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RESEARCH ARTICLE

Evaluating design-bid-build and design-build delivery methods based on scope definition and differing site conditions

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Abstract

There has been considerable literature written on the benefits of design-build (DB) project delivery method. Numerous research on this topic compared design-bid-build (DBB) to design-build based on cost and time, but little has been written to evaluate both delivery methods based on scope definition and differing site conditions. This research sought to investigate scope definition change orders and differing site condition change orders on Washington State Department of Transportation (WSDOT) design-bid-build and design-build projects. This research quantitatively analyzed if significant differences exist and if such differences are statistically significant enough to be attributed to the project delivery methods used. The research used available data from WSDOT on projects completed from 2002 to 2016. There were 1813 new design-bid-build projects and only 28 new design-build projects completed within this period with the first design-build project awarded in 2002 for the Sr 16, New Tacoma Narrows Bridge awarded for $615M. This paper presents a snapshot of the state of design-bid-build and design-build delivery methods at WSDOT from 2002 to 2016. Based on the data analyzed for this research, there were no significant differences in the two project delivery methods considering contract changes related to scope definition and differing site conditions.

1. Introduction

Construction professionals know firsthand that projects do not always go as planned. Scope changes, mistakes, errors, omissions, differing site conditions, weather, and so many other factors can affect project performance. The construction industry is a very risky industry due in part to various factors that negatively affect project outcomes. One of those factors relates to contract changes, claims, and disputes. Under different types of contract changes and considering the risk associated with poor management of contract changes, it might be beneficial to understand if projects behave differently in design-bid-build as compared to design-build delivery method. In addition, as the landscape of project delivery methods keeps getting broader it might be important to specifically evaluate project delivery methods based on key contract changes as different from the current practice where the majority of the research focuses on time and cost. Considering the socioeconomic consequences of project failures, this research should help focus research in this area

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for a better understanding of where the strength of each project delivery method lies when viewed from different types of contract changes. Change is a part of construction irrespective of the project delivery method – evaluation based on types of contract changes could provide a better insight into the performance of design-bid-build as compared to design-build delivery method. There is a growing number of project delivery methods in practice within the construction industry. There is also the need to assess the impact of the project delivery methods. The design-build delivery method has continued to gain attention and is widely used. While a lot of studies have concluded that the use of design-build offers savings in time and cost, there are still cases where the use of the design-build delivery method has resulted in cost overruns and/or time overruns. According to Chen et al. [1] after evaluating a large set of data, the authors found that design-build delivery method provides relatively good time performance, with more than 75% of the projects completed on time, and they also found that 50% of design-build projects were completed over budget. As a result, the authors concluded that cost saving advantage of design-build remains uncertain. While much of the focus on the research in this area has been on parameters such as time, cost, and quality, very few have focused on more granular parameters such as specific types of changes. Extensive research has been conducted on the types of changes and sources of changes. In addition, each state department of transportation (DOT) has developed its own list of change order codes to guide them in managing and evaluating sources and reasons for contract changes. The aim of this research is to compare the performance of design-bid-build projects to that of design-build projects based on the number and value of contract changes resulting from scope definition issues, and the number and value of contract changes resulting from differing site condition issues. In this research WSDOT projects completed from 2002 to 2016 were reviewed and selected for analysis. The results show that the project delivery methods do not have any effect on the number or value of change orders as they relate to scope definitions and differing site conditions. In other words, in this research and based on the data analyzed, the impact of the design-build delivery method on the number or value scope definition change orders and differing site condition change orders remain uncertain.

2. Literature review

2.1. Increasing interest and variations of design-build project delivery method

Design-build is not a new method of project delivery. It goes back to ancient times when the master builder served as both designer and builder. However, over the years, design-bid-build became the delivery method of choice, but the shift back to design-build delivery method is growing. Current data from the Design-Build Institute of America (DBIA) in [2] show that the impact of design-build are as follows:

- Market share – 47% percent market share
- Faster project delivery - 102% faster than traditional design-bid-build
- The growth in the number of projects delivered using design-build – 600% increase
- Number of states in the US with legislation for use of design-build delivery method – 48 states + DC
- Project owners' satisfaction ranking of design-build delivery method – higher than other delivery methods

Design-build is becoming the project delivery method of choice and does offer several key advantages.

There are nearly as many variations of the design-build delivery method as there are different types of project delivery methods. There is the traditional design-build where the owner contracts with a single design-build contractor to provide the design and construction for the project. The design-build contractor is often selected through a two-step process. In a two-step process, owners first identify a short list of design-builders based on responses to a request for qualifications (RFQ) issued by the owner. The selected design-builders are then issued a request for proposal (RFP), which includes a baseline design and technical specifications. The baseline design is prepared by a consultant hired by the owner. Based on the baseline design, the design-builders prepare and submit a detailed technical proposal with a design containing enough detail to define both scope and price. This method is also referred to as lumpsum design-build method. On the other hand, there is the progressive design-build method which is focused on a qualifications-based procurement process. This approach allows the owner to select the design-build contractor prior to developing a baseline design, saving time and money. In the progressive method, the owner issues a request for qualifications and selects the design-build contractor based on the contractor's qualifications and past performance. The design-build contractor and owner then collaborate to develop the project's design and budget. The progressive design-build method has an off-ramp option, where the owner can choose to go back to the design-bid-build delivery method if agreements are not reached after the design portion has been completed. It is important to note that the use of an off-ramp is merely an option in the progressive design-build method and not a major differentiator between progressive design-build and other design-build variations. Design-build is continuing to evolve, and several variations will continue to emerge in the future to the extent that design-build continues to offer owners and the design-builder advantages that outweigh the use of other project delivery methods.

2.2. Previous research on comparision of project delivery methods

This section takes a look at previous studies conducted to measure the performance of the predominant project delivery methods. Warne [3] evaluated DB performance characteristics by surveying project managers to understand what should be included as measures of performance of project delivery methods. Schedule, cost, quality, and owner satisfaction were among the performance measures identified and used in the research by the author. The findings from Warne [3] 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 research used objective measures of growth in cost and number of contract change orders. 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. [4] include cost and time savings. The authors compared 38 DB and 39 DBB projects that were completed by U.S. Naval Facilities (NAVFAC) within 1995 to 2004, and they found that DB projects performed better in all ten comparative dimensions used. Goftar et al. [5] 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. [6]; Park et al. [7]; Pocock et al. [8]; Rosner et al. [9]; Riley et al. [10]; Shrestla & Fernane, [11]) 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 majority of the research in this area were conducted without using projects of the same scope and size. The research by FHWA [12] used an equal number of DB and DBB projects. Following the recommendation of using similar and equally sized projects, Okere [13] evaluated Washington State DOT projects selected based on project scope, size, and type, and then analyzed them based on DBB and DB. The researched used only 7 DBB projects and 7 DB projects due to the fact that it was difficult to find projects that were of the same scope and size. However, the research found that cost growth, time growth, and number of contract changes are higher on DBB projects as compared to DB projects. Sullivan et al. [14] synthesized two decades of research work on design-bid-build, design-build, and construction manager at risk bases on fives performance indicators which included: cost growth, unit cost, schedule growth, delivery speed, and quality. The research combined 30 previously completed research with a combined total of 4,623 projects, and the research concluded that design-build is the most effective in controlling cost growth with cost growth of +2.8%, when compared to construction manager at risk with cost growth of +5.8%, and design-bid-build with cost growth of +5.1%. In addition, construction manager at risk and design-build were found to be the better at controlling increase in schedule growth, with an average schedule growth of +10.2% and +10.7%, respectively, as compared to design-bid-build with +18.4%. The research by Hale et al [4] compared the performance of DB and DBB projects at U.S. Naval Facilities (NAVFAC) Navy Bachelor Enlisted Quarters built between 1995 and 2004. The research was conducted to evaluate if there is a statistically significant difference in the project delivery method used. The research by Fernane [15] was conducted to determine whether the design-build projects outperformed the design-bid-build projects in terms of cost, schedule, and change orders. The research found that both schedule and cost were statistically significant, however, the result on change orders was not found to be statistically significant. Shrestha et al [16] investigated 22 highway projects in Texas and the research found an increase of about 18% in project cost when DB was used, however, the research found that the results were not statistically significant. Konchar and Sanvido [17] research also sought to understand the performance of different project delivery methods. A study was conducted by Roth [18] on six Navy child-care facilities on how DB affects project cost as compared to DBB. The result of the analysis showed that DB results in 10% cost savings on average, with a p-value of 0.083 – not statistically significant. Another study was conducted by Bennett et al [19] and included 332 projects and showed 13% cost savings for DB as compared to DBB, however, the study did not report statistical significance. Extensive work by Konchar and Sanvido in [17] compared the cost, schedule, and quality performance of 351 projects completed between 1990 and 1996 for Construction Manager at Risk (CMAR), DB, and DBB projects and observed about 6% cost savings for DB compared to DBB, with high statistical significance. The research evaluated the three project delivery methods on several dimensions including quality, cost, and schedule, and showed that design-build did better than the CMAR and design-bid-build as it relates to cost and schedule.

2.3. Potential causes of delays and cost overruns of projects and their relation to the project delivery methods

According to Sullivan et al. [14], cost growth is the percent change from the initial contract amount to the actual cost at project completion, while schedule growth is the percent change from planned duration to actual duration at completion. Many factors are attributed to cost overruns and delays. The study by FHWA [12] found that for the projects analyzed, 5% of the cost overruns were the result of contract change order. In addition, the research found that design-build projects had fewer change orders as compared to design-bid-build projects, however, the research also found that the average cost per change order was greater for the design-build projects as attributed to the larger size of design-build project. The causes of delays and cost overruns is captured by Fashina et al. [20] and presented in Table 1.

The research by FHWA [12] found that while the choice of project delivery delivery method is a contributing factor when it comes to reducing project cost, the study found that project delivery method was not perceived as the major driver of project cost, but as one of the contributing factors.

Table 1. Causes of delays and cost overruns. Adapted from Fashina et al. [20]

Research	Sources	Factors
Fashina et al. (2021) in [9]	Owner-Related	Delay in honoring payment progressively
		Delay in the provision or delivery of project site
		Slow decision-making process
		Errors in design and specifications
		Lateness in the revision and approval of design documents
		Poor communication and coordination with contracting parties
		Difficulties in accessing credit facilities (E.g. Loan)
		Change orders during construction by owner
		Conflicts between project joint-owners
		Indefinite suspension of work by owner
		Lack of complete documentation before commencement of project
		Delay in the approval of sample materials
	Consultant-Related	Delay in the approval of major changes in the work scope
		Poor communication and coordination
		Lack of significant experience of consultant
		Mistakes and discrepancies in contract documents
		Delays in creating design documents
		Inadequate site survey and data collection before design
		Delay in instructions from consultants
		Back report of the consultant
	Contractor-Related	Difficulties in project financing
		Errors during construction
		Improper planning and preparation during construction project
		Poor site management and coordination
		Delays in sub-contractor's work
		Underestimation or overestimation of the project cost
		Conflicts between contractor and other parties
		Delays in the mobilization of workers
		Regular change of sub-contractor's technical staff
		Conflicts in sub-contractor's schedule in execution of project
		Underestimation of the project durations
	Labor-Related	Lack/shortage of labors
		Labor strike
		Personal conflicts between labors
		Lack of sufficient skilled labors

Table 1. Continued

Fashina et al. (2021) in [9]	Material-Related	Materials procurement difficulties (Lateness)
		Shortage/lack of materials in the market place
		Increase/Fluctuation in the prices of materials
		Delay in the delivery of materials
		Changes in material types during construction
		Damage of sorted materials that are needed urgently
	Construction Equipment-Related	Shortage/lack of equipment
		Breakdown/Failure of equipment
		Low level of equipment-operator's skills
		Challenges with the efficiency and effectiveness of equipment
	External Force-Related	Unfavorable site conditions
		Change in weather condition
		Delay in securing permits
		Occurrence of accident during construction
		Introduction of new government policies, regulations, and laws
		Delay in services provided by utility service providers

The research by Okere [13] found that there were 219 change orders encountered on the 7 design-build projects as compared to 1075 change orders encountered on the 7 design-bid-build projects analyzed. The study also found that on the design-build projects, the key change order type that contributed to the majority of the change orders was grouped under unanticipated conditions, and for the design-bid-build, the key change order types that contributed to the majority of the change orders were grouped under engineer's judgement, plan error info/mistake, and unanticipated conditions. As such, different project delivery methods may encounter different types of change orders at different level of cost impact and cost overrun.

The research by Shoar, et al [21] found that from the engineering services point of view, project cost overruns result from design issues and found that the level of computer-aided design technologies adoption, the level of communication among the project team, and scope definition adequacy are the three factors that contribute to issues of cost overruns. As it relates to differing site conditions in design-build delivery method, several state DOTs take a different point of view as to which party should be responsible for the geotechnical investigation. According to Schwidder [22], Minnesota Department of Transportation (MnDOT) engineers struggled with the issue of how to best transfer the risk related to geotechnical investigations. The agency considered the case where a minimal geotechnical investigation is performed to prepare the contract documents, leaving the risk for additional geotechnical exploration to the design-build team. On the other hand, there is the case where the agency takes on the full responsibility of performing the geotechnical exploration and analysis and leaving the responsibility and risk to the agency. Even when the contracting agency takes on the risk of full geotechnical investigation, there might still be a need for additional geotechnical investigation by the design-build team who then takes on the risk related to their investigation. It is typical for the owner to conduct an early geotechnical investigation and provide a report to the proposers. It is also typical that after the contract award, the design-build team is allowed a specified time to supplement the initial investigation (if required) and identify changes that may reduce cost and schedule impacts. For WSDOT [23], section 3-4.1 of the agency Guidebook for Design-Build Highway Project Development states that "at a minimum, site investigations should be performed by WSDOT to minimize overall project risk and provide the necessary base information for Proposers to complete their pursuit designs without redundant investigations being performed by each Proposer."

To help measure performance on the projects as it relates to change orders, the state DOTs use different codes to track and document the reason for the change orders encountered on their projects. For Ohio DOT, the groups of change orders are captured in Ohio DOT [24] . On WSDOT [25] projects, Table 2 includes the codes the agency uses for specifying what created the need or caused the change order. In this research, the focus is on four change order codes that are related to, 1) changed conditions, 2) plan error information, 3) plan error mistake, and 4) specifications conflict or ambiguity.

Table 2. WSDOT contract change order codes for what created the need or caused the change orders

AP* admin problem	MS* material substitution
BC* budget constraints	NS* non-spec material
CC* changed conditions	**PI* plan error-info.**
CE* contractor error	**PM* plan error-mistake**
EE* const engr error	**SC* spec conflict/ambig**
EV* environmental	TP* third party request
HZ* hazardous material	UC* unanticipated cond
IP*CRIP	

3. Research methodology

In this study, WSDOT projects with completion dates ranging from 2002 to 2016 were analyzed. The highway projects included a mix of DBB and DB projects of various scopes, sizes, and types. The research data came from two datasets. The first dataset had data fields on:

1) original contract value;
2) original contract time,
3) the amount paid at completion;
4) contract time at completion;
5) project delivery method used;
6) contract title;
7) project type;
8) contract description; and
9) other related parameters.

The second dataset had data fields on:

1) the number of change orders executed on each project; and
2) what created the need or caused the change.

The data was further analyzed by project type, and size, and the projects selected for further analysis were projects that were similar for both design-bid-build and design-build delivery methods. This was important to make sure that projects of similar sizes and types were being evaluated.

The DB and DBB projects were evaluated based on what created the need or caused the change per the change order codes in Table 3.

The first three codes in Table 3 represent changes that relate to modification to the contract drawings or/and specifications resulting from errors, and omissions while the fourth code relates to differing site conditions.

To gain a descriptive picture of the state of practice, The following questions were asked of the data:

1. What is the total number of projects that were constructed by WSDOT using DB and DBB delivery methods from 2002 to 2016?
2. What is the total prime bid amount of projects that were constructed by WSDOT using DB and DBB delivery methods from 2002 to 2016?
3. From 2002 to 2016, and based on the select change order codes related to scope definition and differing site conditions, what is the distribution of design-bid-build and design-build project types, the number of projects, the number of contract change orders encountered, and the dollar value for those change orders?

Table 3. Select WSDOT change order codes that are the focus of this research

1. PI*PLAN ERROR-INFO. =	Plans Contain A Mistake That Resulted From The Designer Working With Insufficient Information.
2. PM*PLAN ERROR-MISTAKE =	Plans Contain A Mistake That, Given The Information Available To The Designer, Should Not Have Been Made.
3. SC*SPEC CONFLICT/AMBIG =	There Is A Conflict Or Ambiguity Between Specs Or Between Specs And Plans.
4. CC*CHANGED CONDITIONS =	Site Conditions (Other Than Hazardous Materials) Differ from Design Expectations And Section 1-04.7applies. Applies.

The research objective aimed to compare two groups – the design-bid-build group and the design-build group as they relate to four change order codes. For statistical inferential analysis, the research hypothesis is as follows:

1. Null Hypothesis: From 2002 to 2016, and based on the change order codes related to scope definition and differing site conditions, design-bid-build and design-build delivery methods do *not affect* the number of change orders encountered and the value of the change orders encountered.
2. Alternative Hypothesis: From 2002 to 2016, and based on the change order codes related to scope definition and differing site conditions, design-bid-build and design-build delivery methods do *affect* the number of change orders encountered and the value of the change orders encountered.

To test this hypothesis, the study accepts a confidence level of 95% (significance level of 5%). This means that if the calculated p-value is less than the significance level (e.g., 0.05), the null hypothesis will be rejected. In other words, for the null hypothesis to be false, the p-value must be less than or equal to 0.05. This result means that the difference between the two means is statistically significant and that the data provides strong enough evidence to conclude that the two population means are different.

This research falls under the case of an imbalanced research design where a comparison is made between two independent groups with unequal sample sizes. In this case, the research considered the following options:

1. Fix the design and make the group sample sizes equal,
2. Collect more data to make the sample sizes equal,
3. From the group with the large sample size, randomly select enough samples to equal the size of the group with the small sample size, and
4. Use Welch's t-test instead of the student t-test since Welch's t-test does not have the assumption of homogeneity of variance between groups, and unequal sample size will not affect the analysis.

Because of the unequal number of design-bid-build versus design-build projects analyzed, and the data type being analyzed, it was determined that Welch's t-test analysis of variance will be the statistical analysis to use. The qualitative analysis is based on Welch's t-test with a p-value of 0.05. Welch's t-test is a type of inferential statistic used to study if there is a statistical difference between two groups. Mathematically, it establishes the problem by assuming that the means of the two distributions are equal. Weltch's t-test was conducted to evaluate if there is a statistically significant difference between design-bid-build projects and design-build projects when compared based on 1) the number of scope definition changes and differing site condition changes encountered, and 2) the dollar value of scope definition changes and differing site condition changes encountered.

It is important to note that for the inferential analysis using Welch's t-test, there are 50 design-bid-build projects and 14 design-build projects both are of similar project types. While 14 projects may seem small, a study by de Winter [26] showed that t-test analysis can be completed with a small sample size and that a small sample size will not pose problems for the analysis.

3.1. Dataset used in this study

From 2002 to 2016 Fig. 1 describe the distribution of projects executed based on design-bid-build and design-build delivery methods. The data show that only about 1.5% of the projects were constructed using the design-build delivery method.

As shown in Fig. 2, the value of projects constructed using the design-build delivery method was 37% of all the projects constructed during this period.

1813 design-bid-build projects and only 28 design-build projects were completed from 2002 to 2016 by the agency. However, data on the number of, and dollar value of the change orders executed on the projects were only available on 82 projects. For those 82 projects, Fig. 3 detial the breakdown and distribution of those projects based on the project types. The project type classification was developed specifically for this research based on the contract scope of work as described in the contract title, contract description, and other relevant parameters.

Out of 82 projects, 18 projects related to building facility, wall, seismic retrofit, ramp, and pavement repair were removed, leaving 64 projects. Fig. 4 describes the distribution of the final selection of projects used in this research, and for which data were available.

Table 4 below, is a distribution of the 64 projects that made the final selection, the number of changes encountered on each project, and the value of the total change orders based on project type.

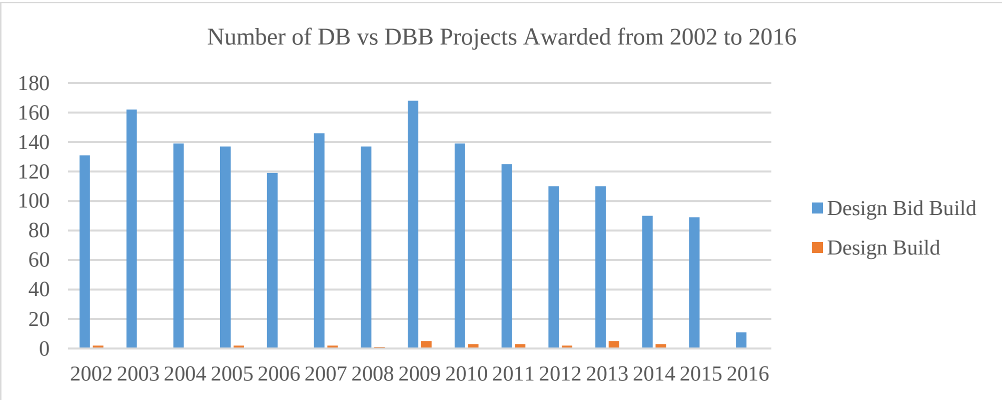

Fig. 1. Distribution of the number of WSDOT projects constructed from 2002 to 2016 under design-bid-build and design-build delivery methods

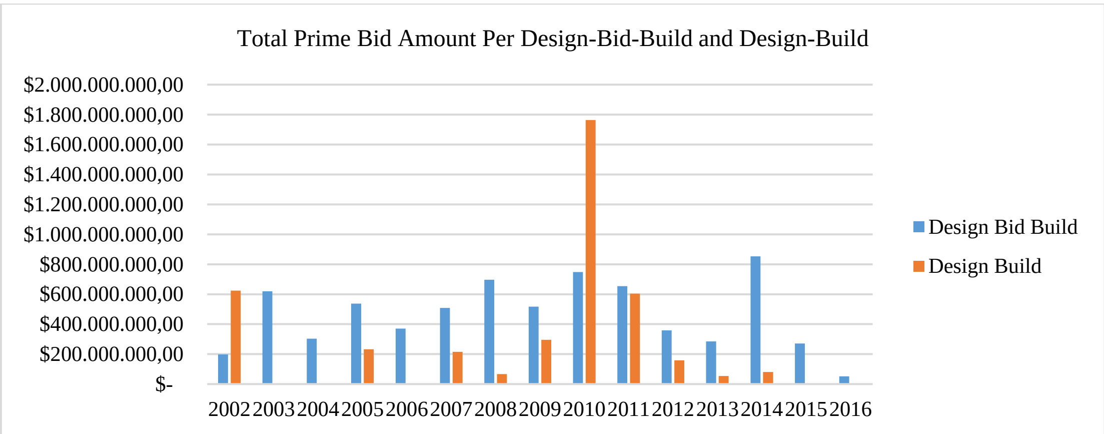

Fig. 2. Distribution of project values of WSDOT projects constructed from 2002 to 2016 under DBB and DB delivery methods

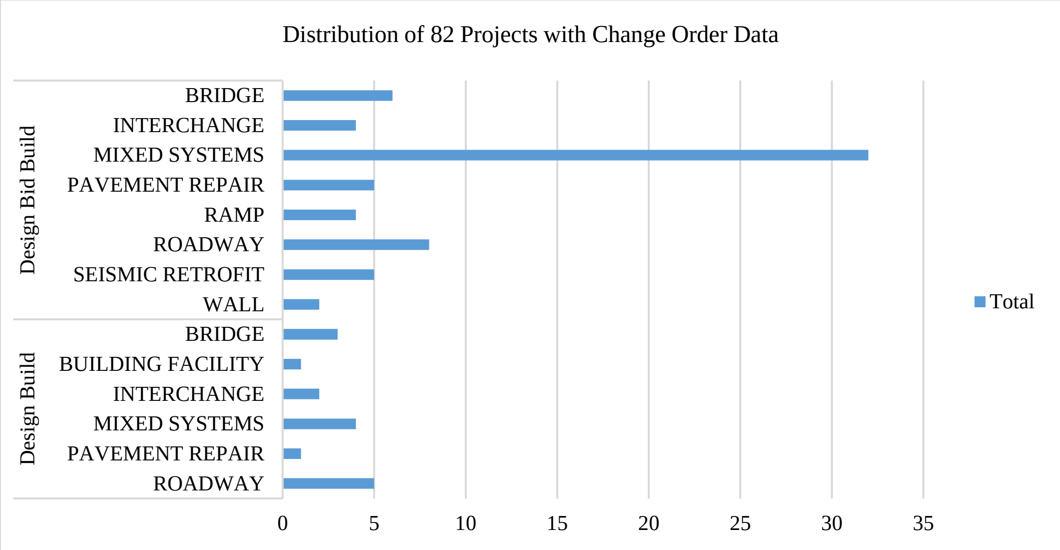

Fig. 3. Distribution of 82 projects for which change order data was available for analysis

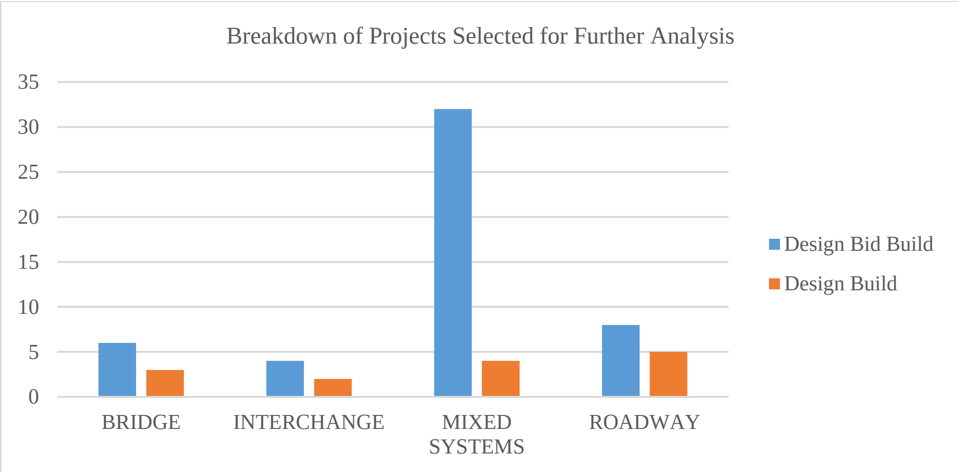

Fig. 4. Distribution of 64 WSDOT projects from 2002 to 2016 finally selected for further analysis

Table 4. Descriptive data showing the distribution of project values of the 64 WSDOT projects selected for further analysis

	Design-Bid-Build		Design-Build	
Project Type	Sum of Bid Amount	Sum of Number of Change Orders	Sum of Bid Amount	Sum of Number of Change Orders
ROADWAY	$ 149,624,303.44	979	$ 503,354,865.00	253
MIXED SYSTEMS	$ 457,509,991.30	1993	$ 199,335,198.00	224
INTERCHANGE	$ 50,197,756.76	256	$ 110,846,888.00	49
BRIDGE	$ 250,343,716.65	535	$ 989,205,800.00	332
Grand Total	$ 907,675,768.15	3763	$ 1,802,742,751.00	858

For each of the project types, the data in Fig. 5 show the number of change orders based on what created the need or caused the change.

The data in Table 5 and Fig. 6 describe the distribution of the dollar value of change orders based on what created the need or caused the change.

The data selected for further analysis included 50 design-bid-build projects and 14 design-build project.

For the 50 deign-bid-build projects evaluated, the range of data go from a project with 10 change orders to a project with 941 change orders. For those 50 design-bid-build projects evaluated, the range of data go from a project with cost growth of $65,723 to a project with cost growth of $202,547,819.87

For the 14 design-build projects evaluated, the range of data go from a project with 7 change orders to a project with 387 change orders

For the 14 design-bid projects evaluated, the range of data go from a project with cost growth of -$853,187.88 to a project with cost growth of $244,441,367

The data show that there are more design-bid-build change orders than design-build change orders. In terms of the dollar value of the change order, the data show that the dollar values of the design-bid-build change orders are more than the dollar value of the design-build change orders. The data also showed a unique case, where over $70 million in design-build project change orders from bridge projects were the result of only 24 plan error mistakes.

4. Data analysis and discussion

To evaluate the performance of design-bid-build and design-build in this research, the research chose to compare the number of change orders and the dollar value of change orders from the two delivery methods.

The most common statistical analysis to compare the means between two independent groups is to use a two-sample t-test. However, this test assumes that the variances between the two groups are equal. In this research, the sample size from the design-bid-build delivery method is 50 and the sample size from the design-build delivery method is 14. With an unequal sample size and unequal variance, it was decided to use Welch's t-test, which is the nonparametric equivalent of the two-sample t-test. Welch's t-test analysis was conducted to evaluate if there is a statistically significant difference in the means of the number and value of change orders encountered in the two delivery methods, which could indicate that the project delivery method has an effect. Welch's t-test instead of a Student's t-test was used because Welch's t-test does not have the assumption of homogeneity of variances between groups, so unequal sample sizes will not affect it, like with Student's t-test. This evaluation focused only on the four change order codes evaluated in this research.

One of the aims of the research was to find out if the number of scope definitions and differing site conditions change order were a result of the use of the design-bid-build or design-build delivery method.

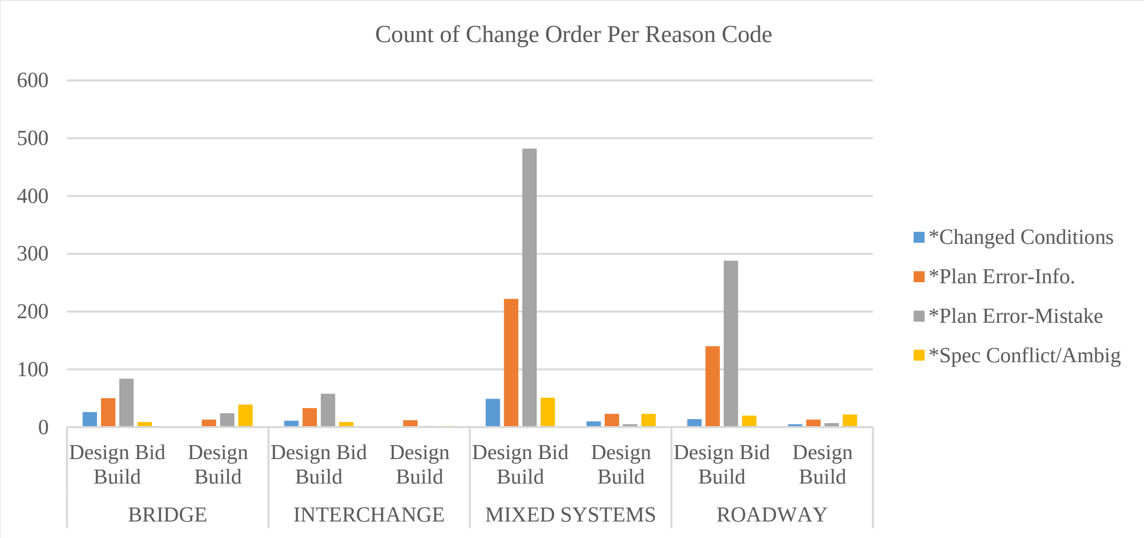

Fig. 5. Descriptive data showing the distribution of the number of scope definition change orders and differing site conditions change orders encountered on the 64 WSDOT projects selected for further analysis

Table 5. Descriptive data showing the distribution of dollar value of scope definition and differing site conditions change orders encountered on the 64 WSDOT projects selected for further analysis

Dollar Value of Change Order Per Reason Code	Change Order Reason				
Project Type	*Changed Conditions ($)	*Plan Error-Info.($)	*Plan Error-Mistake ($)	*Spec Conflict/ Ambig ($)	Grand Total ($)
BRIDGE	6,834,898.88	3,887,840.56	70,806,883.57	348,136.57	81,877,759.58
Design Bid Build	6,834,898.88	2,908,840.56	799,736.57	216,083.57	10,759,559.58
Design Build	----	979,000.00	70,007,147.00	132,053.00	71,118,200.00
INTERCHANGE	103,527.02	1,608,944.08	635,370.84	68,346.00	2,416,187.94
Design Bid Build	103,527.02	628,166.52	510,096.84	13,972.00	1,255,762.38
Design Build	----	980,777.56	125,274.00	54,374.00	1,160,425.56
MIXED SYSTEMS	5,948,736.52	7,900,131.04	6,249,278.09	653,283.09	20,751,428.74
Design Bid Build	5,057,429.52	5,997,056.98	6,001,314.09	167,284.67	17,223,085.26
Design Build	891,307.00	1,903,074.06	247,964.00	485,998.42	3,528,343.48
ROADWAY	3,018,804.23	2,924,424.80	10,785,509.63	2,364,045.96	19,092,784.62
Design Bid Build	1,668,361.93	2,165,619.80	10,205,998.90	1,936,988.96	15,976,969.59
Design Build	1,350,442.30	758,805.00	579,510.73	427,057.00	3,115,815.03
Grand Total	15,905,966.65	16,321,340.48	88,477,042.13	3,433,811.62	124,138,160.88

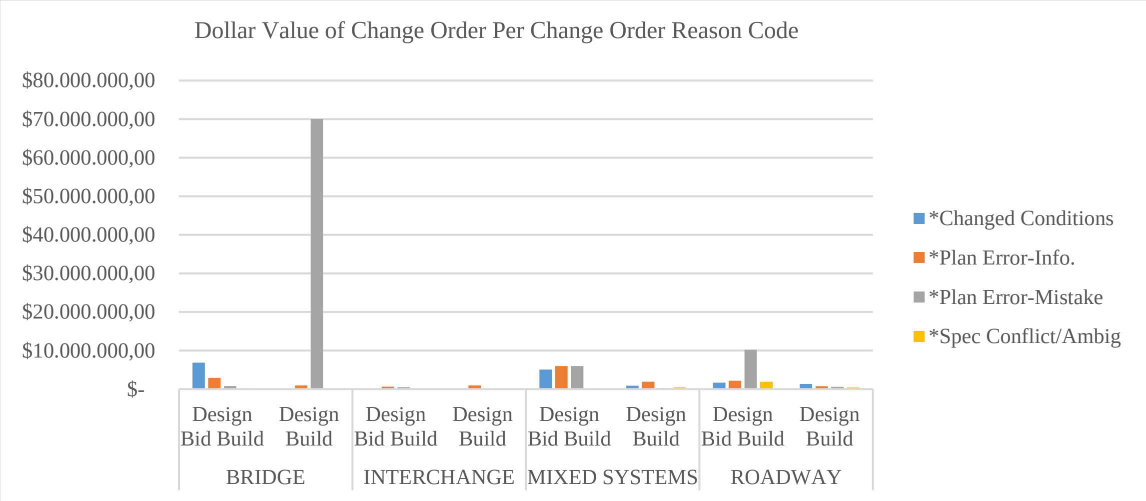

Fig. 6. Descriptive data showing the distribution of dollar value of scope definition and differing site conditions change orders encountered on the 64 WSDOT projects selected for further analysis

The analysis was conducted to evaluate if the project delivery method has any effect on the number of change orders encountered on the projects – where the assumption is that there is no difference in the number of change orders encountered on a design-bid-build when compared to design-build.

Further analysis was conducted on the 50 DBB projects and 14 DB projects to identify outliers.
Two outliers were identified and removed from the analysis. The first outlier removed was a DBB project with 868 change orders that resulted in a cost growth of $202,547,819.87 and the second outlier removed was a DB project with 387 change orders that resulted in a a cost growth of $244,441,367. With the outliers removed, data from 49 DBB and 13 DBB was then analyzed based on the number of contract changes orders encountered on each project delivery method.

The result presented below in Table 6 shows that there is no significant difference or variation between the two project delivery methods. This indicates that the project delivery methods did not affect the number of change orders encountered in both project delivery methods.

To answer the question of how strong is the difference between the two groups. The larger the effect size the stronger the difference between the two groups. Cohen's d = (M2 - M1) ⁄ SDpooled, where SDpooled = √((SD12 + SD22) ⁄ 2). Cohen's d = (126.46 - 158.85)⁄128.393178 = 0.252272.The result from Cohen’s d analysis indicates that there is a negligible difference between the two groups. This result supports the p-value obtained in Table 6.

Another aim of the research was to find out if the dollar value of scope definitions and differing site conditions change order were a result of the use of the design-bid-build or design-build delivery method.

Further analysis was conducted to evaluate if the project delivery method has any effect on the dollar value of change orders encountered on the projects – where the assumption is that there is no difference in the dollar value of change orders encountered on a design-bid-build when compared to a design-build.

The corresponding Welch’s t-test is presented below in Table 7, and the p-value indicates that there is no significant difference or variation between the two project delivery methods. This indicates that the project delivery methods did not affect the dollar value of change orders encountered in both project delivery methods. This could be read as saying that for the projects analyzed, the project delivery method did not influence the dollar value of change orders encountered.

Table 6. Test result from welch's t-test on whether there is a statistically significant difference in the number of change orders encountered and if such difference was influenced by the project delivery method
t-Test: Two-Sample Assuming Unequal Variances (Welch's t-test)

	DESIGN-BID-BUILD	*DESIGN-BUILD*
Mean	158.8571429	126.4615385
Variance	25145.83333	7825.769231
Observations	49	13
Hypothesized Mean Difference	0	
df	35	
t Stat	0.970101117	
P(T<=t) one-tail	0.169326364	
t Critical one-tail	1.689572458	
P(T<=t) two-tail	0.338652728	
t Critical two-tail	2.030107928	

Table 7. Test result from Welch's t-test on whether there is a statistically significant difference in the dollar values of change orders encountered and if such difference was influenced by the project delivery method
t-Test: Two-Sample Assuming Unequal Variances (Welch's t-test)

	DESIGN-BID-BUILD	*DESIGN-BUILD*
Mean	3688911	11344325.83
Variance	3.19514E+13	4.09015E+14
Observations	49	13
Hypothesized Mean Difference	0	
df	13	
t Stat	-1.350878787	
P(T<=t) one-tail	0.099889553	
t Critical one-tail	1.770933396	
P(T<=t) two-tail	0.199779106	
t Critical two-tail	2.160368656	

To answer the question "how strong is the difference between the two groups. The larger the effect size the stronger the difference between the two groups. Cohen's d = (M2 - M1) ⁄ SDpooled, where SDpooled = √((SD12 + SD22) ⁄ 2). Cohen's d = (11344325 - 3688911) ⁄ 14848676.239423 = 0.515562. The result from Cohen's d analysis indicates that there is a negligible difference between the two groups. This result supports the p-value obtained above.

The result, while not unexpected, provides a number of implications. Although the number of design-build projects used in this research is small compared to the number of design-bid-build, however, the empirical findings are compelling when added to the body of research in this area. It is also unique to note that while most investigations in this area are focused on evaluating project delivery methods on the basis of overall time and cost, this research looks at the same problem based on the types of contract changes encountered. The research findings indicate that the number and value of change orders encountered on the projects are not driven by the types of project delivery methods used. However, more design-build project data is needed for a conclusive quantitative comparison. The findings of such research may result in a change in the current procurement policies. In addition, further investigations of the underlying reasons for the time and cost overruns are required. The current performance evaluation of design-build and design-bid-build is based on overall cost and time, it is hoped that this research will redirect and focus the research specifically on the performance of the project delivery methods based on types of contract changes encountered on a project. For example, how does a project perform under differing site conditions when the delivery method is design-build as compared to design-bid-build? Such analysis will provide a better insight than the use of overall time and cost.

5. Conclusions

The shift from design-bid-build to design-build delivery method has gained momentum and almost all the state DOTs in the US have some form of design-build delivery method in use. There has been considerable literature written on design-bid-build and design-build based on cost and time, but little has been written to compare the two delivery methods based on scope definition and differing site conditions. This research gathered and analyzed data on scope definition change orders and differing site condition change orders on WSDOT design-bid-build and design-build projects. A comparative analysis of design-build to design-bid-build was conducted based on scope definition and differing site condition change orders. The projects selected for this research were similar in types and sizes for both design-bid-build and design-build delivery methods. This research evaluated if significant differences existed and if such differences were statistically significant enough to be attributed to the project delivery methods used. The expectation in the construction industry is one of improved performance and arguably that the use of the design-build delivery method should improve time, and cost, both of which are directly dependent on the number of change orders encountered and the dollar value of changes orders encountered. The findings of this research are aligned with what other researchers have found when evaluating if there is a statistically significant difference in the project delivery method used. Based on the data analyzed for this research, there were no significant differences in the two project delivery methods considering contract changes related to scope definition and differing site conditions. One of the limitations of this research is that the number of design-build projects that were available for use in the analysis was only about 1.5% of the total projects constructed by WSDOT from 2002 to 2016. More design-build projects are needed to answer the question of if the project delivery method has any influence on the number of and dollar value of scope definition and differing site condition change orders encountered. Finally, it is important to note that these conclusions are made considering that the available data represented a snapshot in time on the state of contract administration at WSDOT from 2002 to 2016.

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Author Contributions

G. Okere: Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Writing Original Draft, Writing- Review & Editing.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

Not applicable.

Conflict of Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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