Comparison of DB to DBB on highway projects in Washington State, USA

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ABSTRACT

Comparative evaluations of design-build (DB), to design-bid-build (DBB), are documented in literature. However, a recent study suggests that even though several studies have been completed to compare DB and DBB, there are few statistically significant comparative results. Comparative analyses of highway projects of the same scope, size, and type could provide the basis to make the argument for the use of either DB or DBB on highway projects. The objective of this research is to compare DB to DBB on highway projects. The basis of comparison includes project cost, contract duration, number and type of contract change orders. Projects used for this research were obtained from the Washington State Department of Transportation (WSDOT). The projects were subsequently selected based on project scope, size, and type, and then analysed using quantitative methods. The research found that there is enough evidence to support the use of DB over DBB on highway projects. The findings of this study have significant implications for practitioners and policymakers on highway projects and should inform decisions on the choice of project delivery method. The main limitation of the research is that the study used only 14 projects due to the difficulty of finding matching projects, and as such the results could not be generalized. However, the findings add to the body of research on criteria for comparing DB to DBB. To enhance understanding of how project scope, size, and type might affect or be affected by project delivery methods, the research recommends the standardization of project types classification for highway projects.

KEYWORDS: Design-build, Design-bid-build, Highway projects, Project types.

INTRODUCTION

There is a growing number of project delivery methods in practice within the construction industry. There is also the need to assess the effectiveness and impact of the delivery methods on practice and policy. On a Design-Build (DB) project, both design and construction services are procured under the same contract from a single, legal entity referred as the Design-Builder. Typically, the project owner would provide performance specifications and drawings that define the scope and limit of the contract. Such document could take the form of a criteria document or a bridging document. Within the department of transportation (DOT), the number of state DOTs and projects using the DB delivery method is growing as compared to the traditional delivery method (design-bid-build, DBB). Some state DOTs using DB delivery method include Washington State DOT (WSDOT), California DOT, Oregon DOT, Florida DOT, Georgia DOT, Virginia DOT, Colorado DOT, and others. Much of the literature on the use of DB posit that DB delivers advantages over DBB. However, very few studies have been conducted to understand the effectiveness of DB and DBB on highway projects. The work by Shrestha et al. (2007) compared DB to DBB using 11 projects total, and the authors found that

DB was 9.6% lower in cost growth and 5.5% higher in schedule growth. A similar study by FHWA (2006) was conducted using 22 projects total, and the research found that DB was 3.8% higher in cost growth and 9% lower in schedule growth. Several other studies have made the case in support of DB, and there has been a mix of theoretical and empirical underpinnings to those research.

To help provide an objective basis for decision making in this area, this research follows a comparison approach. It is informed by the research completed by Goftar *et al.* (2014 p. 1397) in "A meta-analysis of literature comparing project performance between design-build (DB) and design-bid-build (DBB) delivery systems." The authors conclude that "although several studies have been completed in this area, there are few statistically significant comparative results for a good portion of the metrics considered". The authors indicated that there is a need for more research to compare projects delivered using DB and DBB. While some comparative studies have been conducted objectively based on cost and time, others have been subjective. Warne (2005) evaluated DB performance characteristics by surveying project managers to understand what should be included as measures of performance. Schedule, cost, quality, and owner satisfaction were among the performance measures identified and used in the research by the author. The findings from Warne (2005) included some objective and subjective findings. The research found that 76% of the DB projects were completed ahead of schedule and that the average cost growth for DB projects was less than 4%. Therefore, the study concluded that DB method offers better time and cost alternative. Based on subjective evaluations from the managers, the research gathered that the 21 projects evaluated were built faster with the DB method than they would have been with the DBB method. In this article, to compare DB to DBB, the researcher seeks to use objective measures of growth in cost, time, and number of contract change orders.

The literature review section of this paper looks at why owners are interested in DB, the current trends towards DB, the performance metrics for both delivery methods, and the enablers of each delivery method. The research design and method section describes how the project was selected and analysed. The data analysis and findings section presents the study results, while the discussion section presents the research approach and results within the context of previous research.

LITERATURE REVIEW

The Trend towards DB

In construction, the two main parameters that are typically used to evaluate project performance is being on time and within budget. Time overruns are evidenced through time extension, and cost overruns are shown through contract change orders. The cause of time extension and change orders have been well-documented over the years and owners are doing everything they can to mitigate them. For example, many project disputes arise from design errors, omissions, and changes (Gray & Larson 2008; Hassanein & Nemr 2009). These problems have given way to the trend towards DB as a way to mitigate time and cost overruns. The National Academies (2007) identified that one of the best practices to reduce construction cost associated with disputes is the use of an alternative contract delivery method such as "best value". The recommendation was the use of "best value" approach in bid selection, as opposed to a low bid process. A good example of best value is the use of DB delivery method, where the contractor-designer company takes the risk of design and could no longer go after the owner for omissions and error resulting from the design. Sami and George (2004) state that the DB eliminates the adversarial environment found in the DBB where contracting parties point fingers at one another for design errors and omissions. The trend towards DB is well documented, and Songer and Molenaar (1996) found that reduction in cost, duration, and claims are a few of the main reasons that have encouraged owners to pursue DB as an alternative delivery method. Also, Molenaar *et al.* (1999) highlight the significant milestones, the trends, and the growth in the number of contracts awarded under DB delivery method. The work by Melenaar *et al.* (1999) also provided some performance measures for the analysis of DB, and they included, cost growth, schedule growth, and quality of project. The trend toward the use of DB is increasing, and there are data to support such move. A recent study conducted by Vashani *et al.* (2016) looked at the top 100 design-build firms and found a large increase in their DB revenue and a forecast that shows an increasing trend toward the use of DB in the coming years.

Design-build and Design-bid-build Performance Measures

Some of the benefits of DB as captured in literature include reduced cost, time, and the number of contract changes resulting from design errors and omissions. Several authors have compared DB to DBB, and they all highlight the growing use of DB. Some of the advantages of DB as captured by Hale *et al.* (2009) include cost and time savings. The authors compared 38 DB and 39 DBB projects that were completed by NAVFAC within 1995 to 2004, and they found that DB projects performed better in all ten comparative dimensions used. Gibson *et al.* (2007) are of the opinion that public agencies are using the DB delivery method to improve time to deliver projects. Goftar *et al*'s (2014) in-depth literature review synthesized various research finding on DB and DBB performance benefits. The research found that the commonly used metrics include unit cost, cost growth, delivery speed, schedule growth, and project quality. Other research (Ibbs *et al*., 2003; Park *et al*., 2015; Pocock *et al.*, 1996; Rosner *et al.*, 2009; Riley *et al.*, 2005; Shrestla & Fernane, 2017) has included performance measures that relate to cost-saving, time-saving, and reduction in the number and size of change orders. As it relates to the basis used by the researchers to reach a conclusion on preferred delivery method, the criteria included cost growth analysis, schedule growth analysis, quality performance, owner satisfaction, and contract change order growth analysis.

The trend towards DB is not a panacea for all, because DB also has some shortfalls. As captured by Tenah (2001), some of the disadvantages of DB include: a) mistakes made by the designer can be covered up by the contractor, b) the selection of a qualified design-build firm requires more effort than the DBB due to the two-stage selection process, which includes the request for qualifications (RFQ) and the request for proposals (RFP), and c) DB does not provide the owner a good control of the design and construction process

Project Phasing as Enabler of DB

The construction phase in the DBB delivery method differs from that of DB due to the design-construction continuity as executed by the same entity. The literature presents a good picture on the benefits of using DB, and several factors enable DB performance. For example, bringing together the designer and contractor as one entity is one benefit, and as depicted in figure 1, concurrent design and construction effort is another. The unique difference between DB and DBB is the relationship between the designer and the contractor and how that relates to the phasing of the project. According to Stillman (2002), an important aspect of a DB project is that the project manager is responsible for coordinating and integrating design and construction. The project manager must coordinate design releases and make sure that design related issues are addressed quickly in the field. One aspect of DB that makes it attractive is the fact that the design does not have to be 100% complete before construction can start. DB provides the fast track alternative where some portion of construction can be started while the design is on-going. The overlapping phasing of DB makes it unique and opens up the opportunity for a fully integrated and collaborative construction effort.

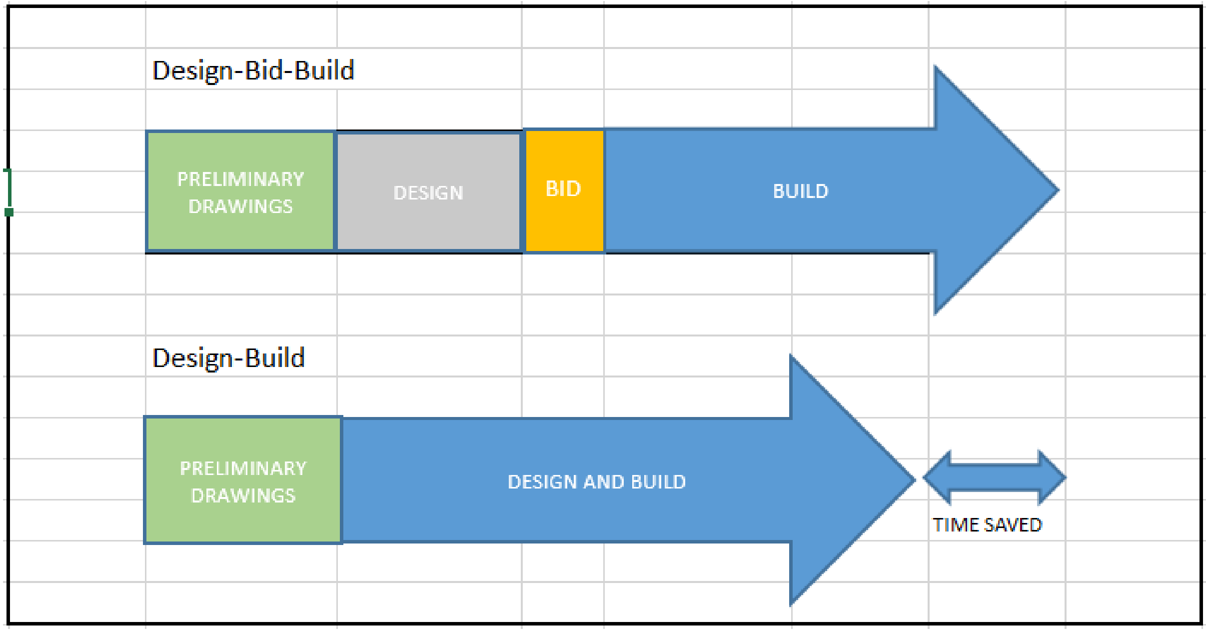

Figure 1: Comparing DB to DBB

Project Management Practices as Enabler of DB

Effective practice may start from the organizational structure. DB entities usually structure their management organization to establish clear responsibilities and reporting at all levels. The organizational structure that they implement must result in all team members working effectively as one team. Unlike the DBB, in DB the project manager is responsible for the design, the construction, and their integration. This is different from DBB where two separate project managers are required, one for the design phase of the project, and one for the construction phase of the project (Stillman, 2002). In DBB, and due to lack of continuity in the management of the design and construction phase, constructability issues, design errors and omissions may arise, all of which may eventually result in contract changes. In DB, the project managers have a broader understanding of the entire project from start to finish. The management team in a DB must tackle a wide variety of responsibilities, including:

- Scope of work for design and construction
- Conceptual design
- Design documents
- Material of construction
- Health and safety in design and construction
- Quality aspects of design and construction
- Construction approach
- Value engineering

- Communications
- Human resource management
- Project schedule for design and construction
- Procurement
- Cost estimate and control budget for design and construction
- Contract administration, risks, and contract changes

According to Beard *et al.* (2001), considering the complex nature of DB, the lead project manager on a DB project must understand the requirements of design management as well as construction management.

Project management practice in a DB environment is different from that of DBB, and the responsibilities of a project manager in DB indicate a broad knowledge of design and constriction practices. According to Chan *et al.* (2005), there is the need to shift from traditional thinking and learn the necessary skill for effective management of DB projects. DB is a single-point of responsibility delivery method and requires a change in practice, or in other words, DB requires an integrated practice of design-construction. Hence the risks must be understood even by the designer-contractor team. According to Liu *et al.* (2017), in DB, the contractor is responsible for catching design risks. The same goes for the DB designer, who is responsible for construction risk resulting from errors and omission of suggestions provided by the DB contractor during design. To mitigate some of these risks, DB companies will typically have their construction engineers participate in the design process to ensure that constructability ideas are incorporated into the design and minimize field design changes during construction.

Project Controls as Enabler of DB

DB is an integrated delivery method with the design and construction phase coordinated and executed by a single entity. Project control in DBB at the design phase is independent of the project controls at the construction phase due to the nature of the contractual agreement. In DB, project control is interwoven and interconnected, and the model is different from that of the DBB. Effective project control creates a plan and measures progress against the plan to remain within scope, meet quality requirements, be on schedule, and be on budget. Project controls on a DB project are unique and very different from project controls in DBB project. DB projects are schedule and communication intensive, and the project controls in DB ensures that the right tool is set up to manage the inherent complexity of DB effectively. This is important because to maintain a collaborative and partnering environment and avoid pointing of fingers; the project controls system must be integrated, transparent and comprehensive. Some of the ways that DB companies have effectively maintained integrated project controls systems include:

- Locating construction and design coordination staff in one office
- Use of collaboration tools such as ShareFile, SharePoint, and ProjectWise
- Internal and external partnering in an open and honest atmosphere.

One of the most demanding aspects of any project is meeting the project schedule. This is even more consequential in a DB project where there is no clear line of when design stops and when construction starts. DB projects require a fully integrated design and construction schedule. Due to the fast-track nature of DB project, there is an inherent dependency between design and construction. Hence an integrated project schedule provides the best tool to manage the dependencies and control the project effectively.

Low Cost as Enabler of DBB

When selecting an appropriate project delivery system, project owners generally want one that will deliver the highest quality, be completed on time and at the lowest possible cost. The lowest bid is what the owners seek for in DBB delivery method. The main basis of award in DBB is cost. According to Beck (2002), the main drive for DBB is to make every effort to keep the project cost as low as possible. At local, state, and federal levels, government regulations mandate competitive bidding on some projects for the selection of contractors by the "lowest responsive bidder." Competitive bidding is seen as a process that is very open and transparent to both the owners, the contractors, and the public. Research has shown that initial low bid may not necessarily result in low project completion cost, hence the trend towards DB. However a study by Perkins (2009) has shown that DB does also result in cost increases.

Design Control as Enabler of DBB

The shift from DBB to DB has been driven by contract overruns and delays resulting from contract changes such as design errors and omissions. According to Pishdad-Bozorgi and Garza (2012), DBB has been known to result in adversarial environment, claims, and litigation due to contract changes. The study by Burati *et al*. (1992) concluded that 78 % of contract changes on the projects the authors evaluated were related to design issues. The research by Shrestha and Mani (2014) explored the impact of design cost on the cost and schedule growth of highway projects. The research found a significant negative correlation between the design cost percentage and the total cost growth of the project. This goes to show that when owners increase the amount of time and resources allocated to design and constructability review, they, in turn, reduce the level of contract changes. One of the main reasons State DOTs choose DBB is because it allows them to control the design. Controlling the design sets the stage for effective management of the construction phase. DBB offers to the owners a high degree of project control, involvement, and oversight (Beck, 2002).

Simple and Non-complex Projects as Enabler of DBB

For projects that are simple, repetitive and that are not complex, there may be no justification to use DB delivery methods. WSDOT (2015) evaluated the use of DB on small projects with contract values between \$2m and \$10m. The study concluded that projects with significant risks could benefit from DB. Projects with complex design, schedule risk, complex phasing, and closures are good candidates for DB. However, in cases where a project is simple and non-complex, the preferred delivery method would be to use DBB. Simple projects have few surprises and are stable enough to allow the use of DBB delivery method. In DBB delivery method where the project is simple, design engineers can reuse similar components of plans and specifications (Beck, 2002).

Gaps in Literature

Most previous studies on DB and DBB project delivery methods included building projects or industrial projects and a few highway projects. Also, most of the studies were not conducted using projects of the same scope and size. The majority of the research in this area were conducted without much thought about using projects of the same scope and size. According to WSDOT (2015), "although a modest benefit in cost is generally accepted using the DB delivery method over DBB, it cannot be directly proven unless the same project is contracted using both methods." In construction, it is an accepted fact that no two projects are the same.

Comparing project delivery method would require using projects with relatively similar features. The research by FHWA (2006) used an equal number of DB and DBB projects. However, other research, such as that by Shrestha et al. (2007) and Ibbs *et al.* (2003), used unequal numbers of DB and DBB. Comparing DB to DBB should be objective and conducted using projects of similar characteristics. This research is designed to address these gaps.

RESEARCH DESIGN AND METHOD

The method used in this research is a quantitative method and made use of secondary data obtained from the Washington State DOT. According to Aliaga and Gunderson (2006), quantitative research explains phenomena through numerical data collected and analysed using mathematically based methods. The projects included in this study were selected based on projects of the same scope, size, and type. The research obtained 100 highway projects from WSDOT, and the projects had project completion dates ranging from 2001 to 2017. The highway projects included a mix of DBB and DB projects of various scopes, sizes, and types. The project types selected included new roadway projects, reconstructed roadway projects, and reconstructed bridge project. Seven projects were selected for each delivery method. The sum of the original contract value for the seven DB projects was $286m and $296m for the seven DBB project. The dataset had information on original contract value, original contract time, amount paid at completion, contract time at completion, and the number of change orders executed on each project. Using the dataset from WSDOT, the research evaluated DB and DBB delivery method on cost, time, and number and type of contract change orders.

DATA ANALYSIS AND FINDINGS

The report presented in this section provides the research data and analysis based on cost, schedule, contract change orders encountered, and the types of contract change orders encountered. The research compared the performance of the two delivery methods, by analysing the data based on the cost and schedule. The cost growth rate column in Table 1 indicates that the rate of contract amount increase is smaller for DB projects with contract amount increase ranges from 2% to 7%. This is in contrast to DBB with higher contract amount increase ranging from 3% to 25%. This result indicates that for similar types of highway projects, contract cost increases are higher on DBB as compared to DB.

To understand the rate of contract duration increase, the data were analysed based on the contract duration at completion as compared to the original contract duration. Table 1 also indicates that while there were no increases in contract duration for the DB projects, there were increases in contract duration for some of the DBB projects. This result indicates that for similar types of highway projects, contract duration increases are higher on DBB as compared to DB.

Comparing the rate of contract change orders encountered on both delivery methods, the data were analysed based on the number of change orders executed. Table 1 indicates that the change orders resulting from the DBB projects were four times higher than the change orders encountered on the DB projects. This result indicates that for similar types of highway projects, a higher number of change orders are encountered on DBB as compared to DB.

To evaluate the type of change orders encountered in DBB as compared to DB, this research analysed the change orders based on pre-defined categories established by WSDOT. Figure 1 indicates that for DB the major reason or cause for the change orders encountered was due to unanticipated project conditions. As compared to DBB, Figure 2 indicates that the major reason or cause for the change orders encountered was due to plan errors and mistakes. This result presents a clear picture of the predominant sources of contract change orders in both delivery methods.

Table 1: Comparison of DB to DB Based on Cost, Schedule and Contract Change Orders

Project ID	Original Contract Amount	Amount Paid at Completion	Amount Paid at Completion as a % of Original Contract Amount	Cost Growth Rate	Original Contract Duration	Contract Duration at Completion	Schedule Growth	Number of Contract Change Orders Executed
	DESIGN-BUILD PROJECTS							
DB1	$ 107,500,000.00	$ 109,837,379.02	1.022	0.022	929	929	0	46
DB2	$ 19,263,000.00	$ 19,558,375.58	1.015	0.015	270	270	0	14
DB3	$ 91,500,005.00	$ 95,808,121.32	1.047	0.047	1061	1061	0	75
DB4	$ 3,346,888.00	$ 3,505,476.18	1.047	0.047	237	237	0	3
DB5	$ 7,277,888.00	$ 7,744,393.27	1.064	0.064	247	247	0	14
DB6	$ 50,415,851.00	$ 53,896,516.82	1.069	0.069	646	646	0	52
DB7	$ 6,875,800.00	$ 7,139,139.48	1.038	0.038	78	86	0.10	15
	$ 286,179,432.00	**$ 297,489,401.67**	**1.040**					**219**
	DESIGN-BID-BUILD PROJECTS							
DBB1	$ 36,650,726.20	$ 37,963,893.38	1.036	0.036	470	470	0.00	71
DBB2	$ 42,021,909.76	$ 51,829,963.73	1.233	0.233	500	661	0.32	192
DBB3	$ 22,810,188.25	$ 28,641,902.16	1.256	0.256	400	497	0.24	70
DBB4	$ 33,750,315.27	$ 36,942,700.32	1.095	0.095	300	300	0.00	108
DBB5	$ 31,466,232.29	$ 35,844,033.57	1.139	0.139	400	400	0.00	148
DBB6	$ 47,295,053.85	$ 58,742,673.03	1.242	0.242	400	441	0.10	332
DBB7	$ 76,699,232.66	$ 90,257,027.94	1.177	0.177	519	562	0.08	154
	$ 290,693,658.28	**$ 340,222,194.13**	**1.77**					**1075**

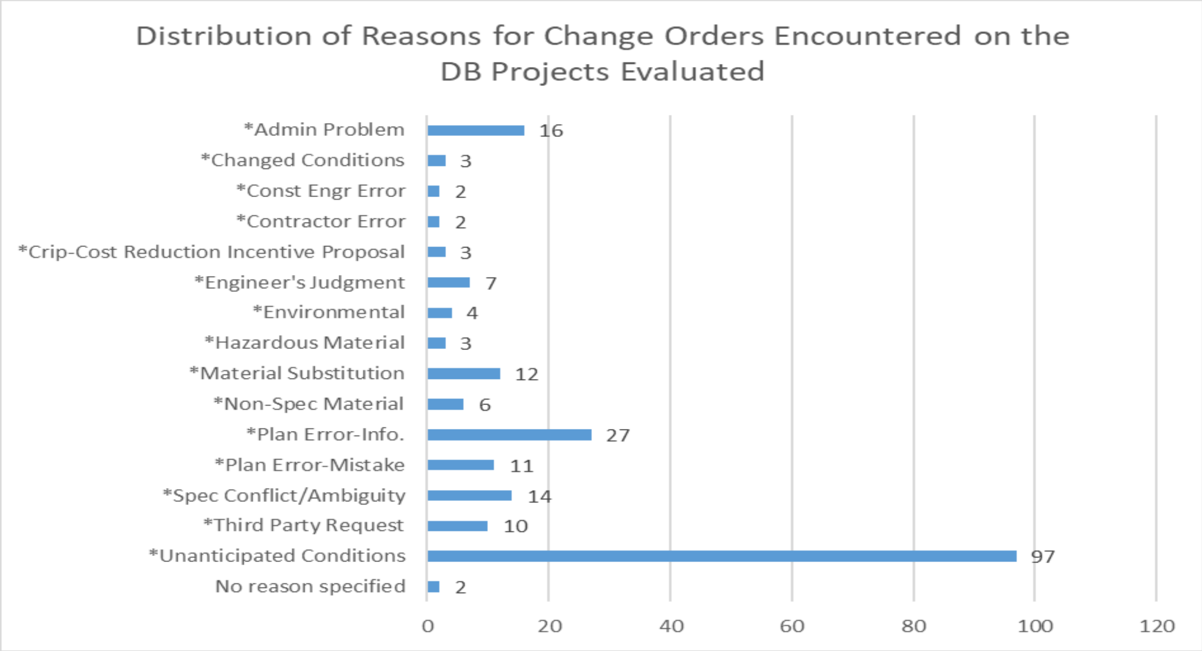

Figure 2: Types of Change Orders Encountered on the DB Projects Evaluated

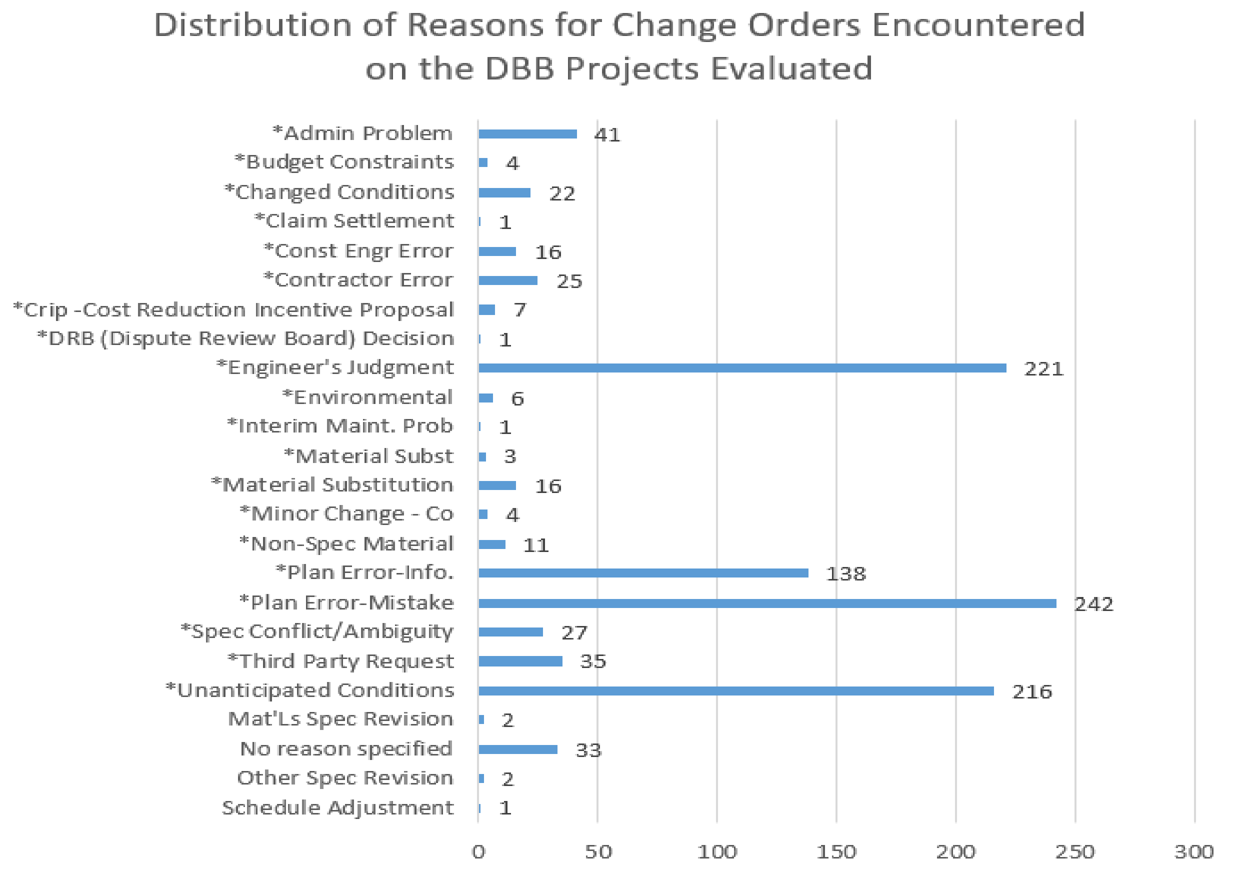

Figure 3: Types of Change Orders Encountered on the DBB Projects Evaluated

Additional analyses were conducted using ANOVA to evaluate if the cost and schedule differences were significant. To check if the data were a good fit for ANOVA, cost and schedule growth data were checked for normality and homogeneity. Table 2 and 3 present the normality and homogeneity test. In both cases, significant values above 0.05 are required for ANOVA.

Table 2: Normality Test

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Delivery Method		Statistic	df	Sig.	Statistic	df	Sig.
Cost Growth	Design-Build	0.148	7	.200*	0.946	7	0.696
	Design-Bid-Build	0.211	7	.200*	0.924	7	0.499
Schedule Growth	Design-Build	0.504	7	0.000	0.453	7	0.000
	Design-Bid-Build	0.232	7	.200*	0.835	7	0.088

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Table 3: Homogeneity Test

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
Cost Growth	10.829	1	12	0.006
Schedule Growth	7.154	1	12	0.020

The cost and schedule growth data were then evaluated using ANOVA. Table 4 presents the result of the test for ANOVA performed on the data.

Table 4: ANOVA Report

		Sum of Squares	df	Mean Square	F	Sig.
Cost Growth	Between Groups	0.055	1	0.055	15.114	0.002
	Within Groups	0.044	12	0.004		
	Total	0.098	13			
Schedule Growth	Between Groups	0.029	1	0.029	3.289	0.095
	Within Groups	0.107	12	0.009		
	Total	0.136	13			

The result from the ANOVA test indicates that the difference found in the cost growth is statistically significant. However, the difference found in the schedule growth is not statistically significant.

DISCUSSION

This study compared DB to DBB delivery method on highway projects based on cost, schedule, and change order growth. This study found cost, schedule, and change order growth to be more in DBB. This finding is in alignment to research by others (Goftar *et al.* 2014; Ibbs *et al*. 2003; Park *et al*. 2015; Pocock *et al*. 1996; Rosner *et al.* 2009; Shrestla & Fernane 2017).

Regarding cost growth, Pocock *et al.* (1996) found that in DB projects, the cost growth was 50% less than what was found in DBB projects. Similarly Ibbs *et al.* (2003) found that DBB projects had 100% more cost growth than DB projects. On schedule growth, Ibbs *et al*. (2003) found that there was more schedule growth in DBB projects compared to DB projects, and Park *et al*. (2015) found that the speed of construction of DB projects was greater than for DBB projects.

On contract change order growth, Ibbs *et al.* (2003) found that change order costs were less on DB projects compared to DBB projects. Rosner *et al.* (2009) found that construction change orders were significantly lower in DB projects than in DBB projects. Also concerning the type of change orders, the study found that plan errors-info was the predominant type of change order on DBB projects, while unanticipated conditions were the predominant type of change order on DB projects.

While this research makes the same conclusion as other researches that compared DB to DBB, the major point of departure is that every effort was made to compare projects of similar characteristics. As Shrestla and Fernane (2017 p.9) note, "to conduct a reasonable performance comparison of DB and DBB projects, one should restrict the effect of various variables (e.g. types of projects, size of projects, owner types, locations, procurement methods) so that the effect of delivery methods can be identified". The findings of this study have significant implications for practitioners and policymakers on State DOT projects and should help them make informed decision on the selection of suitable project delivery methods.

The clear implications of the findings (to theory and practice) is that it encourages the use of projects of similar size and scope when conducting a comparative evaluation of DB to DBB.

Due to the limited number of cases used in this study, the findings could not be generalized. However, the research should serve as a guide for proper selection of projects to include in future comparative evaluations of DB to DBB

CONCLUSION

In the past, DBB was the predominant project delivery method used by state DOTs, but that has changed. Today, there are over seven types of delivery methods used by these agencies, of which design-build is one of them. Each delivery method offers some sets of advantages and disadvantages under certain context, and much has been written on the benefits of using each method. It is common knowledge that the construction industry is fragmented; it has a plethora of stakeholder/players with limited levels of collaboration and unequal risk sharing situations. Comparative evaluation of design-build (DB), to design-bid-build (DBB), have been documented in literature. However, a recent study suggests that even though several studies have been completed to compare DB and DBB, there are few statistically significant comparative results. A comparison could help provide the evidence to make a case for the use of either DB or DBB based on empirical data. The objective of this research was to compare DB to DBB using seven projects for each delivery method with total contract values within $300M. This research compared DB to DB by using projects of the same scope and scale. The projects were evaluated based on four dimensions: cost, time, number of changes orders, and the type of change orders. The result indicates that cost growth, time growth, and contract changes are higher on DBB projects as compared to DB projects. The findings of this study have significant implications for practitioners and policymakers on State DOT projects. The main limitation of the research is that the study compared only 14 projects completed by one agency. However, the findings add to the body of research on comparing DB to DBB. The research highlights the need to use projects of the same scope and size on future studies. To enhance understanding of how project scope and size might affect or be affected by project delivery methods, the research recommends the standardisation of project type classification for highway projects.

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