examine whether the mean RII values differed among the different groups. Unlike parametric tests such as the student's t-test, Mann-Whitney does not require the assumption of normal distributions for the underlying data (MacFarland and Yates 2016), making it an appropriate hypothesis testing choice for the actual context of the survey responses. This test evaluates the null hypothesis that it is equally likely that a randomly selected value from one sample will be less (or higher) than a randomly selected value from another sample. The level of significance for the test was 0.05.

The respondents were also provided several opportunities to make additional comments under each question throughout the survey. This study considered the depth of response. For instance, some respondents provided valuable insights into the issue by explaining a particular choice. Some respondents provided real-world stories from actual cases they had been involved in. These respondents were identified as those with high-quality responses.

3.3 Results

3.3.1 Design Claim Issues in Design-Build Environment

3.3.1.1 Number of Design Claims

A single point of responsibility brings several benefits, such as shortened project duration and reduced cost over the traditional DBB projects (Beard et al. 2001). In addition to the benefits, the literature identified reduced claims as a desired feature of DB for the owner (Beard et al. 2001; Gransberg and Barton 2007; Levy 2006; Molenaar et al. 1999; Scott and Molenaar 2017). To obtain opinions from the SMEs in the transportation DB industry, they were asked the specific question: “In your opinion, on average, is the number of design claims greater in DB projects compared to those in design–bid–build projects?” Figure 9 shows the results of the question related to the difference in the perception of a reduced/increased number of claims for different parties.

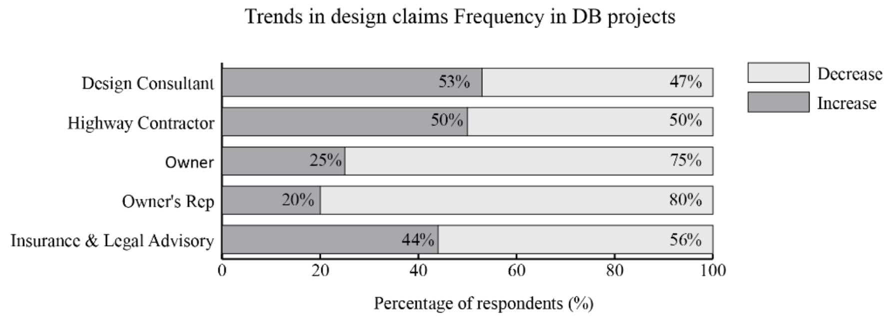


Figure 9. Perceived increase or decrease in the number of design claims in DB projects

Public owners, owner's representatives, and insurance and legal advisors responded that the DB method results in fewer design claims because the design-builder has a greater vested interest in design. The DB team has been able to integrate well as an actual team. The survey results by these groups align with the desired features of DB. Similar to those three groups, design-builders (highway contractors) think the DB contract may or may not increase design claims. They do not feel the difference because they are working in an integrated team with the designers, but, at the same time, they have full responsibility for both design and construction services.

Unlike the four groups mentioned above, the DB contract may not reduce claims from the designers' perspective. One of the respondents commented that the number of claims was significantly higher in DB than in DBB. However, because most claims were settled through mediation or arbitration, the increased claims were not public knowledge and were included in most comparison metrics. Some respondents were concerned that, because of the higher risk of the DB project by nature, the owner tried to shift the risk onto the DB team, and contractors (design-builders) seek to transfer risks and recovery to the designer when problems arise, regardless of fault, by using the designer's DPLI coverage.

In the DB environment, the contractor can file a direct claim against the designer because it lowers the bar for suits of alleged negligence against the designer.

3.3.1.2 Design Claim Sources

Based on the literature review, this study identified nine design claim sources throughout the different phases of DB projects. Table 3 shows the sources and the key studies that helped define them. This study interviewed SMEs and further refined the language used to describe design claim sources. To identify their relative significance, this survey question was added: "In your opinion, what is the relative importance of the following factors as the source of design claims against the engineering consulting firm in DB projects?"

Table 3 – Design Claim Source

Code	Design claim Sources	Key sources
C1	Engineer's negligence in preparing plans, drawings, designs, and specifications	(Vinet and Zhedanov 2011), (Pishdad and Garza 2012), (Construction Specifications Institute (CSI) 2011)
C2	Significant deviation of quantity estimates as the basis of cost estimation during the pre-award phase	(Avitabile et al. 2018)
C3	Recovery of losses due to differing site conditions	(Pishdad and Garza 2012), (Bartholomew 2001),
C4	Recovery of losses due to contractor's negligence in preparing the bid	(Avitabile et al. 2018)
C5	Recovery of losses due to contractor's faulty work during the construction phases	(Pishdad and Garza 2012), (Construction Specifications Institute (CSI) 2011)
C6	Inadequate investigation during the pre-award phase	(Gransberg and Loulakis 2016), (Loulakis et al. 2015),
C7	Failure to notice the contractor's important information during the pre-award phase	(Avitabile et al. 2018)

C8	Recovery of losses due to defective owner-furnished documents	(Pishdad and Garza 2012), (Construction Specifications Institute (CSI) 2011)
C9	Failure of an engineer to provide reasonable inspection during the construction phase	(Loulakis et al. 2015)

For further analysis, the RII method will be used to determine the overall importance of each claim source from the perspective of the survey respondents in each industry group. Table 4 shows the calculation breakdown for quantifying the relative importance of design claim sources from the perspective of each DB stakeholder: the design consultants, highway contractors, public owners, owner's representatives, and insurance and legal advisors. For each of the nine identified sources of the design claims, Table 3 shows what percent of each stakeholder group evaluates the factor as *extremely important, very important, important, or less important*. The above assessment categories are labeled by cardinal numbers 1-4: 1 represents "less important," 2 represents "important," 3 represents "very important," and 4 represents "extremely important." A selection approach based on a four-choice response option (an even number response) was used in the design of this survey to avoid a neutral response option. This survey design strategy helps minimize the concern that including a neutral option will affect the distribution of the responses and sometimes lead to different conclusions (Bertram 2017).

Table 4. Percentages of the importance of design claim sources

Claim sources	Design consultants (%)				Highway contractors (%)				Public owners (%)				Owner representatives (%)				Insurance and legal advisors (%)				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	n
C1	7.6	22.6	28.3	41.5	12.5	0.00	50.0	37.5	25.0	50.0	25.0	0.00	25.0	25.0	0.00	50.0	0.0	0.0	44.0	56.0	83
C2	15.1	30.2	26.4	28.3	0.0	25.0	12.5	62.5	0.0	50.0	37.5	12.5	20.0	20.0	20.0	40.0	0.0	22.2	66.7	11.1	83
C3	7.6	34.0	28.3	30.2	12.5	37.5	50.0	0.0	12.5	37.5	37.5	12.5	40.0	20.0	20.0	20.0	11.1	44.4	44.4	0.0	81
C4	23.1	28.9	15.4	32.7	62.5	12.5	25.0	0.0	25.0	25.0	37.5	12.5	20.0	0.0	80.0	0.0	0.0	33.3	44.4	22.2	82
C5	24.5	28.3	22.6	24.5	75.0	25.0	0.0	0.0	25.0	25.0	37.5	12.5	20.0	40.0	20.0	20.0	33.3	11.1	22.2	33.3	83
C6	15.1	41.5	20.8	22.6	0.0	37.5	62.5	0.0	12.5	37.5	12.5	37.5	20.0	20.0	20.0	40.0	11.1	77.8	11.1	0.0	83
C7	25.0	36.5	23.1	15.4	0.0	50.0	37.5	12.5	12.5	75.0	12.5	0.0	20.0	40.0	20.0	20.0	0.0	62.5	25.0	12.5	82
C8	26.4	34.0	22.6	17.0	25.0	37.5	12.5	25.0	37.5	37.5	0.0	25.0	20.0	40.0	20.0	20.0	22.2	66.7	11.1	0.0	83
C9	43.4	35.9	11.3	9.4	25.0	62.5	12.5	0.0	25.0	25.0	37.5	12.5	0.0	60.0	40.0	0.0	11.1	22.2	33.3	33.3	83

Note: 1 = less important; 2 = important; 3 = very important; and 4 = extremely important; C1 = Engineer's negligence in preparing plans, drawings, designs, and specifications; C2 = Significant deviation of quantity estimates as the basis of cost estimation during the pre-award phase; C3 = Recovery of losses due to differing site conditions; C4 = Recovery of losses due to contractor's negligence in preparing the bid; C5 = Recovery of losses due to contractor's faulty work during the construction phases; C6 = Inadequate investigation during the pre-award phase; C7 = Failure to notice the contractor's important information during the pre-award phase; C8 = Recovery of losses due to defective owner-furnished documents; and C9 = Failure of an engineer to provide reasonable inspection during the construction phase

The values of RII were calculated for claim sources across the different professional groups. The claim sources were ranked from highest to lowest for each professional group. Table 5 summarizes the overall rankings of the design claim sources for each stakeholder group.

Table 5. Ranked claim sources based on the calculated RII values for each professional group

	Design consultants		Highway contractors		Public owners		Owner's representatives		Insurance and legal advisors	
Rank	Claim Sources	RII	Claim Sources	RII	Claim Sources	RII	Claim Sources	RII	Claim Sources	RII
1	C1	0.755	C2	0.844	C6	0.688	C2, C6	0.700	C1	0.889
2	C3	0.703	C1	0.781	C2	0.656	-	-	C2, C4, C9	0.722
3	C2	0.670	C6, C7	0.656	C3	0.625	C1	0.688	-	-
4	C4	0.644	-	-	C4, C5, C9	0.594	C4	0.650	-	-
5	C6	0.627	C3, C8	0.594	-	-	C5, C7, C8, C9	0.600	C5	0.639

6	C5	0.618	-	-	-	-	-	-	C7	0.625
7	C7	0.577	C9	0.469	C8	0.531	-	-	C3	0.583
8	C8	0.575	C4	0.406	C1, C7	0.500	-	-	C6	0.500
9	C9	0.467	C5	0.313	-	-	C3	0.550	C8	0.472

The results show that professional groups have similar opinions on the most critical design claim sources. All groups, except the public owners, agreed that *C1: engineer's negligence in preparing plans, drawings, designs, and specifications* is the most or one of the most important sources when considering design claims. This appears to be a common source that triggers DPLI coverage. Federal and state court cases generally apply this rule, and failing to follow a professional standard of care can cause an unexpected overrun and be typically covered by DPLI policy (Koch et al. 2010; Loulakis et al. 2015). The design consultants (RII = 0.755) and the insurance and legal advisors (RII = 0.889) ranked this source as the most critical design claim source. This source was ranked second and third in highway contractors and owners' representatives, respectively. Unlike these four groups, the pubic owners ranked this claim source as the least important design claim source (RII = 0.500).

All parties agreed that *C2: significant deviation of quantity estimates as the basis of cost estimation during the pre-award phase* is one of the most important design claim sources, ranked in the top three important design claim sources. Since designers are responsible for the quantity risk in the DB environment, this becomes a unique issue in DB projects (Koch et al. 2010). To complete the project within the estimated budget, stakeholders need to perform cost engineering cross-checks and include design contingencies (Design-Build Institute of America (DBIA) 2017; Koch et al. 2010). To minimize this issue, the transportation industry has often implemented progressive design-build (Design-Build Institute of America (DBIA) 2017). In this way, the design-builder collaborates with the owner and their consultants during the preliminary phase of the project, which ensures that each party understands the project's basis of design, programming requirements, and transparent cost estimates (Design-Build Institute of America (DBIA) 2017).

Except for the two claim sources mentioned above, the results show that each professional group has different opinions regarding each claim source. *C3: recovery of losses due to differing site conditions* is the second and third most important design claim source among design consultants (RII = 0.703) and public owners (RII = 0.625), respectively. Compared to these two groups, the other three groups think that this design claim source is relatively less important, ranked fifth by highway contractors, seventh by insurance and legal advisors, and last by owner's representatives. Geotechnical uncertainty is usually high until the post-award site investigation and the completion of the geotechnical design report. To eliminate some of the risks of contingency, the differing site conditions (DSC) clause is recommended for use in the contracts (Gransberg and Loulakis 2016; Loulakis et al. 2015). The basic premise of the clause is to give a contractor cost and time relief if the contractor encounters a "materially different" condition during the execution of the work. (Loulakis et al. 2015) explained that the courts have been highly protective of a contractor's ability to obtain relief under this clause. In the case of *Foster Construction vs. The United States*, the court provided a clear explanation of the benefit of being protective of the contractor's ability to recover under the DSC clause: "Bidders need not weigh the cost and ease of making their own borings against the risk of encountering an adverse subsurface, and they need not consider how large a contingency should be added to the bid to cover the risk. The Government benefits from more accurate bidding, without inflation for risks which may not eventuate" (Loulakis et al. 2015). However, risk allocation approaches under DSC clauses are varied by agencies. For example, the Washington DOT has set a monetary ceiling, and the agency only owes the risks above the indicated amount in the contracts (Gransberg and Loulakis 2016; Loulakis et al. 2015).

C4: recovery of losses due to contractor's negligence in preparing the bid was the second most significant source among the insurance and legal advisory group. This source is ranked fourth by the groups of design consultants, public owners, and owner's representatives. However, the highway contractors consider this claim source the second least important source. (Hatem and Gary 2017) highlighted that claims arise when there are material differences between the design–builder's pre-award bid estimate assumptions and the actual cost. This is usually due to aggressive, unrealistic, and opportunistic bidding by the design-builder. Pre-award cost estimating may or may not include a design development contingency.

C5: recovery of losses due to contractor's faulty work during the construction phases is ranked relatively less important among all groups. The highest rank of this source is the fourth by public owners. This source is difficult to prove whether the design or construction causes design problems and to cover faulty workmanship to fix construction errors and omissions under insurance coverage (Loulakis et al. 2015) (XL Catlin 2016). Although contractors are required to hold a commercial general liability (CGL) policy, the CGL policy will not reimburse the design-builder for these expenses, based on common exclusions in the policy: "Your Work" and "Professional Liability" (Loulakis et al. 2015). Because of this professional liability exclusion, some owners, such as Arkansas and Texas DOTs, require the design-builder to purchase Contractor's Professional Liability Insurance or Contractor's Protective Professional Indemnity that provides coverage for losses arising from professional negligence by the design-builder's self-performed design work (Arkansas Department of Transportation 2018; Texas Department of Transportation 2018).

C6: inadequate investigation during the pre-award phase is ranked the highest among the groups of the pubic owners (RII = 0.688) and owner's representatives (RII = 0.700). Highway contractors selected this as the third most important source (RII = 0.656). However, the other two groups of design consultants and insurance and legal advisors respond that this source is less important. Unlike DBB, the designer may perform design development under pressure, such as an accelerated pace or compressed schedule (Hatem and Gary 2017). To deal with this tightened schedule, the Virginia Department of Transportation (VDOT) utilizes a "scope validation period." The design-builder can investigate and identify "scope issues" that will materially impact their proposed work within the contract price or contract time (Virginia Department of Transportation 2016). The design-builder is given 120 days after the contract award to present claims regarding "scope issue," and the design–builder's rights are waived after the scope validation period (Loulakis et al. 2015).

Concerning *C7: failure to notice the contractor's important information during the pre-award phase*, the group of the highway contractors (RII = 0.656) is higher than the other groups. The other four groups do not select this claim source as the top rank. Since the source itself represents the crucial role of the contractor, the highway contractor group may consider this source a potential claim issue. (Avitabile et al. 2018) suggested that timely notification and documentation regarding claims can be a good strategy for successful practice in DB.

C8: recovery of losses due to defective owner-furnished documents also was not selected as a top claim source among all groups. However, it is essential that the Spearin doctrine still applies to DB projects where an owner provides a detailed specification reasonably relied upon by a bidder to the bidder's detriment (Loulakis et al. 2015). Although the owner is trying to use "weasel words" such as disclaimer, the owner does not get rid of its implied warranty of the sufficiency of its design in DB projects. The owner assumes the risk of the mistakes under the elements of the Spearin doctrine. According to the email interview with one of the attorneys at law, the Spearin doctrine applies if the following aspects of Spearin are met: (1) the contractor was obligated to follow the design provided by the owner, (2) the contractor reasonably relied upon the design, which (3) result in either (i) an unacceptable project (defensive use of Spearin) or (ii) caused the contractor to incur additional cost or time or both trying to work with the defective design. The contractor assumes the risk of mistakes if the elements of Spearin are not met, which would be the case where the design-builder provides the design (Anonymous, personal communication, May 14, 2018). As mentioned above, one example of reflective practices to address this issue is "scope validation" from VDOT. The design-builder is given 120 days after the contract award to present claims related to deficiencies in owner-furnished information (Loulakis et al. 2015).

The groups of the public owners and insurance and legal advisors felt *C9: failure of engineer to provide reasonable inspection during the construction phase* is an important design claim source. (Loulakis et al. 2015) addressed that the owner faces challenges in proving the designer's responsibility for discovering defective construction work during an inspection. However, the courts have rejected the role of design professionals as the guarantor of the quality of construction unless specific contract language requires (Loulakis et al. 2015). Based on the collective knowledge of a professional negligence standard, the design professional's inspection obligation is to perform a reasonable inspection given its contractual inspection of the scope of work (Loulakis et al. 2015).

The results of RII show that professional groups express similar and different opinions on each claim source. Table 6 shows the skewness values of responses from subject matter experts in five professional groups for each of the nine design claim sources. This study used the recommendation made by (Hair et al. 2014) to identify the skewness in the survey responses. Hair et al. (2014) show skewness values within the range of −1 and +1 indicate a substantially skewed distribution. This criterion can be recognized that the responses of subject matter experts in each group for evaluating the relative importance of design claim sources show significant skewness as most calculated skewness values are within the range of -1 and +1. Only four (out of 45 values) in the table do not indicate the skewness of survey responses.

Table 6. Skewness values of responses received from subject matter experts in five professional groups for each of the nine design claim sources

Claim sources	Design consultants	Highway contractors	Public owners	Owner's representatives	Insurance and legal advisors
C1	0.205	-1.486	0.000	-0.370	-0.271
C2	0.205	-0.999	0.824	-0.541	-0.018
C3	0.205	-0.824	0.000	0.541	-0.606
C4	0.177	0.999	-0.045	-2.236	0.216
C5	0.205	1.440	-0.045	0.405	-0.152
C6	0.205	-0.644	-0.090	-0.541	0.000
C7	0.177	0.824	0.000	0.405	1.323
C8	0.205	0.394	0.876	0.405	-0.018
C9	0.205	0.068	-0.045	0.609	-0.552

For each claim source, several pairwise Mann–Whitney U Tests were conducted to determine whether the identified rank of the claim sources is significantly different across each group of the respondents.

After identifying similar and different opinions on each claim source, several pairwise Mann-Whitney U tests will be conducted to determine whether the identified rank of each claim source is significantly different across the independent variables (i.e., professional groups). This study designs two hypotheses:

1. Null hypothesis (H_0): the two professional groups exhibit no significant difference; and
2. Alternative hypothesis (H_A): the two professional groups exhibit significant differences.

The level of significance (critical value) is designed to be 0.05. When the U value exceeds the critical U value by the significance level ($p = 0.05$), the null hypothesis can be rejected, indicating the two professional groups hold different views on the factor. The objective of the U test is to identify potential variance of perceptions of design claim sources across professional groups. This study is expected to identify several claim sources that each professional group has conflicting perceptions. Table 7 summarizes those pairwise comparisons for which the Mann-Whitney U tests were rejected. Therefore, the identified ranks were significantly different among the two groups of respondents for claim sources.

Table 7. Results of Mann–Whitney U Tests to compare statistical differences among group respondents for design claim sources

Claim sources	Group comparisons			*p*-value
C1: Engineer's negligence in preparing plans, drawings, designs, and specifications	Design professional	vs.	Public owners	0.0087
	Highway contractors	vs.	Public owners	0.0250
	Public owners	vs.	Insurance & legal advisors	0.0016
C4: Recovery of losses due to contractor's negligence in preparing the bid	Highway contractors	vs.	Insurance & legal advisors	0.0160
C5: Recovery of losses due to contractor's faulty work during the construction phases	Design professional	vs.	Highway contractors	0.0036
	Highway contractors	vs.	Public owners	0.0269
	Highway contractors	vs.	Owner's representatives	0.0283
	Highway contractors	vs.	Insurance & legal advisors	0.0431
C6: Inadequate investigation during the pre-award phase	Highway contractors	vs.	Insurance & legal advisors	0.0308
C9: Failure of an engineer to provide reasonable inspection during the construction phase	Design professional	vs.	Insurance & legal advisors	0.0089
	Highway contractors	vs.	Insurance & legal advisors	0.0436

The results show that five of the nine claim sources are statistically different among the respondent groups. For example, the highway contractors have significantly different opinions about the relative importance of "C5: recovery of losses due to contractor's faulty work during the construction phases" as a claim source in transportation DB projects compared to the other four groups of respondents. Both design professionals and highway contractors have significantly different opinions about "C9: Failure of an engineer to provide reasonable inspection during the construction phase" as a claim source in transportation DB projects, compared to insurance and legal advisors. It is noteworthy that the test results do not show any significant differences between the opinions of public owners and owner's representatives on the relative ranking of any design claim sources.

3.3.2 Heightened Standard of Care

3.3.2.1 Heightened standard of care languages in DB and DBB

The DB contract can result in a change in the engineer's standard of care compared with that in traditional DBB projects (Friedlander 1998). The added legal repercussions for DB teams can also raise the standard of care for engineers (Coble and Blatter Jr 1999). A survey question was devised regarding the heightened standard of care that the engineer is held to through a contractual agreement. This question aimed to determine whether the heightened standard of care exists in DBB and DB and how frequently the different languages appear in DBB and DB. In addition to the literature review, the study retrieved the typical heightened standard of care languages from the *National Cooperative Highway Research Program (NCHRP) Legal Research Digest 68: Liability of Design-builders for Design, Construction, and Acquisition Claims*. The survey question investigated the following four typical heightened-standard-of-care phrases:

A. Ensuring your design is in compliance with "applicable laws, statutes, ordinance, codes, rules, and regulations, or any lawful orders of public authorities."
B. Ensuring your design is "free of errors, omissions, and defects."
C. Achieving a specific performance standard for any aspect of the work.
D. "Warranting" your design for fitting the intended purpose

Figure 10 shows the responses to the question: "How often have you seen the following Heightened Standard of Care in your Design–Bid–Build (DBB) / DB (DB) projects?" The results show that every heightened standard of care language is always more frequent in DB projects than in DBB projects.

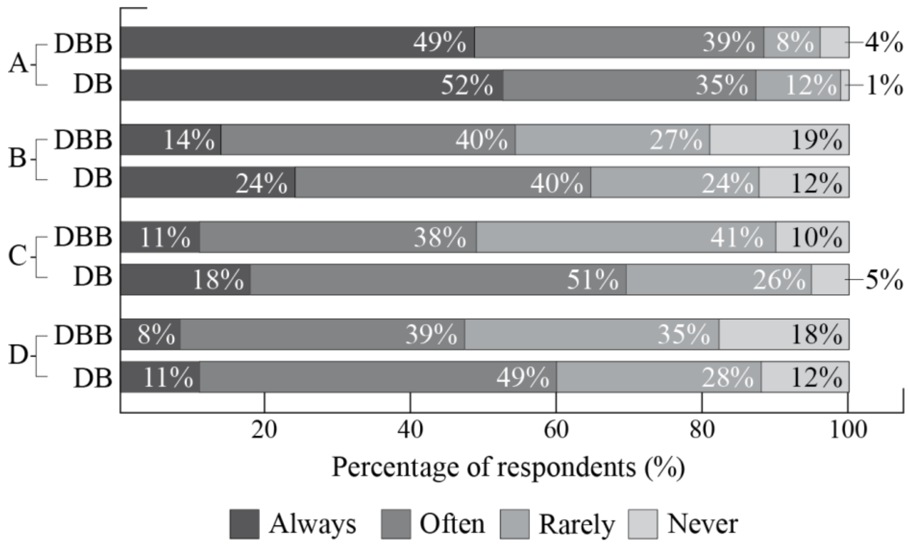


Figure 10. Typical heightened standard of care languages

This confirms the observation of the heightened standard of care in DB projects. The frequency rank of each language is the same in both DBB and DB projects. In other words, those languages, which are in a higher position in DBB projects, exist at the same rank level in DB projects. As shown in Figure 10, "A. Ensuring your design complies with applicable laws, statutes, ordinance, codes, rules, and regulations, or any lawful orders of public authorities" is the most common heightened standard of care language. Of the respondents who selected this language, 52 and 49 percent think the frequency of the language is "always" in DB projects and DBB projects, respectively. "D. Warranting your design for fitting the intended purpose" is the least common heightened standard of care language. Only 11 and 8 percent of the respondents who selected this language thought the frequency of the language is “always” in DB projects and DBB projects, respectively.

Apart from rating the frequency of the given languages, the respondents provided some other heightened standard of care languages that they have experienced before. For instance, “[the design] will achieve ‘best in class’ performance”; “instruments of Service shall be fully coordinated, and 100% complete”; “the designer has an explicit duty to defend the contractor”; and “the designer is responsible for liquidated/consequential damages.”

As mentioned earlier in this study, the root of the heightened standard of care language is, in fact, an intention of the flow-down of liability. One of the comments under this question indicated a heightened standard of care languages in contracts between a design-builder and the designer. At the same time, they are the contractual obligations between the owner and the design-builder. The design–builder’s intention to flow the liability to the designer through the heightened standard of care language is very unfavorable to the designer. One of the design consultant respondents commented that the contractual language such as “fitness for purpose” has to be promised by the contractor. Still, it does not mean the engineering firm will agree to flow down to the design subcontract. As stated in the comment, “[a] prudent engineering firm will not be accepting heightened standard of care in their design subcontracts regardless of what a Prime is signing up to in the prime agreement with the Owner.” Two other design consultant respondents share the same opinion on this issue, mentioning that they will not allow the certain heightened standard of care language to remain in their contract.

3.3.2.2 Influence of heightened standard of care languages on design claims

Followed by the survey question that asked about the observation of the heightened standard of care in DB and DBB projects, another survey question regarding the challenges stemming from the heightened standard of care investigated the impact of the heightened standard of care languages on the number of design claims. Table 8 shows the response to the question: "In your opinion, has the Heightened Standard of Care in DB contracts resulted in more design claims?" More than half of respondents in four groups—design consultants, highway contractors, owner's representatives, and insurance and legal advisors—indicated that heightened standard of care in DB contracts definitely or probably resulted in more design claims. In other words, most of the respondents from these groups think the heightened standard of care in DB contracts has resulted in more design claims. The owner group shows an opinion contrary to all the other professional groups. Only 34 percent of the owners think that the heightened standard of care leads to more design claims. None chose "definitely;" all 34 percent are from those selecting "probably."

Table 8. Results for Question by Professional Groups: Has a heightened standard of care in design-build contracts resulted in more design claims?

Professional groups	Definitely	Probably	Probably not	Definitely not	I do not know
Design consultants	20%	36%	21%	4%	19%
Highway contractors	11%	45%	22%	0%	22%
Public owners	0%	34%	11%	22%	33%
Owner's representatives	20%	40%	20%	0%	20%
Insurance and legal advisors	0%	50%	25%	0%	25%

The divergence of the owner responses compared with the other professions for this question shows consistency with the change in the number of design claims. Of the owner and owner's representative groups, 75 and 80 percent responded with a decrease in the number of design claims, while all other professional groups' results show around 50 percent. Previous literature regarding public and private sector attitudes toward DB provides an idea of why such divergence exists. (Songer and Molenaar 1996) stated that DB projects were the owner's shelter from liability. The engineer does not perform as the agent of the owner but as an entity in the DB team. Design errors and omissions are solely the responsibility of the design-builder and are resolved by the team. Therefore, the number of design claims is reduced from the owner's side. From the comments on the survey question, the heightened standard of care languages in a contract between the design-builder and the designer are contractual obligations between the owner and the design-builder. The owner cannot see the flow-down of liability from this.

As opposed to the owner's opinion, the majority of the other groups responded with an increase in design claims because of the heightened standards of care. As a design consultant respondent commented, "[h]eightened SOC [standard of care] makes it easier for an Owner or Contractor to allege breach of contract or negligence and means more discovery, more defense costs, and more time involved in an engineer or their carrier defending themselves." Another design consultant respondent raised a point on this that, in large DB projects, these issues can easily result in claims, making the design firms hesitate to become involved in DB projects.

3.3.2.3 Gaps with DPLI coverage as to heightened standards of care

If DPLI cannot cover the heightened standards of care, this coverage gap would become a significant challenge to the design consultant. A survey question is developed to determine the coverage issue regarding DPLI: "Does a typical Design Professional Liability Insurance (DPLI) Policy of the engineering consulting firm cover design claims arising from failure to meet the clauses regarding the Heightened Standard of Care in the DB project?" Figure 11 shows the result from different professions.

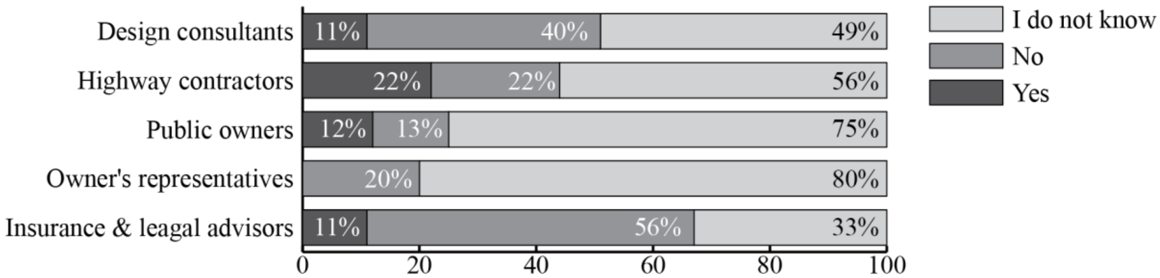


Figure 11. DPLI's Coverage Scope Regarding Heightened Standard of Care

Apart from the insurance and legal advisory group, the majority of the respondents from the groups of design consultants, highway contractors, public owners, and owner's representatives selected "I don't know." Insurance and legal advisors show the most knowledge regarding this issue, with only 33 percent of the group selecting "I don't know." The design consultant and highway contractor groups have 49 and 56 percent of responses, respectively, who do not know the issue, while the owners show even less knowledge; 75 percent of the owners and 80 percent of the owner's representatives selected "I don't know." Among those who chose "yes" or "no," respondents who think the heightened standard of care cannot be covered in the significant majority, while some of the respondents in each group think otherwise.

The results found a significant existing issue. Many professionals in this industry are not familiar with the scope of DPLI coverage. This gray area seems to be a critical issue for DB projects. Survey respondents did not specify any particular instances that their insurance providers denied their claims due to the issue of the heightened standard of care. One respondent mentioned that they know DPLI covers only negligence based on the industry standard of care but has not seen a situation where their insurer has attempted to deny coverage based upon a heightened standard of care. Another respondent indicated a similar case where their insurance policy usually is okay with this issue but generally depends on the policies. Some responded that insurers are charging an additional premium because the DPLI policies for DB projects are out of their standard. Four respondents who answered "no" indicated that heightened standard of care is uninsurable when industry standard and commercially available DPLI is only triggered by professional negligence.

3.4 Chapter Conclusion

This study found that DB project delivery has challenged design liability issues in the DB environment. To identify emerging design professional liability issues, this study surveyed SMEs in the professional associations and interviewed the respondents who accepted the follow-up interviews. The overarching results show that industry professionals hold different perceptions and understandings of these issues based on their experiences in the DB projects. The findings of this study provide insights into two major areas of design liability in the DB transportation industry: key issues of design liability and a heightened standard of care.

The key issues of design liability consist of two subsets. First, the respondents provided different opinions on whether DB contracting increases or decreases the number of design claims. Public owners, owner's representatives, and insurance and legal advisors responded that the DB method results in fewer design claims because the design-builder has a greater vested interest in design, while the designer's perspective does not align with the three groups. Highway contractors, however, do not feel the difference between DB and DBB. Second, the respondents expressed different opinions determining important design claim sources in the DB industry. Among the nine claim sources, one of the most important design claim sources was "*C2: significant deviation of quantity estimates as the basis of cost estimation during the pre-award phase*." Professional groups have similar opinions on this source. However, the professional groups expressed different views on the remaining eight claim sources except for this source. Some sources emphasize the importance of specific professional groups' roles or are more relevant to their responsibilities. For instance, *C5: Recovery of losses due to contractor's faulty work during the construction phases* itself represents the critical role of contractors. The MWW test results show that highway contractors statistically differ from the rest of the professional groups. Overall, the survey results indicate that all nine design claim sources are important and need to be considered. The findings also show that the highway industry has attempted to handle these challenges with new practices, such as the "scope validation" process used by Virginia DOT, the emerging progressive design-build method, and additional insurance policies.

One of the key issues related to design liability in the DB environment is a heightened standard of care. This is because DB projects have a completely different contractual structure where the engineer acts as a design consultant in the DB team, instead of the owner, so that the engineer is now held to the contractors' (i.e., design-builder) promise or warranty. This study found that a heightened standard of care languages was more frequent in DB projects than in DBB projects. Four of five professional groups indicated that a heightened standard of care in DB contracts definitely or probably resulted in more design claims. In contrast, the owner group only thought that the heightened standard of care might not lead to more design claims. The results also show that many professionals in the highway industry are not familiar with the scope of DPLI coverage in DB projects or whether a change of project delivery method would make a different DPLI coverage. Since typical DPLI policies do not respond to designers' professional negligence above the common law standard of care, the study emphasizes the importance of monitoring the contract languages and ensuring satisfactory are necessary for DB projects.

4. CONSTRUCTION QUALITY ASSURANCE

4.1 Introduction

The DB project delivery introduces emerging challenges to the overall quality of projects. In addition to extra responsibilities for the project design liability falling on the design-builder, they also accept the duty of quality control (QC) and quality acceptance (Ashuri et al. 2019, 2021; Lee et al. 2020a). Without the project owner exercising direct control over the project, quality acceptance must be completed by an independent party, such as a CQAF, which is outsourced by the design-builder. While the design-builder directly contracts the CQAF, it is intended to represent DOT interests, so its independence from the contractor remains paramount. This outside firm is directly responsible to the public and has a powerful position over the project process, but contracting it by the design-builder introduces the potential for principle-agent problems and perverse incentives to arise if it does not understand its status as fully independent. Once the CQAF has completed its quality acceptance process on the project, it must be verified by an external review (Ashuri et al. 2018b).

Furthermore, as the roles of the project owner and design-builder shift, the responsibilities of project personnel change, creating ambiguity over what needs to be done to ensure effective QA. Institutional norms and organizational expectations can hinder effective workflow if project personnel are slow to adapt to new expectations or struggle to understand their new responsibilities in the new environment. Understanding the extent and ramifications of these challenges in the DB environment is critical to ensure that the new processes and institutional arrangements these innovative delivery systems bring do not undermine the high standards of quality on public infrastructure projects in the U.S. To identify and analyze understanding gaps in alternative QAP between public owner's expectations and the industry's perception, this chapter addresses the following research question: "Do the public owners and the industry practitioners understand the roles and responsibilities of the construction quality assurance program in the design-build environment?" Research Methodology

4.2 Research Methodology

This study applied a mixed-method approach, combining quantitative and qualitative techniques to identify understanding gaps in QA in the innovative project delivery environment. The data in this study came from two primary sources: a survey and semi-structured interviews. Using quantitative survey data and following up with interviews who participated in the survey helps explain the reasons behind and meaning of the quantitative survey analysis (Creswell and Clark 2014). Figure 12 describes the overview of the research process.

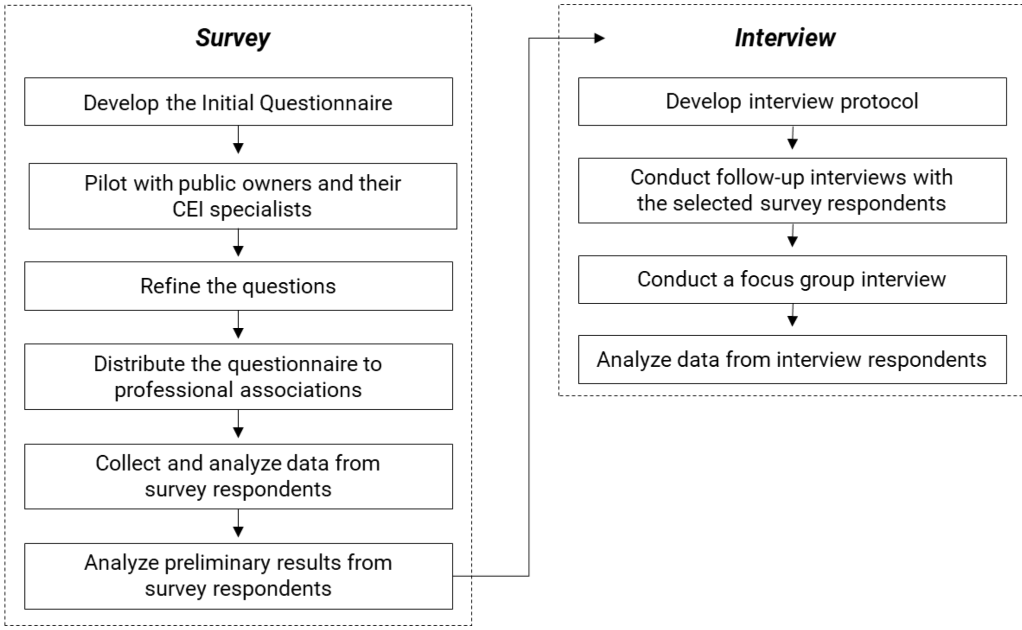


Figure 12 – Overview of Research Process: Construction Quality Assurance

4.2.1 Survey

4.2.1.1 <u>Questionnaire</u>

This study developed a set of initial questionnaires as the first step to better understand the industry perspectives of quality management among different professional groups in the alternative delivery environment. This study refined the questions by conducting dry-run interviews with selected subject-matter experts (SMEs) to ensure that the questions were crafted and the anticipated responses reflected the intent of the research. The initial questionnaires were sent to several public owners and CEI specialists. All SMEs have many years of quality management in the context of the innovative delivery environment.

Overall, the feedback from the SMEs was positive that the survey respondents provided answers under two situations: "when CEI firm is hired by the design-builder" versus "when CEI firm is hired by the DOT." A pilot survey ensured that these SMEs understood the questions this study intended. A few suggestions were made to enhance the quality of the survey to better capture the viewpoints of the CEI industry. For instance, the initial questionnaires included questions related to claim sources. The SMEs agreed with the importance of the claim questions, but they felt that these questions were not particularly relevant to the CEI firms. To avoid any confusion about the scope of the survey, this study removed those questions from the initial questionnaires. The refined set of questions was used to gain and collect information about the current quality management practices in the alternative delivery environment.

4.2.1.2 Data Collection

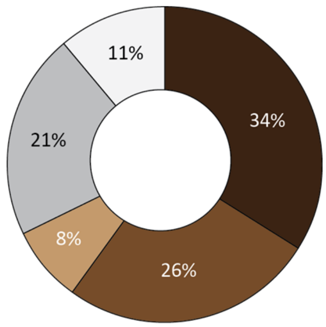
To examine construction quality management practices in the alternative project delivery environment, the survey was distributed on the Qualtrics platform to a broad range of professional associations to achieve high-quality responses from SMEs. The nine professional associations that engaged in the survey were as follows: (1) American Council of Engineering Companies of Georgia; (2) American Council of Engineering Companies of Georgia Partnership for Transportation Quality (GPTQ) Task Force; (3) American Society of Civil Engineering Claims Avoidance and Resolution Committee; (4) American Society of Civil Engineering Construction Institute Board of Governors; (5) American Society of Highway Engineers; (6) DBIA Transportation and Aviation Markets Committee;

(7) DBIA P3 Committee; (8) Transportation Research Board Committee on Quality Assurance Management (AFH20); and (9) Transportation Research Board Joint Subcommittee on Quality Management for Alternative Project Delivery (AFH20 (1)).

The above organizations directly distributed the survey but did not share the email lists of those who received it due to their member privacy policies. Considering the large size of the membership in the organizations, it was confident that this survey had been distributed widely to a considerable number of SMEs within the organizations in the transportation industry. The survey was distributed on the Qualtrics platform. This study received many responses to the survey, of which 53 were complete and ready for further analysis.

4.2.1.3 Overview of Survey Participants

A total of 53 represents five professional groups: agency employees (i.e., DOT staff), CEI specialists, design consultants, general contractors, and owner's representatives. Figure 13 shows the professional groups of the survey respondents. The most participating professionals belonged to the design consultant and CEI groups, representing 34% and 26%. Followed by those groups, public owners and owner representatives represented 21% and 11%, respectively.



Distribution of Respondents' Profession

Survey respondents' DB work experience by professions

Profession	Traditional Quality Management Only	Alternative Quality Management Only	Both Quality Management Models
Design consultants	25%	31.25%	43.75%
CEI Specialists	14.29%	7.14%	78.57%
Highway Contractors	75%	N/A	25%
Public Owners	90%	N/A	10%
Owner's Representatives	16.67%	16.67%	66.67%

Figure 13 – Distribution of Respondents' Profession

It was necessary to obtain insights from SMEs with sufficient work experience in the transportation DB industry. About 8% of the total respondents represent highway contractors. Approximately 45% of the respondents have worked in their current professions for over ten years. Through their experience providing construction quality management services, approximately 40 percent have experience in the traditional quality management model (hired by DOTs) and the CQAF model (employed by the design-builder). Participants' various professional backgrounds, years of experience, and familiarity with the two quality management models added validity and robustness to the survey results.

4.2.1.4 <u>Data Analysis Methods</u>

By sampling CEI respondents from professional groups around the U.S., this study was able to gather a robust dataset to conduct our analyses. The survey analysis allows this study to identify discrepancies between how CEI firms understand their roles in QA and what DOTs expect from them, describe the major challenges facing effective implementation of QA in the DB environment, and determine appropriate strategies for improving the process.

This study first aimed to investigate respondents' views on the stringency of quality acceptance decisions when the design-builder employs them, compared to the typical enforced level of stringency when the state DOT directly hires the CEI firms for quality management. The survey question asked, "On average, how stringent are the acceptance decisions of the CEI firm when it is directly hired by the design-builder compared to the typical level of stringency enforced when it is directly hired by the state DOT?" by using a 5-point Likert scale: Substantially more lenient; Somewhat more lenient; about the same; Somewhat more stringent; Substantially more stringent. Descriptive statistics, Kruskal–Wallis (one-way ANOVA on ranks), and post-hoc (Dunn's test) are used to determine differences in perceptions toward alternative quality management models. This study examined whether all five professional groups of respondents perceived the stringency of quality acceptance as similar or different depending on QA models. Hence, the following null and alternative hypotheses were developed:

- H_0: There are no differences in research participants' perception of the stringency of quality acceptance
- H_A: There is a difference in research participants' perception of the stringency of quality acceptance

Once the Kruskal-Wallis test has found a significant difference in five professional groups, Dunn's Test can be used to pinpoint which specific professional groups are significant from the others. The null hypothesis for the test is that there is no difference between professional groups. The alternate hypothesis for the test is that there is a difference between groups.

To identify gaps in understanding of CEI firm's roles and responsibilities among professional groups, this study asked, "How frequently is the CEI firm responsible for the following tasks in federal-aid design-build projects?" By conducting Kruskal–Wallis test (one-way ANOVA on ranks), This study examined whether all five professional groups of respondents perceived similar or different opinions on CEI roles and responsibilities in traditional and alternative QA models. To do so, the following null and alternative hypotheses were developed:

- H_0: There are no differences in research participants' perception of CEI roles and responsibilities
- H_A: There is a difference in research participants' perception of CEI roles and responsibilities

After the Kruskal-Wallis test has found a significant difference among five professional groups, Dunn's Test can be used to pinpoint which specific professional groups are significant from the others. The null hypothesis for the test is that there is no difference between professional groups. The alternate hypothesis for the test is that there is a difference between groups.

4.2.2 Interview

4.2.2.1 Interview Protocol

This study followed the survey analysis with in-depth interviews and embedded qualitative analysis of experienced CEI perspectives. This research step builds from the survey analysis by exploring its most critical topics in more depth. After completing the survey, this study selected a subsample of experienced respondents and conducted semi-structured interviews to reveal their understanding of QA topics introduced in the survey. This provides the opportunity to pursue survey themes in more detail and explore new questions that the survey responses raise.

This study conducted two interview processes: semi-structured individual interviews and a focus group interview. For the individual interviews, the interviewees were asked to address a series of predetermined but open-ended questions to identify understanding gaps in the roles and responsibilities of the CEI firms depending on their employer. Predetermined questions included whether the CEI firm is responsible for the tasks, indicating discrepancies in the survey analysis and whether they experienced any changes in the CEI firm’s responsibility when the CEI firm is hired directly by the design-builder versus the DOT. The questions differed based on the context and setting of each interview.

Followed by the individual interviews, this study conducted a focus group interview. Predetermined discussion topics included whether the CEI firm is responsible for the tasks in the survey, why the survey respondents have inconsistent perspectives on the CEI firm’s typical roles, and how state DOT could help minimize the understanding gaps. Still, a focus group interview allowed a dynamic and free conversation among the nine SMEs. This focus group interview aimed to gather descriptive narratives regarding QA topics raised from the survey topics to obtain more in-depth perspectives and examine the validity of survey results.

4.2.2.2 Overview of Interview Participants

After creating the interview protocol, this study reached out to individuals who voluntarily provided their contact information in the survey. Figure 14 describes a total of 15 experienced respondents who participated in the individual interview process, representing five CEI specialists; three General contractors; two Design consultants; two DOT staff; three Owner's representatives. Most participants have more than ten years of industry experience and specified their strong familiarity with DB project delivery.

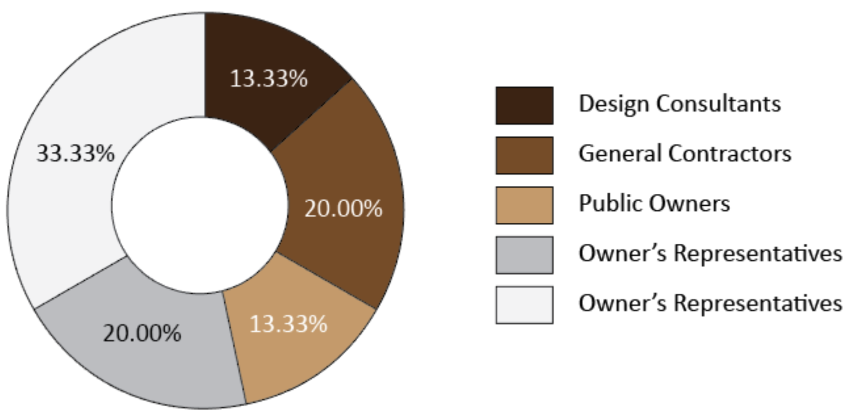


Figure 14 – Distribution of Interview Respondents' Profession

4.2.2.3 Thematic Analysis

This study will code the data from these interviews and conduct a qualitative comparative analysis of expert perspectives, triangulating the results from our survey analysis, increasing the depth of understanding of QA topics, and developing more effective QA strategies at GDOT. This study will use computer-assisted qualitative data analysis software (CAQDAS), NVivo version 12, to analyze the qualitative survey responses and semi-structured interview data. The narrative responses will be coded into themes. The software will allow this study to manage the data, create queries in the qualitative data concerning the narrative responses, and create codes to report the results, ensuring rigor in the analysis process (Jackson and Bazeley 2019). The interview analysis identified three broad themes: (1) Stringency of CEI Firms' decisions; (2) CEI firms' roles and responsibilities; and (3) areas of improvement.

4.3 Results

4.3.1 Survey

4.3.1.1 <u>Stringency in Quality Acceptance Decisions</u>

This study investigated respondents' views on the stringency of quality acceptance decisions when the design-builder employs them, compared to the typical enforced level of stringency when the state DOT directly hires the CEI firms for quality management. In response to the question, "On average, how stringent are the acceptance decisions of the CEI firm when it is directly hired by the design-builder compared to the typical level of stringency enforced when it is directly hired by the state DOT?" this study observed varying CEI firm stringency levels regarding quality acceptance under different contracting structures reported by CEI firms, as shown in Figure 15. The CEI firms perform quality acceptance on behalf of the public owner under the traditional quality management model. When using the CQAF model, the design-builder or the developer will hire CEI firms to perform quality acceptance. The CEI firm performs the same duties but works for different employers.

Interestingly, about 30 to 40 percent of the CEI professionals, design consultants, and owner's representatives responded that quality acceptance decisions are substantially more stringent and somewhat more stringent under the CQAF model than the traditional quality management model. On the other hand, more than 60 percent of the DOT personnel felt that the CEI firm's quality acceptance decision is substantially more lenient and somewhat more lenient under the CQAF model. These results indicate an inconsistency in understanding among CEI personnel, and such differences in stringency may result from misplaced incentives in the process. This inconsistency may indicate a lack of clarity about how contracting influences the level of stringency of CEI firms' acceptance decisions.

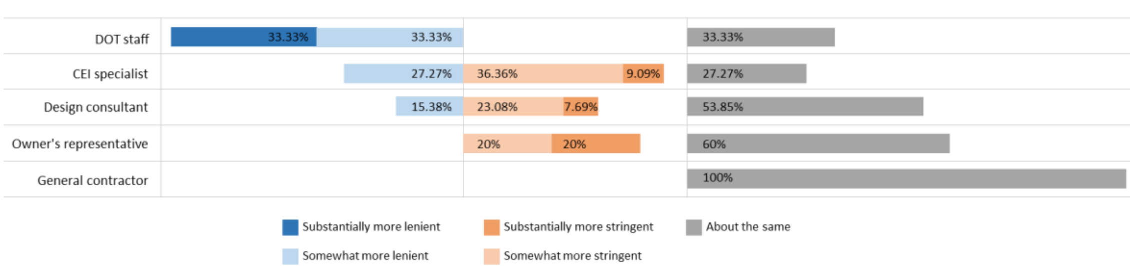


Figure 15 – Stringency of CEI firms' quality acceptance decisions

The study examined whether the five professionals viewed stringency on quality acceptance decisions differently or the same way. Given that the data are not normally distributed, a nonparametric statistical analysis known as Kruskal-Wallis one-way analysis of variance (ANOVA) was employed. This test examines the null hypothesis that no statistically significant differences exist in the perception of the five professional groups on stringency in the quality acceptance decisions. The null hypothesis is rejected based on this hypothetical assumption, where a criterion has a significance level of less than 0.05. Table 9 shows that perspectives towards stringency in quality acceptance decisions were perceived differently by the five professional groups, with their significance level falling below the decision rule (0.05).

Table 9 – Results of the Kruskal–Wallis Test: Stringency in Quality Acceptance

Profession	N	Mean	SD	χ^2	p
CEI Specialists	11	3.27	1.01		
Design consultant	13	3.23	0.83		
General contractor	3	3.00	0.00	11.372	0.0227*
DOT staff	9	2.00	0.87		
Owner's representatives	5	3.60	0.87		
Total	41				

* $p < 0.05$ statistical test: Kruskal Wallis

The Dunn’s test, a method for multiple comparisons, was used as a post hoc test to analyze variance after the Kruskal-Wallis test to determine which disagreements occurred between two parties. The tests were conducted by using R Studio. The statistical analyses only represent the sample that responded to the survey. The results of Dunn’s test are presented in Table 10, indicating that the public owners have different perceptions against almost all parties, except for the general contractors.

Table 10 – Results of the Dunn's Test: Stringency in Quality Acceptance

Comparison	Z	*p*
CEI specialists vs. Design consultants	0.09843564	0.9216
CEI specialists vs. Highway contractors	0.40243551	0.6874
CEI specialists vs. DOT Staff	2.72152747	0.0065*
CEI specialists vs. Owner's representatives	-0.58318446	0.5598
Design consultants vs. Highway contractors	0.34627807	0.7291
Design consultants vs. DOT Staff	2.72792856	0.0064*
Design consultants vs. Owner's representatives	-0.67436199	0.5001
Highway contractors vs. DOT Staff	-1.44167056	0.1494
Highway contractors vs. Owner's representatives	-0.78963549	0.4297
DOT Staff vs. Owner's representatives	-2.75700144	0.0058*

* $p < 0.05$ statistical test: Dunn's test

4.3.1.2 CEI Roles and Responsibilities

Regarding CEI firms' roles and responsibilities, this study asked, "How frequently is the CEI firm responsible for the following tasks in federal-aid design-build projects?" Table 11 presents the typical CEI firm's roles and responsibilities when performing quality acceptance determination from the Georgia Department of Transportation Quality Manual, RFQs, and RFPs. The study observed that the respondents have inconsistent beliefs about the CEI firms' roles and responsibilities, indicating a gap in understanding between the traditional and alternative quality management models.

Table 11 – CEI Roles and Responsibilities

Code	CEI Responsibilities

Task 1	Notifying the DOT of key times in the quality management schedule
Task 2	Issuing noncompliance reports (NCRs) to address deficiencies in the materials
Task 3	Exercising approved engineering judgment to accept deficiencies in the material test results
Task 4	Auditing quality management procedures and records
Task 5	Ensuring compliance of project payroll
Task 6	Ensuring compliance of report submission
Task 7	Ensuring contract compliance
Task 8	Conducting construction measurements to certify payments to the design-builder
Task 9	Ensuring the design-builder's compliance to the contract's goal for using disadvantaged business enterprises (DBEs)
Task 10	Ensuring the design-builder's compliance to the contract requirement for paying the local prevailing wages on public works projects for laborers and mechanics (Davis-Bacon Act)

The next step was to determine whether responses varied by different professions. To discover similarities and differences in CEI's roles and responsibilities across professions, this study conducted the Kruskal-Wallis test. This study first examined the significant differences among professional groups under the traditional QAP. Interestingly, all parties agree with the same opinion that the CEI firms are usually responsible for the following tasks when they perform quality acceptance under the traditional QA model (see Table 12). It concludes that professional groups have no understanding gaps when DOT hires CEI firms.

Table 12 – Results of the Kruskal–Wallis Test: CEI Roles and Responsibilities in Traditional QA model

Code	n	df	χ^2	*p*
Task 1	46	4	7.7966	0.09932

Task 2	46	4	1.7268	0.7858
Task 3	46	4	8.9043	0.06354
Task 4	46	4	2.5628	0.6334
Task 5	46	4	3.9603	0.4114
Task 6	46	4	4.8575	0.3022
Task 7	46	4	4.8867	0.2991
Task 8	46	4	1.7342	0.7845
Task 9	46	4	9.3427	0.05308
Task 10	46	4	8.0952	0.08815

* $p < 0.05$ statistical test: Kruskal–Wallis Test

Coming to the alternative QAP, this study examined the significant differences among professional groups when the design-builder hires CEI firms to perform quality acceptance. The test results for the CEI firm's roles and responsibilities under the alternative QAP with p-values less than 0.05 are summarized in Table 13. Four out of ten tasks show that these tasks are the statistically significant difference among professional groups.

Table 13 –Results of the Kruskal–Wallis Test: CEI Roles and Responsibilities in Alternative QA model

Code	n	df	χ^2	p
Task 1	46	4	6.8893	0.1419
Task 2	46	4	2.8667	0.5804
Task 3	46	4	10.037	0.0398*
Task 4	46	4	1.9870	0.7381
Task 5	46	4	7.4294	0.1149
Task 6	46	4	5.1382	0.2734
Task 7	46	4	5.5307	0.2370
Task 8	46	4	9.9071	0.0420*
Task 9	46	4	12.4450	0.0143*
Task 10	46	4	10.4310	0.0338*

* $p < 0.05$ statistical test: Kruskal–Wallis Test

Followed by the Kruskal-Wallis test, Dunn's test was used as a post hoc test in the analysis of variance to examine which two groups have statistically different opinions towards CEI roles and responsibilities. Regarding *Task 3: Exercising approved engineering judgment to accept deficiencies in the material test results*, the results of the Dunn's test in Table 14 show that highway contractors (μ=2.5) have different opinions against CEI specialists (μ=4.08), design consultants (μ=2.92), and owner's representatives (μ=4.0). Highway contractors tend not to consider *Task 3* as CEI's responsibility when hiring CEI for quality acceptance.

Table 14 – Results of the Dunn's Test: Task 3

Comparison		Z	*p*
CEI specialists	vs. Design consultants	0.6824	0.4950
CEI specialists	vs. Highway contractors	2.7894	0.0053*
CEI specialists	vs. DOT Staff	1.8641	0.0623
CEI specialists	vs. Owner's representatives	0.1546	0.8771
Design consultants	vs. Highway contractors	2.3495	0.0188*
Design consultants	vs. DOT Staff	1.2589	0.2081
Design consultants	vs. Owner's representatives	-0.3483	0.7276
Highway contractors	vs. DOT Staff	1.3705	0.1705
Highway contractors	vs. Owner's representatives	-2.2562	0.0241*
DOT Staff	vs. Owner's representatives	-1.2830	0.1995

* p <0.05 statistical test: Dunn's test

Coming to *Task 8: Conducting construction measurements to certify payments to the design-builder*, Table 15 describes that design consultants (μ=3.77) have different opinions against CEI specialists (μ=3.92) and owner's representatives (μ=4.00). Although Dunn's test exhibits significant differences between design consultants and CEI specialists and between design consultants and owner's representatives, this study concludes that almost all professional groups consider *Task 8* as a CEI responsibility when comparing the mean of their answers.

Table 15 – Results of the Dunn's Test: Task 8

Comparison		Z	*p*
CEI specialists	vs. Design consultants	2.6151	0.0089*
CEI specialists	vs. Highway contractors	1.4643	0.1431
CEI specialists	vs. DOT Staff	1.3511	0.1766
CEI specialists	vs. Owner's representatives	-0.4130	0.6796
Design consultants	vs. Highway contractors	-0.3000	0.7643
Design consultants	vs. DOT Staff	-1.0602	0.2890
Design consultants	vs. Owner's representatives	-2.3505	0.0187*
Highway contractors	vs. DOT Staff	0.4546	0.6494
Highway contractors	vs. Owner's representatives	-1.5721	0.1159
DOT Staff	vs. Owner's representatives	-1.4343	0.1515

* $p < 0.05$ statistical test: Dunn's test

Task 9: Ensuring the design-builder's compliance to the contract's goal for using disadvantaged business enterprises (DBEs) is the most conflicting task that all professional groups have different levels of understanding (see Table 16). CEI specialists (μ=4.08) and owner's representatives (μ=4.00) have similar opinions on this task. Opinions from design consultants (μ=2.69), highway contractors (μ=2.50), and public owners (μ=2.63) align with each other. Interestingly, the public owner and owner's representatives have a conflicting understanding of this task. Furthermore, some of the respondents from the public owner group do not think Task 9 is CEI's responsibility.

Table 16 – Results of the Dunn's Test: Task 9

Comparison		Z	*p*
CEI specialists	vs. Design consultants	2.6397	0.0083*
CEI specialists	vs. Highway contractors	1.7979	0.07220
CEI specialists	vs. DOT Staff	1.9860	0.0470*
CEI specialists	vs. Owner's representatives	-0.7284	0.4664
Design consultants	vs. Highway contractors	0.0198	0.9842
Design consultants	vs. DOT Staff	-0.4380	0.6614

Design consultants	vs. Owner's representatives	-2.5279	0.0115*
Highway contractors	vs. DOT Staff	0.3255	0.7448
Highway contractors	vs. Owner's representatives	-2.0427	0.0411*
DOT Staff	vs. Owner's representatives	-2.1160	0.0343*

* p <0.05 statistical test: Dunn's test

Lastly, *Task 10: Ensuring the design-builder's compliance to the contract requirement for paying the local prevailing wages on public works projects for laborers and mechanics (Davis-Bacon Act)* is another task that almost all parties do not have the same level of understanding. Except for the public owners, four professional groups in Table 17 show significant differences between parties. Design consultants (μ=3.08) have different opinions against CEI specialists (μ=4.08) and owner's representatives (μ=4.00). In addition, owner's representatives differ from general contractors (μ=2.50).

Table 17 – Results of the Dunn's Test: Task 10

Comparison		Z	*p*
CEI specialists	vs. Design consultants	2.3322	0.0197*
CEI specialists	vs. Highway contractors	1.8298	0.0673
CEI specialists	vs. DOT Staff	1.7347	0.0828
CEI specialists	vs. Owner's representatives	-0.6993	0.4843
Design consultants	vs. Highway contractors	0.2610	0.7941
Design consultants	vs. DOT Staff	-0.4073	0.6838
Design consultants	vs. Owner's representatives	-2.2897	0.0220*
Highway contractors	vs. DOT Staff	0.5351	0.5926
Highway contractors	vs. Owner's representatives	-2.0451	0.0408*
DOT Staff	vs. Owner's representatives	-1.9092	0.0562

* p <0.05 statistical test: Dunn's test

4.3.2 Interview

This study conducted semistructured interviews with 15 survey participants, followed by the survey analysis. Critical topics in the survey analysis were chosen as the interview protocols for further exploration. The in-depth interviews allowed this study to explore survey topics and investigate new questions raised from the survey responses. Most interviewees have over ten years of experience working in the industry and are familiar with the design-build project delivery method. Such diverse backgrounds and professions add robustness and comprehensiveness to our interviews. This study summarized the data collected from interviews and qualitatively analyzed expert perspectives. Three broad themes emerged from the interview analysis. From this analysis, this study can enhance our understanding of QA topics and determine more appropriate strategies for alternative QAP.

4.3.2.1 CEI firms' roles and responsibilities

Interviewees mentioned that only a few firms have independent quality firms experience, and the vast majority of firms have experienced the traditional QAP similar to the traditional DBB projects. Thus, some people may not recognize the differences in QA practices between DB and DBB. Even DOT staff may not even know the differences. For instance, Texas has a mature market; historically, they have done three jobs each year, while Georgia has fewer. Furthermore, Florida does not use alternative QAP for their DB projects, which means responsibility doesn't change whether it is DBB or DB. Many interviewees agreed that it all depends on the contract, such as how big and expensive the contract is. Some interviewees brought attention to contract compliance related to the DBE requirements and Davis-Bacon Act. They further mentioned that the CEI firm has a Contract Support Specialist or Contract Compliance Specialist. One of their duties is to track Davis-Bacon Act and DBEs requirements. These responsibilities can be changed depending on QAP models.

Additionally, when asked to describe a CEI firm's typical roles and responsibilities, two DOT officials, a CEI professional, and an owner's representative agreed that inspection is critical for CEI firms. The owner's representative and the CEI professional emphasized that CEI firms need to be aware of any deficiencies. The CEI professional also described its role as the "eyes and ears" of public owners for taking care of checks and balances. This study also received feedback from the owner's representative that CEI firms' roles have no difference between DB and DBB projects.

4.3.2.2 The stringency of CEI Firm's Decisions

Regarding the difference in the stringency of the CEI firms' decisions and actions when hired by the design-builder versus the state DOT, some CEI firms agreed that they tend to have more proactive mindsets when hired by the design-builder before potential issues occur. Another CEI professional commented that the stringency could be the same when hired by either the design-builder or the state DOT, consistent with our survey results. A view from the CEI professional was that CEI firms' performance could depend on their experience levels, personalities, and preference. For instance, if the DB construction manager has more experience, he tends to be more stringent about decisions or actions.

4.3.2.3 Areas of Improvement for CEI Firms' Understanding

This study received recommendations from our interviewees on where the alignment between state DOTs and the CEI industry's understanding can be improved. General contractors, design consultants, owner's representatives, and CEI firms suggested that specifying expectations for every aspect of work and minimum testing levels in the RFQs and RFPs, and including clear minimum requirements and responsibilities would be effective for improving CEI firms' understanding. An owner's representative mentioned that having an oversight process will promote DOTs' and CEI firms' understanding. A CEI firm professional suggested that being proactive, communicative, and having engaged mindsets will also be a helpful strategy.

To make the CEI firms' jobs easier, this study gathered some feedback from experts about state DOTs to reduce gaps in misunderstanding. Interviewees among owner's representatives, DOT personnel, and CEI professionals commonly advised having a clear RFQ and RFP, specific quality management plans, detailed documentation and daily reports, and clear responsibility and requirements of positions. Two owner's representatives suggested that having an independent quality firm such as the alternative QA model can help reduce the chance of misunderstanding. The CEI professional mentioned that dedicating time to critical items and performing risk-based inspection can help lessen gaps in misunderstanding.

4.4 Chapter Conclusion

Several state DOTs have already implemented an alternative QAP for their DB, requiring the developers' construction quality acceptance firm to be an essential part of project quality management. This transition to an alternative QAP can cause ambiguity and confusion for both DOTs and CEI firms. Greater clarity and specificity are necessary to mitigate this ambiguity, providing QA personnel a better understanding of DOT expectations to ensure high-performance project delivery. This chapter provides an in-depth analysis to study state-of-practices in contract requirements for QAP across the DOTs and their DB projects and the current understanding of the CEI's roles and responsibilities and the stringency of the CEI firm's decisions.

Coming to the survey analysis, this study identifies high levels of variance or consistency and high divergence under different contracting structures. The industry has inconsistent beliefs over CEI firms' typical roles and responsibilities, and different roles are identified when hired by design-builders versus state DOTs. This study observes conflicting perspectives about the stringency of CEI firms' decisions, resulting from the lack of clarity about how contracting influences the level of stringency of CEI firms' acceptance decisions between the traditional quality management model and the CQAF model.

The interview process allowed this study to gather more detailed and thorough perspectives from the survey participants. With a shared understanding from interviewees of CEI firms' roles and responsibilities, CEI firms could have a more comprehensive view of the roles expected of them by different professional groups and reduce the gaps in their understanding from that of state DOTs. Similarly, the second and third areas discussed in the interviews help improve the alignment of the CEI industry and DOTs' understanding of CEI firms' roles and responsibilities and lessen the gaps between their understanding. Some typical comments included having clear expectations and specific minimum requirements for every aspect of work and a clear RFP, RFQ, and QMP. The interviewees further elaborated on the difference in the stringency of their decisions when hired by the design-builder versus by the state DOTs. While some CEI professionals agreed on similar stringency levels of CEI firms' decisions when hired by either the design-builder or state DOT, consistent with the survey results, a few others thought CEI firms tend to be more stringent when hired by the design-builder.

5. A NEW CRITICAL POSITION IN ALTERNATIVE DELIVERY

5.1 Introduction

Because of the nature of design-build, which requires integrating design and construction, the roles and responsibilities for the design and construction quality management have shifted from the public owner to the design-builder. The project becomes larger and more complex, and multiple parties are involved in the engineering decision-making process. It is important to handle the overall integration of work. It resolves engineering issues during the design and construction phase, leading to an increasing need for a position capable of managing the overall integration of design and construction.

One of the main challenges that state DOTs face in their DB projects is to ensure that the design-build team upholds the highest standard of care in making complex engineering decisions involving multidisciplinary works. In addition, during the construction phase of the project, all critical decisions, such as moving traffic to a temporary shoulder and other engineering issues related to temporary structures, must be made with direct input and the approval of a professional engineer licensed in the state. Thus, it is crucial to understand the underpinnings of engineering-related problems during both the design and construction phases and identify an effective approach to address these issues in the innovative delivery environment.

The owner shifts interface risk between design and construction to the design-build. Since large and complex DB projects involve multidisciplinary parties on board, these projects should be considered a system. The projects devote trustworthy leadership to handle issues arising from multidiscipline (Fischer et al. 2011; Gharaibeh 2014). There is a need for a position that is responsible for the overall integration of work and can handle multiple engineering disciplines, and resolve engineering issues (Ashuri and Lee 2021).

This research project focuses on elevating engineering decision-making practices in the design-build environment by exploring opportunities offered by a new leadership position in the design-build team. This position is expected to become a go-to person in the design-build team who stands to certify that appropriate engineering standard of care is administered in all the design-build contract work and who state DOTs can discuss all engineering-related issues with. An urgent need exists to identify what specific qualifications and skillsets are critical for the success of the new position as key personnel in the dynamic design-build project delivery. This chapter addresses the last question: "What would be the desired skillsets to ensure an appropriate standard of care in the multidisciplinary engineering decision-making process, especially during the construction phase, in megaprojects and their insurability?"

5.2 Research Methodology

The primary purpose of this exploratory study is to determine the engineering decision-making practices in the design-build environment by exploring opportunities offered by a new leadership position in the design-build team. No previous study has investigated new engineering position whether adding this position would add value to solving these problems. To achieve the objectives, this study used qualitative research methods. The data in this research primarily came from interviews collected in written or verbal forms via an email and a video call and then summarized in narrative form. This study aimed to understand better a new leadership position as key personnel for DB megaprojects. The goal was to develop a detailed description rather than a measurement of particular variables. Thus, qualitative approaches were considered the most suitable methods to capture the views and perspectives of the people and embrace the contextual conditions (Seidman 2006; Yin 2016). Through a series of interviews with subject-matter experts (SMEs) in the DB transportation market, this study obtained enriched data to understand existing key personnel and a new leadership role in the context of the DB environment. Figure 16 describes the interview process.

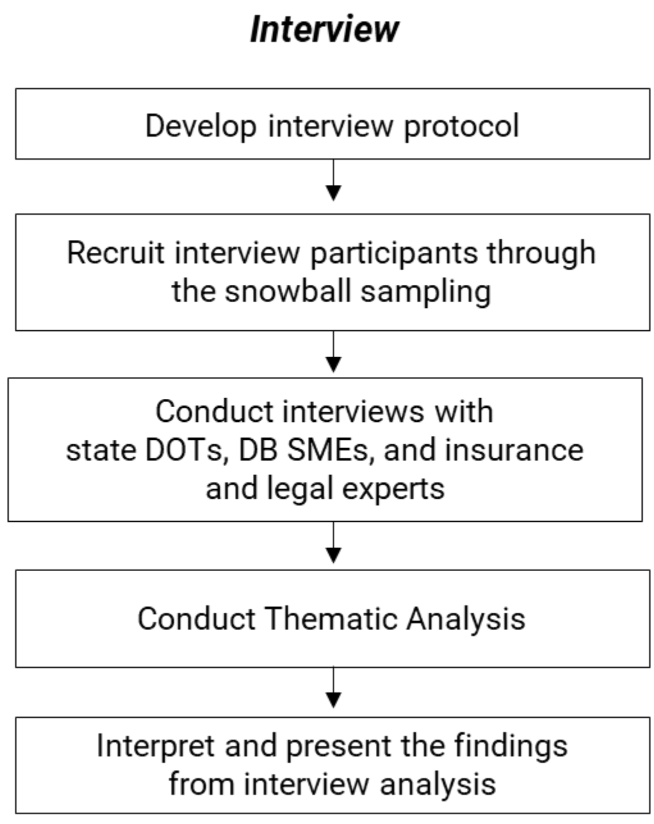


Figure 16 – Overview of Research Methodology: Research Thrust 3

5.2.1 Interview Protocol

As a new engineering leadership requirement on the DB team, the study focused on describing the PCE found in the GDOT RFQ. The study borrowed the language from the PCE description from the GDOT RFQ and tweaked the descriptions. The following seven critical functions presented in Table 18 were identified from the GDOT RFQ and embedded in the interview invitation with a brief explanation of the needs of the PCE on the DB team. The interviewees were asked to address a series of predetermined but open-ended questions. The questions differed based on the context and setting of each interview.

Table 18 – Critical Functions of a New Leadership Position

Code	Description
Task 1	Being responsible for the supervision and quality of all design work and the design process throughout the design and construction period
Task 2	Being responsible for design accuracy, adequacy, and conformance to professional standards of practice
Task 3	Making all decisions throughout design and construction that are related to an engineering aspect of the project
Task 4	Rejecting or approving the design work throughout the design and construction period
Task 5	Resolving disputes regarding engineering work for the design integration into the final constructed product
Task 6	Verifying that construction processes do not undermine the safety and soundness of the design
Task 7	Having the authority to stop work on the project if any work does not meet the standards, specifications, or criteria for the project

5.2.2 Data Collection

With the pressing need to identify key personnel required by the DB team, this exploratory study is timely and required to target the managerial level of the subject-matter experts in the DB transportation infrastructure market. To obtain further expertise in the large and complex DB projects, this study reached out to the following three professional associations: (1) ACEC of Georgia, Georgia Partnership for Transportation Quality Task Force; (2) DBIA, P3 Committee; and (3) DBIA, Transportation & Aviation Committee. To facilitate in-depth discussion with a wide range of professional groups, this study used the snowball sampling method for current research participants to recruit future ones by identifying other possible interviewees. This study conducted the first round of interviews with members of the above-listed professional associations, and they referred SMEs in their network. This process allowed this research to obtain valuable opinions from various professional groups, especially the insurance market.

The selected interviewees were each sent an email describing the PCE roles and responsibilities presented, and this study followed up after the email to schedule a video call interview. As the researcher had embedded the PCE language that appeared in the active GDOT RFQ, described in Table 18, into the interview invitation, some members of the professional associations expressed concerns about any conflict of interest and did not participate in the interview. Figure 17 describes a profile of the 40 interview participants and their professional groups, including highway contractors, design consultants, owner's representatives, legal experts, and insurance experts. One of the insurance experts works as an insurance underwriter, and the remaining respondents in the insurance expert group represent insurance brokers. This interview analysis included the one with the legal experts via email.

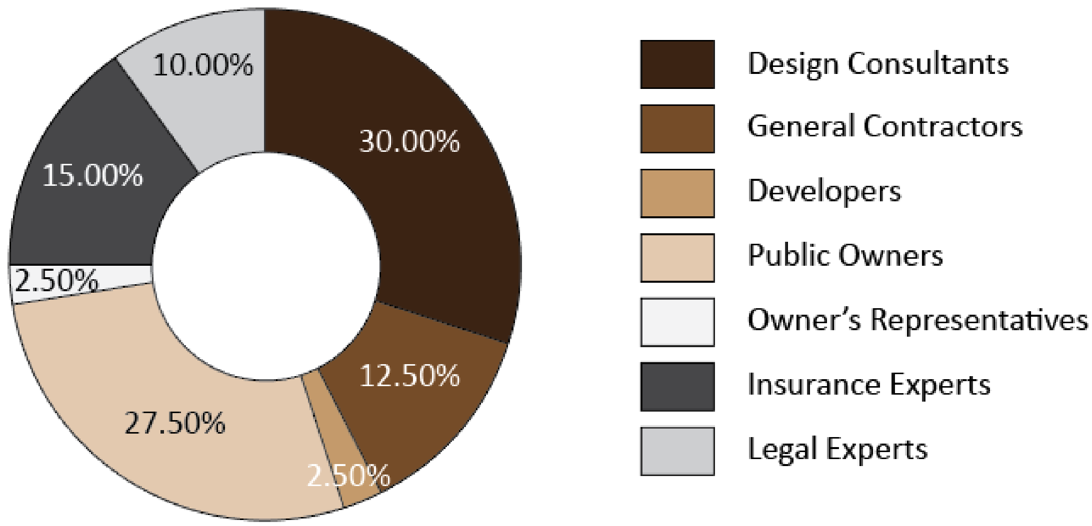


Figure 17 – Interview Participants by Profession

5.2.3 Thematic Analysis

The interview began with the question, "We'd like to know your thoughts about the position and how it may be applicable for delivering complex DB projects." The interviewees were then asked to address a series of predetermined but open-ended questions. The questions differed based on the context and setting of each interview. This study used computer-assisted qualitative data analysis software (CAQDAS), NVivo version 12, to analyze semi-structured interview data. The narrative responses were coded into themes. The software allowed this study to manage the data, create queries in the qualitative data with reference to the narrative responses, and create codes to report the results, ensuring rigor in the analysis process (Jackson and Bazeley 2019). The interview analysis identified six major themes: (1) overall opinions; (2) types of projects that gain value from PCE; (3) areas that need PCE attention; (4) recommendations for the description of PCE; (5) best practices for implementing the new PCE position; and (6) interface with other DB team members.

5.3 Results

5.3.1 Theme 1: Overall Opinions

Two sub-themes—benefits and challenges—emerged from interview responses regarding the overall opinions on PCE implementation. Most DOTs like the idea of requiring the new position in large and complex DB and P3 projects. One respondent mentioned that it would benefit the PCE to know the intricacies of financing and issue escalation. Several DB subject matter experts from all backgrounds (design consultants, general contractors, owner officers, owner's representatives, and insurance and legal experts) believe this role can add value for an owner in complex megaprojects. One insurance expert mentioned that "the owner does not want to go to many other people to seek answers. The owner will ask for the Project Chief Engineer." They further explained that using an engineering firm's corporate professional liability (PL) policy would not be a problem to cover the Project Chief Engineer position. The engineering firm's professional liability (PL) insurance policy may not be anything specific that would preclude the design firm from taking on the role. But for the most part, the issue at hand would be taking on liability that would not otherwise be the design firm's absence accepting this role.

On the other hand, some insurance industry expressed concerns that considering the breadth of the new role, the engineering consulting firm extending its liability may put its PL policy at risk. However, it is perhaps not an insurance issue but rather an insured extending its liability and putting its PL policy at risk when it usually would not be. For instance, a designer normally would not accept responsibility for the design-builder's own design works related to temporary structures. However, it should be noted that the Project Chief Engineer role is new, and assigned responsibilities are not typical for the design firm to accept in regular design-build projects.

Also, several interviewees expressed some challenges related to the PCE implementation. It seems as though the PCE is required to have a unique set of skills both in design and construction. They wonder how the owner can fulfill candidates with specialized skill sets. Most respondents mentioned that it would be better for the PCE to be on the construction side than the design side, but this position requires a licensed PE. Continuity from the proposal phase to the project execution phase was another desired feature for including the PCE. One interviewee highlighted that good wording is needed to acquire a higher-level person to handle the appropriate authority and responsibility.

Some interviewees expressed concern about potential challenges in implementing the new role because the PCE has great power on the engineering side, especially the authority to stop work. One general contractor and several other design consultants said it should be okay if it's generally in the realm of safety concerns—In essence, everybody at work has the authority to stop work for safety concerns. However, a design consultant and a general contractor mentioned that the "stop work authority" is an authority that a consulting engineer should not accept. Needless to the applicability, some designers said they are not much in favor of accepting this authority. One design consultant further expressed that he would prefer that the contract stays silent about the authority to stop work.

This study also noticed that insurance experts are less concerned about assigning this task to the PCE as long as PCE's responsibility is limited to professional engineering practices and excludes all construction means and methods. In addition, a legal expert explained the authority delegation from a different perspective, whether it is right to stop work or a duty to warrant the work.

5.3.2 Theme 2: Types of Projects that Gain Value from PCE

Most participants agreed that the PCE adds value to large and complex projects and is beneficial when projects need to strengthen the design manager's role. Commenting on the factors influential in the decision to include the PCE as key personnel, the interviewees mentioned several areas to consider: project dollar values; complexity thresholds; project size; projects with several phases; interfaces with other projects in the neighboring area, management of several interfaces among multiple design disciplines; and systems integration and testing needs.

5.3.3 Theme 3: Areas that Need PCE Attention

Moving to which areas the PCE needs to pay special attention to, most interviewees mentioned two primary areas: field design changes and temporary structure. Field design changes have to go through the respective EOR for disciplines affected by the changes. Without the EOR's approval, changes should not be implemented. Also, temporary structure design and implementation are the contractor's primary responsibility, not the design team. Thus, the PCE needs to ensure that the construction quality manager oversees. A design consultant further mentioned that the distinction between temporary and permanent work is insurance. Insurance coverage between temporary and permanent work is very different. It's easier to ensure the temporary than the permanent structures. The design community can benefit from clarifying the distinction between the two types of structures and how it applies to the PCE role. They highlighted that design and implementation of the temporary structure are the contractor's primary responsibility, not the design team. Thus, the PCE needs to ensure that the construction quality manager oversees the process.

5.3.4 Theme 4: Recommendations for the Description of PCE

Regarding the recommendations for PCE description, most interviewees indicate two broad sub-themes: organizational structure and contract languages. First, the organizational structure needs to be enhanced to indicate a clear line of reporting, such as decision-making authority. A general contractor mentioned that the described PCE position has unusual reporting lines. They further explained that, ultimately, the owner might want to decide whether to impose a preferred reporting structure and communication channels on the DB team. However, several respondents advised against such rigid prescriptions and suggested the public owner allow the DB team decides what organizational structure best fits the needs of the project, which brings more flexibility. One concern from a developer is that the PCE adds another layer to resolve a dispute in a timely manner. The developer further expressed a potential issue that this additional position may delay the decision-making process and the overall schedule by stating, "All the stakeholders raise their hands and say it doesn't work. With PCE, you're inserting yet another person who can raise her/his hand."

Coming to contract languages, most interviewees mentioned that the duties of the PCE during construction need to be clearly spelled out in the RFQ and RFP. Also, one DOT personnel said this position could not serve other duties. In fact, double-duty should not be allowed. In the RFP, one participant thought technical scores need greater weight in proposal evaluation than price scores. Most insurance and legal experts commented on the language describing the PCE's responsibilities. There are specific terms that may need further elaboration to avoid any misunderstandings. For instance, "accuracy" and "adequacy" may imply a heightened standard of care. "Certify" may imply a "warranty" and "guarantee" that are above the typical standard of care. "Safe and sound design" can be further defined. Several respondents from insurance also commented on the term "supervision" used in the PCE description. Several design and construction sub-consultants are working on a DB project anytime. The PCE does not have contractual privity with most design and construction sub-consultants. Accepting the supervision responsibility extends the professional liability of the PCE firm beyond those firms that the PCE firm actually hires.

5.3.5 Theme 5: Best Practices for Implementing the New PCE Position

Various perspectives were expressed regarding the best practices for implementing the New PCE Position in the DB team. Desired qualifications for the new PCE position should be explicitly outlined in the RFQ to provide a basis for evaluating the new key personnel. The majority of interviewees agreed with the importance of key personnel. One interviewee commented that keeping the list of key personnel short is preferred as many changes are anticipated throughout project pursuit to project execution. Another interviewee also said that it is recommended to provide flexibility to the design-build team to staff its team as appropriately as possible, keeping prescriptive positions to the minimum level necessary. The design-builder can add more key positions depending on the project needs and its own preference to perform the job. The design-builder has the latitude of a showcase of experts. Other responses to this question included keeping the list of key personnel consistent throughout the entire program to clarify the industry.

Some respondents commented that staying with minimum qualifications can help the DOT to keep the pool of qualified professionals open as much as possible. Also, the RFQ and RFP requirements for key personnel do not need to be too prescriptive. Some reported a need to develop a resolution ladder for the project. The design manager, quality manager, construction manager, and department should sit down together to resolve the issues by following the process in the issue escalation. One interviewee mentioned that their department uses dispute review boards (DRBs) as an alternative dispute resolution mechanism. Another interviewee highlighted that working experience with the local market is essential when selecting a design-builder and its key personnel.

DOT staff commented that familiarity with the state DOT's engineering design and construction practices is required for successful candidates for the new PCE position.

Overall, the PCE needs to clearly define how to implement systems integration throughout the project development. The PCE needs to articulate how engineering design issues are resolved inside the DB team. A systematic approach should be developed for issue escalation and resolution.

5.3.6 Theme 6: Interface with Other DB Team Members

Various responses indicated multiple positions are related to the PCE in the line of reporting and decision-making process. However, it is important to clearly differentiate the role of the Project Chief Engineer from other key personnel in the DB team, such as the design manager, EOR, independent quality manager (IQM), and design-build coordinator, to avoid any perception of the redundancy.

Various responses indicated multiple positions related to the PCE. Figure 18 describes the results of the interview analysis for this question. About 70 percent of answers indicated that the PCE is similar to the design manager. The design manager wears multiple hats, including conflict resolution. However, the design manager in the current setting for design-build teams may not be high enough in the organizational structure to advocate for good design. The PCE is slightly different as the design manager typically has no authority to stop the work. The interviewee who mentioned the DB coordinator is similar to the PCE without the heightened authority level further explained that the design manager oversees 95 percent of submission, including all plans and specifications. The design-build coordinator coordinates comprehensive contractual documents. The other interviewees indicated that both the project manager and design manager are similar to the PCE. The project manager has the authority to make decisions on-site, and the design manager and the EOR need to visit the job site to address issues raised by the DOT. The analysis shows that 29 percent of the interviewees consider the PCE to be similar to the independent quality manager responsible for both design and construction compliance and has the authority to stop work for design and construction services. However, rejecting the work may not appear as a core responsibility of the quality manager. In addition, the EOR and other design stakeholders are expected to go to the field for design changes but are not required to visit the site regularly.

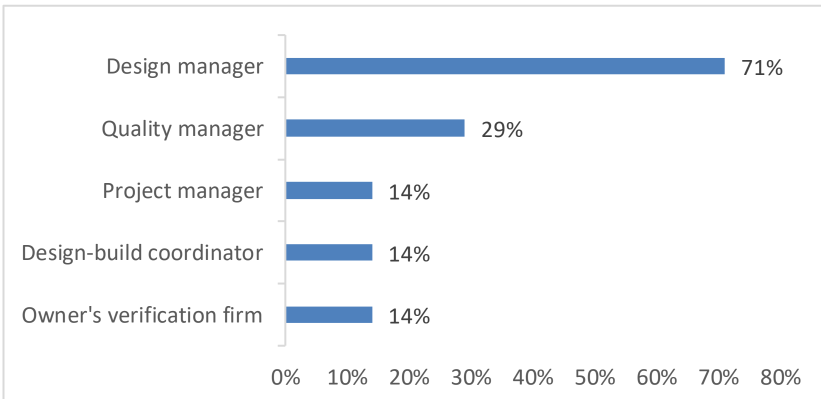


Figure 18 – Responses to Existing Roles Similar to Project Chief Engineer

5.4 Chapter Conclusion

Revisiting the research question, the results concluded that this new engineering leadership requirement on the DB team is expected to add value to large and complex DB projects. It is anticipated that the PCE can empower different design disciplines to take the lead at the appropriate time and mitigate any conflicts among design disciplines. This study provided in-depth analysis to examine the understanding of the needs for a new engineering leadership position and reviews the PCE role introduced by GDOT. Special attention was given to determining the challenging areas to uphold the integrity of engineering practice. This study explored the roles and responsibilities of key personnel and which entity in the DB team is in charge of making engineering decisions during the construction phase of the project.

Throughout the qualitative analysis, the viability of the PCE role and its importance were evident. As the projects become larger and more complex, multidisciplinary parties are required to participate in the projects. State DOTs need somebody at a high-level decision-making position in the DB team to protect the public interests overall in engineering practice. It is anticipated that a new leadership role like the PCE can empower different design disciplines to take the lead at the appropriate times and ensure that all others, especially people on the construction side, align with the appropriate engineering decision-making process. This new engineering leadership position can become a go-to person in the DB team with whom state DOTs can discuss all engineering-related issues within the appropriate engineering standard of care. Still, the PCE requires a unique set of skills both in design and construction, which may limit the pool of candidates.

6. CONCLUSION

6.1 Discussion

The overarching purpose of this study is to support decision-makers in streamlining project delivery by identifying challenges related to understanding gaps between public owners' expectations and the industry's perceptions and suggesting recommendations to mitigate the gaps. By doing so, this study is ultimately expected to contribute to increasing healthy competition in the transportation infrastructure market. This study addresses issues found in DB transportation infrastructure projects and recommends innovative solutions to overcome those issues in three research thrusts: (1) design liability, (2) construction quality assurance, and (3) a new engineering leadership requirement on the DB team. To achieve the research objectives and address three research thrusts, this study identifies research questions: (1) What are the emerging challenges in transferring design liability in the design-build environment? (2) What are the gaps between the industry perception and public owner's requirements regarding the roles and responsibilities of the construction quality assurance in the design-build environment? and (3) Would the new engineering leadership requirement on the DB team add value to large and complex design-build projects? Chapters 3, 4, and 5 address each research question, respectively.

Chapter 3 discusses important challenges related to design professional liability issues in the transportation DB industry. This study developed a national survey and distributed it to a wide range of subject-matter experts from multiple disciplines: design consultants, highway contractors, public owners, owner representatives, and insurance and legal advisors. The study identifies two broad areas of challenges for design liability: design claim sources and heightened standards of care.

Chapter 3 identifies nine claim sources and their significant importance perceived by the SMEs from various industry stakeholder groups. They expressed different viewpoints regarding the increased number of design claims in transportation DB projects. Among the nine claim sources, one of the most important was *C2: significant deviation of quantity estimates as the basis of cost estimation during the preaward phase*. The respondent groups had similar opinions on this. However, respondents expressed different opinions on important design claim sources in the DB industry for the remaining eight claim sources. However, they expressed different views on the remaining eight claim sources. Some claim sources emphasize the importance of specific professional groups' roles or are more relevant to their responsibilities. For instance, *C5: Recovery of losses due to contractor's faulty work during the construction phase* represents the critical role of contractors.

Chapter 3 also found that language on a heightened standard of care can be identified more frequently in DB projects than in traditional design-bid-build projects. The results align with the previous research by Chan and Yu (2005) and Ahmadifar (2013) that explains differences in design liability in the DBB and DB. The results also state that including a heightened standard of care has incurred a design professional liability insurance coverage gap. These results corroborate the findings of a great deal of the previous work by Kalach et al. (2020). Furthermore, this study confirms that many professionals are not familiar with the scope of DPLI coverage. This gray area seems to be a critical issue for DB projects.

Chapter 4 focuses on the second research thrust: construction quality assurance. This chapter aims to identify and analyze whether the industry's perception of alternative QAP meets public owner's requirements. This study applies a mixed-method research methodology, analyzing data from a survey and semi-structured interviews of various professional groups such as public owners, owner's representatives, general contractors, design consultants, and CEI specialists. First, this study investigated respondents' opinions on the stringency of quality acceptance decisions when the design-builder employs CEI firms, compared to the typical enforced level of stringency when the state DOT directly hires the CEI firms for quality management. The results show that public owners perceive CEI firms are more lenient under the alternative QAP. On the other hand, the remaining four professional groups consider that CEI firms are about the same no matter which QA model they follow, or CEI firms are somewhat more stringent.

Chapter 4 further investigated the industry's perceptions toward CEI roles and responsibilities. This study identified ten tasks from the GDOT quality manual, RFQs, and RFPs. Interestingly, professional groups have no significant differences under the traditional QA model. On the other hand, this study found conflicting opinions on several CEI roles and responsibilities when implementing an alternative QA model. Some tasks that indicated conflicting opinions showed that such a professional group does not usually perform those tasks in the traditional DBB environment. For instance, *Task 3: Exercising approved engineering judgment to accept deficiencies in the material test results* is usually performed by the design (i.e., engineering) team. The results show that highway contractors do not consider *Task 3* as CEI's responsibility when hiring CEI for quality acceptance. This perception significantly differs from CEI specialists, design consultants, and owner's representatives. Similar to *Task 3*, design consultants have different opinions against CEI specialists and owner's representatives about *Task 8: Conducting construction measurements to certify payments to the design-builder*. This study also found that all professional groups have diverse opinions on compliance with DBEs and the Davis-Bacon Act, which are more related to contract requirements.

Chapter 5 determines the engineering decision-making practices in the design-build environment by exploring opportunities offered by a new leadership position in the design-build team. It is an emerging trend that several state DOTs, such as Virginia, Texas, and Georgia, have included a new engineering leadership requirement on the DB team. This study borrowed the language and descriptions of a Project Chief Engineer from the GDOT RFQ to analyze this new engineering leadership position in-depth. This study utilized a qualitative research methodology to collect profound data by interviewing SMEs from multiple domains. This is a relatively new position for the DB and P3 industry, so it is quite normal to see some reservations and confusion in the DB industry. However, several SMEs from all backgrounds believe this role can add value for an owner, especially for large and complex DB projects.

Most of the interviewees agreed that it is imperative to clearly differentiate the role of the Project Chief Engineer from other key personnel in the DB team, such as the design manager, engineer-of-record (EOR), independent quality manager (IQM), and design-build coordinator, to avoid any perception of the redundancy. Most respondents suggested that there is room to improve the RFP language to reduce gaps between the GDOT's expectations and the DB industry's perceptions. Insurance and legal experts also align with other SMEs to improve PCE languages. Still, for the most part, there may not be anything specific in the engineering firm's professional liability (PL) insurance policy that would preclude the design firm from taking on the role.

6.2 Contribution

This study supports decision-makers in streamlining project delivery by identifying issues found in DB transportation infrastructure and suggesting recommendations to overcome those issues in the following areas: (1) design liability, (2) construction quality assurance, and (3) a new engineering leadership requirement on the DB team. In this respect, the three research thrusts address the unique aspect of issues in the integrated design and construction environment. The findings of this study have important implications for future practice and offer constructive guidance on streamlining project delivery in the DB transportation infrastructure market.

This study contributes to the body of knowledge on identifying nine design claim sources in the DB environment and the frequency and severity of design claim sources based on opinions from DB subject-matter experts. Primarily, this study contributes to identifying four typical languages that indicate the heightened standard of care in DB contracts and potential coverage gaps in PL insurance due to those languages. DB industry practitioners will have a significant opportunity to use the contribution of this research when monitoring the contract languages related to design liability issues. This study also contributes to the body of practices providing decision-makers insights into design liability issues and opportunities to reduce them. The industry practitioner can also develop guidelines or implement new practices to handle these challenges, as this study observed from other DOTs, including the scope validation period used by Virginia DOT, emerging progressive design-build methods, and additional insurance policies.

This study also contributes to the body of knowledge on identifying gaps between the industry perception and public owner's requirements in quality assurance programs in the DB environment. Notably, the traditional QA model is well understood, while the alternative QA model indicates two tasks related to workmanship and two related to contract compliances that the industry practitioners have different opinions on. This study provides significant areas where public owners can develop appropriate outreach and training materials to educate the CEI industry and the DB team for the DB project. Adapting strategies against inconsistencies between CEI perceptions and DOT requirements for quality assurance roles and responsibilities can help transportation agencies make better decisions and can be used to develop useful educational materials to educate the CEI industry for DB projects. This study adds value to strengthening the alternative QA model in current and future DB projects by addressing how the alternative QA model should function.

Finally, the last research thrust contributes to articulating the value of the new engineering leadership requirement on the design-build team. These findings do not limit their scope only to the PCE implementation. Instead, this study contributes to the body of practice by proposing six considerable areas of the new engineering leadership in the design-build team without incurring the PL insurance coverage gaps. The guide will define the primary responsibilities of the new engineering leadership position as a key member of the DB team to ensure that an appropriate standard of care exists for all aspects of the engineering decision-making process without incurring the PL insurance coverage in the

DB transportation infrastructure projects. Additionally, this study methodologically contributes to the body of knowledge by proposing an exploratory approach to determine emerging areas that can advance design and construction integration. In response to the influx of transportation infrastructure projects and its rapid changes in alternative project delivery, academic researchers can refer to this research method to explore the urgent need to understand new information and test the feasibility of starting a more in-depth study.

6.3 Limitations and Future Study

This study mainly utilized opinions perceived by SMEs in the DB transportation infrastructure industry. This study recruited professionals from multiple domains with expertise in alternative project delivery. However, the nature of this research topic led to more attentive participation in the survey and interviews from the designer group and CEI specialists than from the other groups. It requires additional samples from highway contractors to obtain more reliable results about industry practitioners' perceptions of research thrusts. Future studies can also benefit from receiving more opinions from legal and insurance experts.

In addition, performance data that can compare outcomes between traditional and alternative QA models should be further investigated to consolidate a holistic decision-making system. In the future, more quantitative data analytics toward quality performance comparison should be utilized to empower a new practice. Extending to performance data, this study is limited in validating the findings from the exploratory research used for a new engineering leadership position, as no project has been completed with this position. For the future study, the industry's experience with a new engineering position and their performance data can be further investigated to conclude whether this position per se adds value to large and complex DB projects.

APPENDIX A. QUESTIONNAIRE FOR RESEARCH THRUST 1

A.1 Background and experience in DB

1. What best describes your primary design-build background?
    a. Consulting engineer/lead designer/design professional
    b. General Contractor/Specialty Contractor
    c. Concessionaire
    d. Insurance industry representative
    e. Public Owner
    f. Owner's representative
    g. Legal or financial consultant
    h. Other (please specify)
2. How many years of experience do you have in the design-build transportation industry?
    a. Less than 5 years
    b. Less than 10 years
    c. Less than 15 years
    d. Less than 20 years
    e. More than 20 years

A.2 Issues in design claims

1. In your opinion, on average, is number of design claims greater in design-build projects compared to those in design-bid-build projects?

a. Yes

b. No

2. In your opinion, what is the relative importance of the following factors as the source of design claims against the engineering consulting firm in design-build projects?

Design claim sources	Less important	Important	Very important	Extremely important
Inadequate investigation during the pre-award phase				
Inadequate investigation during the pre-award phase				
Failure to notice the contractor important information during the pre-award phase				
Engineer's negligence in preparing plans, drawings, designs, and specifications				
Failure of engineer to provide reasonable inspection during the construction phase				
Recovery of losses due to defective owner-furnished documents				
Recovery of losses due to contractor's negligence in preparing the bid				
Recovery of losses due to contractor's faulty work during the construction phase				
Recovery of losses due to differing site conditions				

A.3 Heightened standard of care

1. How often have you seen the following Heightened Standard of Care in your Design-Bid-Build (DBB) projects?

Heightened standard of care languages	Never	Rarely	Often	Always
"Warranting" your design for fitting the intended purpose				

Ensuring your design “free of errors, omissions, and defects”				
Ensuring your design in compliance with “applicable laws, statues, ordinance, codes, rules and regulations, or any lawful orders of public authorities”				
Achieving a specific performance standard for any aspect of the work				

2. How often have you seen the following Heightened Standard of Care in your Design-Build (DB) projects?

Heightened standard of care languages	Never	Rarely	Often	Always
“Warranting” your design for fitting the intended purpose				
Ensuring your design “free of errors, omissions, and defects”				
Ensuring your design in compliance with “applicable laws, statues, ordinance, codes, rules and regulations, or any lawful orders of public authorities”				
Achieving a specific performance standard for any aspect of the work				

3. In your opinion, has the Heightened Standard of Care in design-build contracts resulted in more design claims?

    a. Definitely

    b. Probably

    c. Probably not

    d. Definitely not

    e. I don't know

4. Does a typical Design Professional Liability Insurance (DPLI) Policy of the engineering consulting firm cover design claims arising from failure to meet the clauses regarding the Heightened Standard of Care in the design-build project?
    a. Yes
    b. No
    c. I don't know

APPENDIX B. QUESTIONNAIRE FOR RESEARCH THRUST 2

B.1 Survey Questionnaire

1. What best describes your primary background?

    a. Construction engineering and inspection (CEI) specialist
    b. Design consultant
    c. Specialty sub-consultant
    d. General contractor
    e. Specialty contractor
    f. Developer
    g. Agency employee (e.g. DOT staff)
    h. Owner adviser
    i. Other (please specify)

2. How familiar are you with design-build project delivery?

    a. Totally unfamiliar
    b. Somewhat unfamiliar
    c. Neither familiar nor unfamiliar (neutral)
    d. Somewhat familiar
    e. Extremely familiar

3. In your experience providing quality management services, which of the following entities have you been hired by? (select all that apply)
    a. The design-builder
    b. The state DOT
    c. Other (please specify)

4. On average, how stringent is the administrative oversight of the CEI firm when it is directly hired by the design-builder compared to the typical level of stringency enforced when it is directly hired by the state DOT?
    a. Substantially more lenient
    b. Somewhat more lenient
    c. About the same
    d. Somewhat more stringent
    e. Substantially more stringent
    f. It depends (please specify)

5. How frequently is the CEI firm responsible for the following tasks in federal-aid design-build projects when the CEI firm is directly hired by the design-builder?

CEI Responsibility	Never	Rarely	Sometimes	Often	Always
Notifying the DOT of key times in the quality management schedule					
Issuing noncompliance reports (NCRs) to address deficiencies in the materials					
Exercising the approved engineering judgement to accept deficiencies in the material test results					

Auditing quality management procedures and records					
Ensuring compliance of project payroll					
Ensuring compliance of report submission					
Ensuring contract compliance					
Conducting construction measurements to certify payments to the design-builder					
Other (please specify)					

6. How frequently is the CEI firm responsible for the following tasks in federal-aid design-build projects when the CEI firm is directly hired by the state DOT?

CEI Responsibility	Never	Rarely	Sometimes	Often	Always
Notifying the DOT of key times in the quality management schedule					
Issuing noncompliance reports (NCRs) to address deficiencies in the materials					
Exercising the approved engineering judgement to accept deficiencies in the material test results					
Auditing quality management procedures and records					
Ensuring compliance of project payroll					
Ensuring compliance of report submission					
Ensuring contract compliance					
Conducting construction measurements to certify payments to the design-builder					
Other (please specify)					

7. How frequently is the CEI firm responsible for ensuring the following aspects of the contract in federal-aid design-build projects when the CEI firm is directly hired by the design-builder?

CEI Responsibility	Never	Rarely	Sometimes	Often	Always
Ensuring the design-builder's compliance to the contract's goal for using disadvantaged business enterprises (DBEs)					
Ensuring the design-builder's compliance to the contract requirement for paying the local prevailing wages on public works projects for laborers and mechanics (Davis-Bacon Act)					

1. How frequently is the CEI firm responsible for ensuring the following aspects of the contract in federal-aid design-build projects when the CEI firm is directly hired by the state DOT?

CEI Responsibility	Never	Rarely	Sometimes	Often	Always
Ensuring the design-builder's compliance to the contract's goal for using disadvantaged business enterprises (DBEs)					
Ensuring the design-builder's compliance to the contract requirement for paying the local prevailing wages on public works projects for laborers and mechanics (Davis-Bacon Act)					

B.2 Interview Protocol

Background/Context:

1. What's your background/experience with QA in the DB environment?
    a. Current role
2. What are the biggest differences between working for DB vs. DOT?
3. What are the biggest differences working in different states?
    a. What is the biggest difference between GDOT and other states?

Roles and Responsibilities:

We have seen a lot of inconsistency in how different members of the CEI industry understand the roles and responsibilities of the CEI firm.

1. Is it the CEI firm's responsibility to …
    a. Exercise engineering judgements to address any incidents during the construction phase?
        i. Does this change when hired directly by the design-builder vs. the DOT?
    b. Conduct construction measurements to certify payments to the design-builder?
    c. Audit quality management procedures and records?
        i. Why might other CEI personnel disagree?
    d. Ensure compliance of project payroll?
        i. Do you set a certain amount for quality management from the overall construction costs?
    e. Ensure design-builder's compliance to contract goal for using disadvantaged business enterprises (DBEs)?
    f. Ensure design-builder's compliance to contract requirement for paying local wages for laborers/mechanics (Davis-Bacon Act)?
    g. Is CEI firm required to monitor/evaluate MOT on projects (maintenance of transportation)?

2. How are expectations typically communicated to the CEI firm?
    a. Do contracts specify everything?
    b. What other methods are used to communicate responsibilities to CEI?
3. Are there any implicit expectations for the CEI firm in QA that are not explicitly specified?
    a. How are CEI firms made aware of what these are?
        i. Norms of the DOT vs. design-builder
    b. How well are CEI firms informed their responsibilities when hired by the design-builder?
        i. Any changes related to reporting line or decision-making time?
4. How can we improve alignment between the DOT and CEI industry's understanding?
    a. What causes these gaps?
    b. What strategies would be most effective for reducing these gaps?

Stringency:

1. How stringent are CEI decisions/actions when hired by the design-builder vs. the DOT?
    a. Why do you think this is the case?
    b. Is the opposite ever true?
    c. Are there incentives for the CEI firm to be lenient when working for the design-builder?

i. What structures?

Suggestions:

1. Is there anything else about the QA process that we missed that you want to discuss?
2. Do you have any suggestions for how to improve the QA process?

APPENDIX C. QUESTIONNAIRE FOR RESEARCH THRUST 3

C.1 An example of an Interview Invitation

My name is Jung Hyun Lee, and I am Dr. Baabak Ashuri's Ph.D. student at Georgia Tech. We are currently working on a project sponsored by the Georgia DOT on the Design-Build Team's increasingly important roles.

Our research is about new key personnel in the design-build team called "Project Chief Engineer." Georgia DOT recently requested the Project Chief Engineer in the RFQ phase of the SR 400 Express Lanes megaproject. This P3 project (DBFOM project) is now in the RFP phase. I included the major responsibilities for this new design-build team position below.

Can we borrow a few minutes of your time to discuss this position from the design professional liability insurance standpoint? Are there any following times working with you this week?

- Wednesday the 27th, 10 am - 6 pm (EST)
- Thursday the 28th, 2-3 pm or after 4 pm (EST)

<u>Project Chief Engineer description as appeared in the RFQ of the SR 400 Express Lanes</u>

Project Chief Engineer Responsibilities:

- Responsible for the supervision and quality of all design work and design process throughout the full design and construction period, including accuracy, adequacy, and conformance to professional standards of practice.
- All decisions throughout design and construction that are related to an engineering aspect of the project must be made under the supervision of the Project Chief Engineer.
- The Project Chief Engineer shall certify the above prior to submission of design work for GDOT review and/or use.
- The Project Chief Engineer is responsible for rejecting or approving the design work, resolving disputes regarding engineering work, for the design integration into the final constructed product and verifying that construction processes do not undermine the intent of safe and sound design.
- The Project Chief Engineer must have the authority to stop work on the Project if and when he/she knows or has reason to believe that any work does not meet the standards, specification, or criteria established for the Project.
- The Project Chief Engineer shall verify that qualified and appropriately licensed and registered specialty/discipline engineers sign and seal work products for a given item, element, or phase of the work as applicable, including the released for construction plans, as well as revisions on construction and shop drawings.

C.2 Interview Questionnaire

1. Could you briefly talk about your DB/P3 experiences?

2. We are curious how you think about the new engineering leadership position required on the design-build team that the Georgia DOT recently requested?
3. What would be the challenges of this new position?
4. Would these following responsibilities be a common practice for the design manager or whoever is responsible for design?
    a. Having the authority to stop work
    b. Working full-time during the construction phase
5. What would be the differences between the design manager and PCE?
6. Have you seen any similar roles as PCE required in large/complex DB projects?
7. What kinds of the project would Project Chief Engineer be needed?
    a. When would PCE be meaningful?
8. What would you recommend for the successful PCE implementation?
9. What are the best practices for large Design-Build projects?

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