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ABSTRACT

State highways agencies policies and procedures for articulating geotechnical information and requirements on Design-Build (DB) projects is a means to manage geotechnical risks. Successful approaches and practices to managing geotechnical risk not only reduce the level of geotechnical uncertainty for both the owner and the competing design-builder, but also distribute the remaining geotechnical risk between the parties. This paper discusses the differences in regard to geotechnical risk management, aspects of the DB procurement process, and contract aspects between state departments of transportation (DOT) with experience delivering projects using DB versus those who are not as experienced. Results are presented from two independent sources of information; one was obtained through literature review of aspects related to geotechnical requirements and management of DB projects, and the other was through an online-survey of 38 DOTs. Results of the study statistically demonstrate the value of DB experience in managing geotechnical risks, and accordingly presents a set of recommended practices for agencies that are relatively new to DB project delivery, during both procurement and contract formation.

INTRODUCTION

For the past two decades, the courts have continually upheld the principle that construction project owners are liable for differing site conditions, regardless of the exculpatory language inserted into contracts in futile attempts to shed this risk (*1*). Research has also shown that managing geotechnical risk in Design-Build (DB) projects may well be the most difficult aspect of alternative project delivery (*2, 3, 4, 5*). Not only is DB selected by public owners for those projects that need accelerated schedules (*6*), but the geotechnical exploration, design, and construction activities are also the first tasks that must be completed as the DB project starts, making them the ones with little or no float (*7*). Therefore, combining DB delivery of a project that includes significant geotechnical uncertainty can easily create the "perfect storm" of risk, and as such, demand that public agencies give the geotechnical aspects of a given project more early attention than a typical project (*8*).

The Federal Highway Administration's (FHWA) Special Experimental Projects No. 14 (SEP-14): *Alternative Contracting* was introduced in 1990 and by 2009 more than 400 DB highway projects had been authorized (*9*). In June 2010, FHWA announced its *Every Day Counts* (EDC) initiative to address the rapid renewal of the nation's deteriorating infrastructure. The program is designed to accelerate the implementation of immediately available innovative practices (*10*). DB project delivery has proven itself to be one method to accelerate the construction, reconstruction, and rehabilitation of aging, structurally deficient infrastructure because it allows construction to begin before the geotechnical design is fully complete (*9*). DB also allows agencies to shift some of the responsibility for completing the geotechnical investigations necessary to support the geotechnical design to the design-builder after the award of the DB contract (*8*). However, in addition to these benefits, there may be some disadvantages that can arise if the contract is poorly documented, particularly related to the management and allocation of subsurface risk between the owner and contractor (*11*).

Many studies have addressed the need to identify, quantify, and mitigate geotechnical risk during the procurement phase of DB projects (*2*). Daoulas (*12*) addresses key elements that should be considered regarding geotechnical risk during the proposal preparation phase. Another study suggests effective practices, such as enhancing communication between the owner and the design-builder, the use of differing site conditions clauses, and expediting geotechnical design reviews after the contract is awarded, can be employed to mitigate/reduce the geotechnical risk (*13*). Likewise, other studies have concentrated specifically on the legal aspects of DB geotechnical issues (*14*). According to the NCHRP Synthesis 429: *Geotechnical Information Practices in Design-Build Projects*, the design-builder is entitled to rely on the geotechnical information contained in the DB Request of Proposal (RFP), and the DB contract's differing site condition (DSC) clauses furnish a mechanism under which the design-builder can claim compensation for additional cost and time if the RFP does not reasonably match the actual conditions (*8*).

The purpose of this paper is, thus, to identify and report the differences among agencies' perceptions toward managing geotechnical risks in DB projects, and accordingly present a set of recommended practices for agencies that are relatively new to DB project delivery. DOTs were divided based on the total number of DB projects that the agencies have delivered. The information comes from a comprehensive literature review supplemented by manuals or documents that the respondents attached in their responses in regard to information that specifically describes the procedures to be used with geotechnical requirements of DB projects, and the output from a survey that sought to identify successful approaches to managing geotechnical risk. The paper will report the variations in the approaches used for DB geotechnical risk management and how those relate to the DB procurement process. It will then compare DB contracting procedures between experienced and non-experienced DOTs.

Background

Because of the need to accelerate the delivery schedule of transportation projects (*9*), DB project delivery has grown steadily over time. With the EDC initiative that proliferated DB project delivery, currently 47 states implemented DB in their highway projects (*15*), yet many DOTs still lack DB experience and have encountered issues dealing with potentially high levels of geotechnical uncertainty during the procurement phase. Thus, effective practices to deal with geotechnical risk during the procurement phase are essential to ensure the quality of the final constructed project. "It is during the development of the Request for Qualifications (RFQ) and RFP that the ultimate quality of the project can be most influenced" (*16, 8*). During procurement phase and beginning of the design phase, quality is the most influenced and then falls off during next stages such as construction and maintenance (*8*). Quality management (QM) is a term that describes the tasks undertaken during the planning, procurement, design, and construction to ensure that the final project conforms all the requirements agreed upon by the owner and the construction contractor (*17*). In a DB delivery projects, QM is implemented using a systems approach involving three primary components (*18, 19*): 1) personnel, 2) plans, and 3) procedures.

According to DOT surveys conducted for NCHRP Syntheses 376 and 429 (*20, 8*), the qualifications of the members of the DB team and its past projects experience were rated as having the most impact on final projects quality. The qualifications of the design-builder's geotechnical engineers and their past experience with project-specific geotechnical issues are also key to achieving quality in the constructed DB project (*8*). Additionally, appropriately weighting geotechnical evaluation factors with regards to all evaluated factors is also essential to selecting the best DB team for a given project (*8*). NCHRP Synthesis 429 found two methods for assigning weight to evaluation criteria. The first consists of assigning a specific number of points to each evaluation criterion with the ratio of individual criterion's point score to the total available points for the entire evaluation representing its weight to the other evaluation criterion. The second method weights each evaluation category in parallel with the objective of the project (*8*). The synthesis concludes that the weight of geotechnical factors must be assigned according to the other factors that define success for a given DB project. A subsequent study suggested that the geotechnical content of the RFP must be tailored for each project (*21*).

A successful DB project depends on a well-written, unequivocal RFP that contains the required information for competing design-builders to prepare approachable proposals that impartiality price the value of the DB project's scope of work and the risk associated with competing that work (*22*). In addition, the amount of geotechnical information expressed in the procurement phase plays an important role over the probability to a given DB project ends in a DSC claim. McLain et al. (*13*) found that providing all the geotechnical information on hand when the project is advertised and forming the DSC clause in a manner that makes it specific to the available geotechnical data instead of using a standard DBB boilerplate DSC was an effective alternative to manage geotechnical risk.

There are four principal areas of the project's solicitation documents that can be addressed in a typical DOT's DB procurement process and that was used by the researchers to identify and evaluate the DOT's geotechnical risk management practices.

1. The geotechnical qualifications for key personnel in the request of proposal (RFP);
2. Specific geotechnical design and construction experience evaluation criteria;
3. Inclusion and weighting of geotechnical evaluation criteria in the proposal evaluation plan, and
4. Geotechnical information requirements required by the RFP to be included in competing proposals (*8*).

RESEARCH METHOD

The study's methodology relied on two independent research instruments. The first instrument was a comprehensive review of literature on managing geotechnical risks in DB projects. The literature review focused on current DOTs processes used regarding geotechnical requirements of DB projects and it included review of DOT risk management manuals.

The second instrument was an online-survey whose purpose was to identify DOT policies and procedures for articulating geotechnical information and requirements on DB projects. The survey was initially issued to the members of the AASHTO Subcommittees on Construction and Design in each of the 50 DOTs. The subcommittee members were asked to then forward the survey to the person best-qualified to respond on an overall department basis. Responses were received from 38 DOTs yielding an overall response rate of 76%. Around 80% of the respondents either work in the department's geotechnical/foundations section. Hence, the survey results reflect the perceptions of the most technically qualified group in each agency.

ANALYSIS AND RESULTS

As detailed in the methodology, the analysis of the survey sought to investigate the differences between experienced and non-experienced DOTs in regard to geotechnical factors. Results of the survey was analyzed using both descriptive and inferential statistics, and was divided into responses from experienced versus non-experienced DOTs as shown in Table 1. The inferential statistics implicated hypotheses testing with the Pearson chi-square to determine whether there is statistically significant difference in the perception of DB projects' geotechnical factors/areas adopted by agencies. The descriptive statistics included the findings of the geotechnical requirements and management approaches online-survey. Table 1 shows the locations and the positions at the time of the online-survey.

TABLE 1. Survey respondent and categorization based on experience in DB projects

Category	**Responding States**
Experienced DOTs *(>10 DB projects)*	Arizona, California, Colorado, Georgia, Kentucky, Maine, Maryland, Michigan, Minnesota, Missouri, Montana, New York, North Carolina, Ohio, South Carolina, Utah, Virginia, Washington, West Virginia
Non-experienced DOTs *(<10 DB projects)*	Connecticut, District of Columbia, Hawaii, Kansas, Louisiana, Massachusetts, Nevada, New Hampshire

Comparison of Perceptions

"Geotechnical engineering is fundamentally about managing risk" (*23*). Even though geotechnical risk cannot be eliminated from DB projects, it can be better managed by appropriately allocating the risk between the owner and the design-builder (*24*). Differing geotechnical conditions are conditions that materially differ from what the contractor should have reasonably expected when it priced its contract (*8*). Many DOTs believe that contractors should assume full risk of differing site conditions (*2*). However, the results of the online-survey for this research show that not all agencies share the same thought. Particularly, the study found that experienced and non-experienced DOTs allocate unknown geological conditions differently. Experienced agencies are defined as those having completed more than 10 DB projects and they tend to share geotechnical risk; whereas non-experienced agencies tend to either accept or shed all of it. NCHRP Synthesis 429 concluded that the emphasis on formal risk analysis before selecting DB project delivery differentiates experienced and non-experienced DOTs (*8*).

In terms of weight of geotechnical factors, Figure 1 shows a comparison of experienced versus non-experienced DOTs in terms of their perception of geotechnical factors weight with regard to all other evaluated factors if they are included in the DB project's evaluation plan. It is seen that while more than 80% of non-experienced DOTs agree that geotechnical factors have No/Minor weight in their evaluation plans, more than 60% of experienced place a Some/Heavy weight to geotechnical factors. This shows how experienced DOTs, in general, are more aware and realize the importance of the geotechnical factors in the evaluation plan on DB projects.

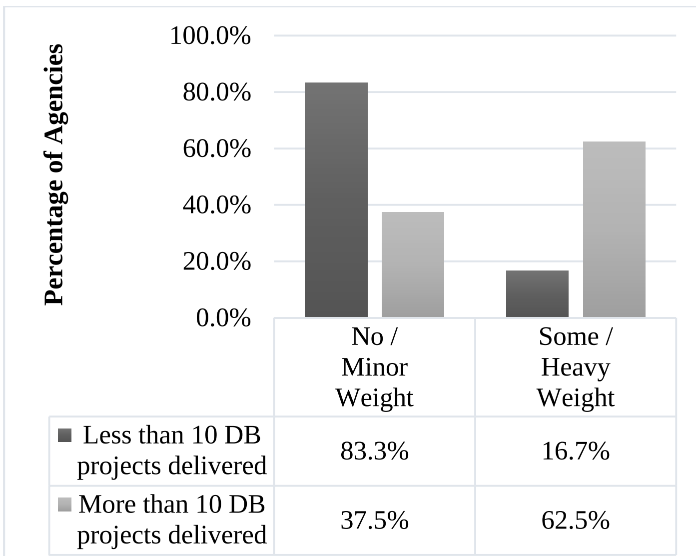
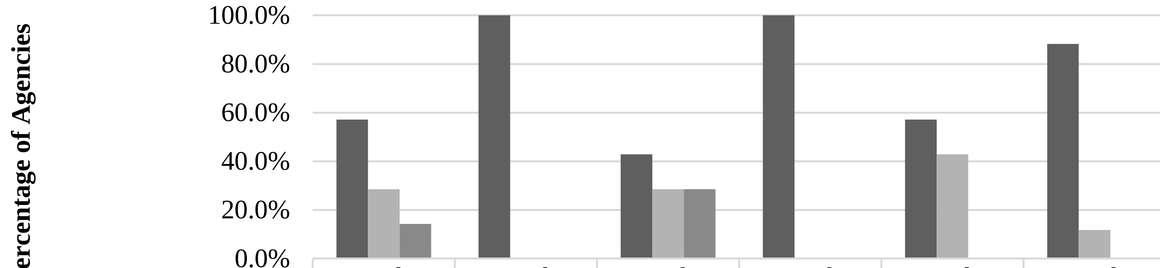


FIGURE 1: Geotechnical Evaluation Criteria Weighting.

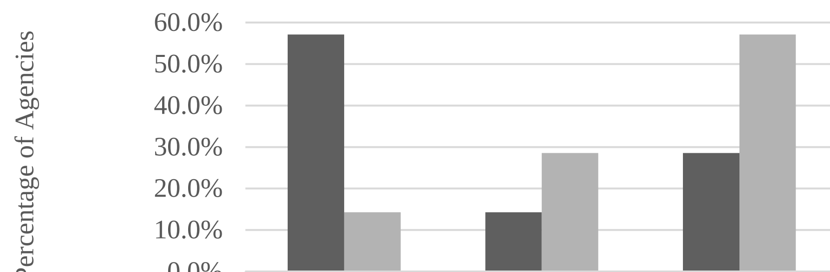
As for the three geotechnical factors shown in Figure 2 in terms of their impact on the final quality/performance of the DB project, a consistent difference is observed in the higher consideration of experienced DOTs of these factors compared the non-experienced DOTs. For instance, 100% of experienced DOTs not only agree in rating the qualification of the design-builder's geotechnical staff as a very/high impact, but also agree in rating the design-builder's past project experience with geotechnical issues as very/high impact. In contrast, non-experienced DOTs results are dispersed across the range of impacts. Non-experienced DOTs do not perceive the importance of qualifying the design-builder's geotechnical experience and workforce as being as important as the experienced DOTs. Experienced DOTs see the amount of geotechnical information included in RFPs as important to decreasing geotechnical uncertainty during procurement, which can make proposals received more competitive (*2*).



	Qualifications of the Design-Builder's geotechnical staff		Design-Builder's past project experience with geotechnical issues		Amount of geotechnical information expressed in the procurement documents	
	Less than 10 DB projects delivered	More than 10 DB projects delivered	Less than 10 DB projects delivered	More than 10 DB projects delivered	Less than 10 DB projects delivered	More than 10 DB projects delivered
Very High/ High Impact	57.1%	100.0%	42.9%	100.0%	57.1%	88.2%
Some Impact	28.6%	0.0%	28.6%	0.0%	42.9%	11.8%
Slight/No Impact	14.3%	0.0%	28.6%	0.0%	0.0%	0.0%

FIGURE 2: Impact of Geotechnical Risk Factors

Another interesting difference between experienced and non-experienced DOTs is related to the allocation of geological uncertainty. Figure 3 illustrates that while 57% of experienced DOTs are more willing to share the subsurface risk uncertainty rather than bear it, more than 50% of non-experienced DOTs are willing to bear the risk rather than share it, and only 14% of these DOTs allocate it to the owner. Thus, experienced DOTs tend to share the risk or bear it, while non-experienced DOTs' tendency is to either take or shed the risk. This could be attributed to the better understanding of the DB project delivery method as compared to the traditional methods in terms of risk allocation.



	Unknown geotechnical condition		
	Owner	DB Contractor	Shared
Less than 10 DB projects delivered	57.1%	14.3%	28.6%
More than 10 DB projects delivered	14.3%	28.6%	57.1%

FIGURE 3. Geotechnical Risk Allocation

Finally, Figure 4 shows the other prominent difference between experienced and non-experienced agencies which was the perception of the level of importance of completing a formal geotechnical risk. Over 70% of experienced DOTs rated a formal geotechnical risk analysis as either "important" or "very important," while 50% of non-experienced DOTs gave the formal analysis of geotechnical risk no importance.

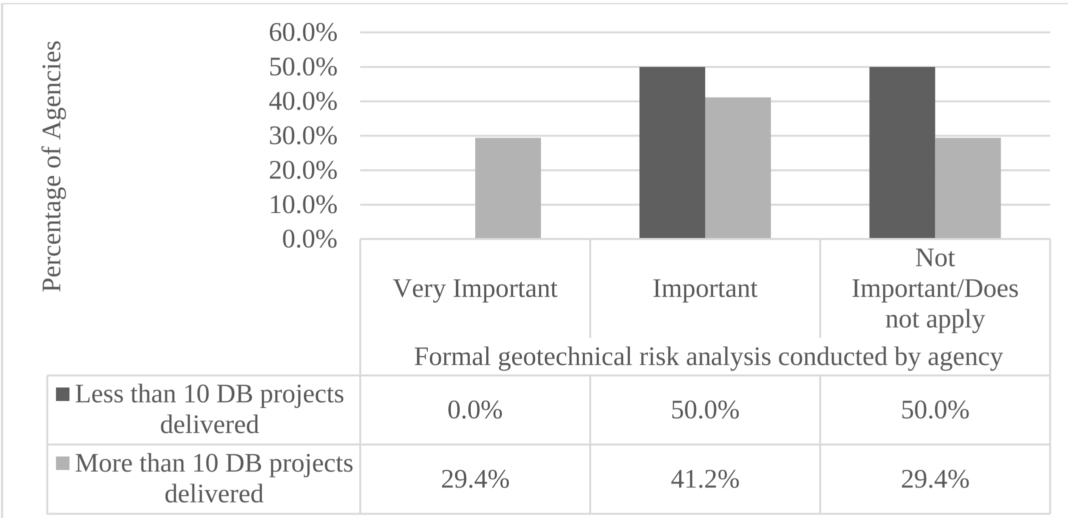


FIGURE 4: Formal Geotechnical Risk Analysis

A statistical analysis was further conducted using the Pearson Chi-Square Test to if there is a statistical significant difference in the perception of DB's geotechnical aspects between the two groups. The Pearson Chi-Square Test is a statistical technique that can be used both as a test of goodness of fit and as a test of independence (*25*).The independence test is used to determine whether two categorical variables are associated with one another (*26*, *27*). Thus, in this study, Pearson Chi-Square Test of independence was used to determine whether there is a significant difference between the perception of experienced and non-experienced DOTs in evaluating geotechnical factors in DB projects during the procurement phase. Table 2 shows the different aspects tested; for example, the hypotheses tested for design-builder's geotechnical staff qualifications was:

H_{o1}: There is no statistical difference between experienced and non-experienced DOTs in their perception of design-builder's geotechnical staff qualifications on the final quality/performance of the DB project.

H_{a1}: There is a statistical difference between experienced and non-experienced DOTs in their perception of design-builder's geotechnical staff qualifications on the final quality/performance of the DB project.

TABLE 2. Summary of Chi-Square Test Results for Experienced versus Non-experienced DOTs

Aspects tested	**Chi-Square (χ^2)**	**Significance (p)**
Impact of the design-builder's geotechnical staff qualifications on DB project quality/performance.	8.327	0.01*
Impact of the design-builder's past project experience with geotechnical issues on DB project quality/performance.	11.657	0.00*
Impact of the amount of geotechnical information expressed in the procurement documents on DB project quality/performance.	2.906	0.08
Geotechnical factor weighting in the evaluation plan compared with other evaluation factors	3.667	0.05
Unknown geotechnical condition risk allocation	4.200	0.12
Formal geotechnical risk analysis conducted by agency	2.385	0.30

As per results shown in Table 2, the following two hypotheses tested were statistically significant:

- Qualifications of the design-builder's geotechnical staff ($\chi^2 = 8.32\ and\ p - value = 0.01$). The null hypothesis was rejected given that *p-value* < 0.05. Thus, there is a statistically significant difference between how experienced and non-experienced DOTs perceive the impact of qualifying design-builder's geotechnical team on the final performance of the DB projects, with experienced DOTs putting more weight on the geotechnical staff experience.
- Design-Builder's past project experience with geotechnical issues ($\chi^2 = 11.65\ and\ p - value = 0.00$). The null hypothesis was rejected given that *p-value* < 0.05. Hence, there is a statistically significant difference between experienced and non-experienced DOTs in rating the design-builder's past project experience with geotechnical issues on the final performance of the DB projects.

The remaining aspects were tested and the hypothesis was accepted, with no statistically significant difference in the perceptions of experienced and non-experienced DOTs.

CONCLUSIONS AND RECOMMENDATIONS

This paper's main objective was to investigate the differences between DOTs experienced and non-experienced in delivering DB projects' in regard to geotechnical risk management, aspects of design-build procurement process, and aspect of design-build contracts. Experience was measured by the number of DB projects delivered. Through an online survey administered to State transportation agencies, it was evident that DOTs with more experience in delivering DB projects viewed and handled geotechnical risks differently. The significant difference was observed in the importance of the qualifications and past experience of the design-builder's geotechnical staff. Another relevant difference was in the degree of impact of the design-builder's past experience with project-specific geotechnical issues. Furthermore, the paper finds that experienced DOTs allocated unknown geological condition risk differently than non-experienced DOTs. Experienced DOTs tend to share unknown geotechnical conditions risk while non-experienced DOTs either allocate all the risk to the owner or attempt to shed it. Also, experienced DOTs do understand the importance of providing as much geotechnical investigation information as possible during the procurement process to reduce uncertainty as much as possible during bidding. Non-experienced DOTs opinions are spread across the spectrum of possible options.

Bringing the above discussed findings into the context of the problem at hand, the study furnishes its main contribution by statistically demonstrating the value of DB experience in managing geotechnical risk. The results can be summarized into the following set of recommended practices for agencies that are new to DB project delivery.

- The qualifications and past experience of the design-builder's geotechnical staff is important to successfully managing geotechnical risk and as such, should be given appropriate emphasis during the procurement process.
- A formal geotechnical risk analysis affords the DOT project staff the ability to identify, quantify and mitigate the geotechnical risk before the procurement process starts and thus adds value to the DB project delivery process.
- Uncertainty is reduced by increasing the amount of information available at the time a decision is made. Therefore, the DOT should provide as much information on subsurface conditions as it has at the time the DB project is advertised to permit competing DB teams the greatest information benefit as they make risk pricing decisions during bidding.
- The cost of geotechnical uncertainty at the time of bidding can be mitigated by the thoughtful allocation and sharing of project-specific geotechnical risks in the DB RFP.

As mentioned in the paper's first section, US case law shows that the owner cannot fully shed geotechnical risk by relying on exculpatory DSC clauses alone. Therefore, this risk must be confronted early in the project development process, producing thoughtful geotechnical risk management plans that rationally share the project-specific risks with the competing design-builders during procurement and after award of the DB contract.

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