Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods

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Abstract: This study compares the performance of design/bid/build and design/build to see if one project delivery method is superior in regards to time and cost. Similar military buildings were used to identify two samples of projects delivered with each of the two delivery methods. These projects provide a meaningful comparison because they include buildings of the same typology (i.e., U.S. Navy Bachelor Enlisted Quarters) delivered using similar design models. Project duration, project duration per bed, project time growth, cost growth and cost per bed were statistically compared. Upon completion of the analysis, the hypothesis that design/build projects are superior to design/bid/build projects in regards to time and cost was tested. Design/build projects were proven superior in performance in almost every measure. Other findings, including recommendations to practitioners and researchers, will be provided as well.

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Introduction

As budgets within the federal government continue to come under pressure, the "do more with less" mantra is often repeated. To increase efficiency, the federal government has adopted several different project delivery methods over the last 10 years. Various project delivery methods are currently in use today. Two prevalent methods are design-bid-build (DBB) and design-build (DB) (Konchar and Sanvido 1998). The following definitions for DBB and DB are used in this paper.

Design/bid/build is a project delivery method in which the owner enters into a contract with an architect/engineer (A/E) firm that provides design services based on the requirements provided by the owner. The A/E deliverables includes plans and specifications for the construction of the project. These documents are subsequently used by the owner as the basis to make a separate contract with a construction company. Although many methods are used for awarding this contract, the most common approach is to solicit bids from different construction companies. The company providing the lowest bid will then build the project based on the documents produced by the A/E. Therefore, two separate contracts, with two separate entities, are utilized by owners to complete one construction project, including two solicitations and procurement steps.

Design/build is a project delivery method in which the owner provides requirements for the specified project and awards a contract to one company who will both design and build the project. Therefore, there is only one procurement step to select one entity to complete the project, and one contract between the owner and this entity.

Before 1996, the Federal Acquisition Regulations made it difficult to utilize anything except the traditional DBB method. Following the private sector's lead, the U.S. Congress passed the "Clinger-Cohen Act" in February 1996 allowing the use of the DB project delivery method (Loulakis 2003). This act establishes guidelines to determine whether DB is appropriate for public projects.

Among many other organizations, the Naval Facilities Engineering Command (NAVFAC) has been in step with the trend toward an increased use of DB. Unfortunately, NAVFAC has had difficulty assessing the impact of using more DB contracts because the data have been dispersed among many different databases throughout the world, with no one person able to easily access all of the necessary data. As a result, no known studies that compare NAVFAC's DB and DBB projects have been completed.

This study analyzed empirical data from two samples of very similar NAVFAC projects. One sample contains 39 DBB projects and the other sample 38 DB projects. Statistical analyses were used to perform an empirical comparison of DBB and DB and to determine if one project delivery method is generally better than the other. These samples were used to statistically compare project duration, project duration per bed, project time growth, cost growth, and cost per bed. The final objective was to test the hypothesis that DB is a superior project delivery method as compared to DBB. The scope of this study was limited to measuring cost and schedule performance of a sample of NAVFAC projects for bachelor enlisted quarters (BEQ) delivered from FY95 to FY04 through the military construction (MILCON) process. The MILCON process timeline is shown in Fig. 1.

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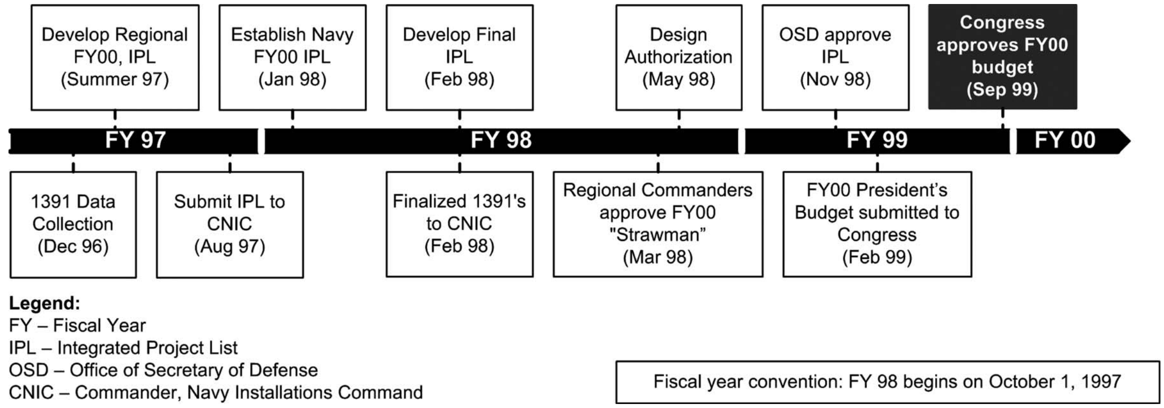

Fig. 1. MILCON process timeline

The study described in the current article is unique because it is based on the comparison of two relatively large and homogeneous samples collected from within a specific organization to determine if one project delivery method outperforms the other in relation to cost and time (Hale 2005). Although there are many variables affecting project performance, this treatment should reduce some of the factors influencing the results of the study.

Literature Review

A significant body of literature comparing DBB and DB has been published, but no significant published research results have compared a relatively large homogeneous sample of projects within one organization.

In 1995, Roth compared six DBB and six DB Navy childcare facilities built through the MILCON process. Using this small sample, Roth found that the use of DB significantly reduced costs associated with design and construction. The results also showed that cost growth was decreased for DB projects. However, his sample was very small from a statistical perspective and compared projects before DB began to be used significantly as an alternative project delivery method within the Navy.

Ibbs et al. (2003) concluded that DB projects outperformed DBB with respect to time, but the results relating to cost were not as convincing. They concluded that the skill of the project management team and the experience of the contractor had greater impacts on project performance than the project delivery method. The projects in this study were much larger than the ones studied for this paper. Of the 67 projects, 30 projects were greater than $50 million, and the project sample was relatively heterogeneous in terms of project type.

Numerous studies have shown that time can be saved by using the DB project delivery method (Songer and Molenaar 1996; Konchar and Sanvido 1998; Molenaar et al. 1999). Songer and Molenaar (1996) used literature and survey results versus more empirical research. Konchar and Sanvido (1998) collected and analyzed data for 351 U.S. projects comprised of six facility types. They used a multivariate model to examine unit cost, construction speed, delivery speed, cost growth, and schedule growth. They concluded that DBB projects were more likely to have changes in schedule than DB. They also concluded that the DB project delivery method would show cost benefits. Bennett et al. (1996) conducted a similar study in England that also used multivariate analysis. They compared cost, schedule and quality performance, with their results similar to Konchar and Sanvido.

Molenaar et al. (1999) described the evolution of the DB project delivery method and analyzed 104 public-sector Design/Build projects. Their results provide important analysis of cost, time, and quality data for DB projects, but they do not compare a similar sample of DBB projects within the same organization.

Uhlik and Eller (1999) provide an excellent description of perceived benefits of using DB versus DBB for military medical construction projects, but have no empirical data. They suggest that a shift to DB would decrease the time to design and build new military medical facilities. They also assert that the overall cost would be reduced.

Warne (2005) published a report on performance assessment of DB contracting for highway projects. The author studied 21 DB highway projects across the country ranging in size from $83 million to $1.3 billion. The study showed that DB projects had better price certainty and the majority of DB projects were completed ahead of schedule.

In 2006, Federal Highway Administration (FHwA) compared project performance of DB highway projects against similar DBB highway projects. DB highway projects were first built under Special Experimental Project 14 (SEP-14) after FHwA started using the DB method in 1990. The cost of projects selected for comparison were less than $20 million and the researchers selected 11 pairs of comparable highway projects built under these two delivery methods. This report analyzes the project performance using descriptive statistics. The study results show that DB projects had higher cost growth but lower schedule growth in comparison to DBB projects (USDOT-FHwA 2006).

Another recent study compared performance of DB and DBB highway projects with project cost higher than $50 million. The DB projects were selected all over the US, whereas DBB projects were selected from the state of Texas. The total sample size of this analysis was 15. The statistical analysis showed that the average cost growth for DB was lower than DBB and statistically significant. However, the schedule growth for DBB was lower than that for DB but not statistically significant (Shrestha et al. 2007). Findings from the cited studies comparing DB and DBB methods are summarized in Table 1.

Research Methodology

Identifying Data Sources and Collecting Data

All data for this study were obtained through various offices of NAVFAC. A request was made for data pertaining to all MILCON

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Table 1. Findings of Studies Done on DB and DBB

Researchers	Methods	Sample size	Project types	Project size	Major findings
Roth (1996)	DB	6	Navy child care facilities	N/A	Cost growth for DB was lower than that for DBB.
	DBB	6			
Songer and Molenaar (1996)	DB	108	Industrial, building, and highways	N/A	Reduced cost and shortened duration were the top ranked factors for selecting DB method.
	DBB	N/A			
Konchar and Sanvido (1998)	DB	155	Industrial and buildings	N/A	Unit cost was 6% and cost growth was 5.2% less in DB. Schedule growth 11.4% less in DB.
	DBB	116			
Molenaar et al. (1999)	DB	104	Industrial, buildings, and highways	N/A	59% of DB projects were with 2% or better of the established budget.
	DBB	N/A			77% of DB projects were within 2% or better of the established schedule.
Ibbs et al. (2003)	DB	24	Buildings	\$5 M to \$1 B	Cost growth for DB was 7.8% higher than that for DBB.
	DBB	30			Schedule growth for DB was 2.4% lower than that for DBB.
Warne (2005)	DB	21	Highway projects	\$83 M to \$1.3 B	76% of DB projects were finished ahead of schedule.
	DBB	N/A			DB offered greater price certainty and reduced cost growth.
FHwA (2006)	DB	11	Highway projects	\$5 M to \$20 M	Cost growth for DB was 3.8% higher than that for DBB.
	DBB	11			Schedule growth for DB was 9% lower than that for DBB.
Shrestha et al. (2007)	DB	4	Highway projects	\$50 M to \$1.3 B	Cost growth for DB was 9.6% lower than that for DBB.
	DBB	7			Schedule growth for DB was 5.2% higher than that for DBB.

projects to enable a comparison of DBB and DB projects. The data were originally restricted to projects approved by Congress for fiscal years 1997 to 2003. The data were exported from financial information system (FIS) database into a spreadsheet. FIS is a mainframe application that "provides funds management, project accounting, and contract accounting for managing construction projects" (Woodie 2004). The data fields included description, location, project delivery method (DBB or DB), original contract amount, final contract amount, original project start date, project completion date, and category code.

The authors wanted to compare similar facilities that were either DBB or DB. All facility types were analyzed to determine which facility type had the most associated projects. BEQs had the most projects during this time period. More specific project information was requested for all BEQ MILCON projects approved from fiscal year 1995 to 2004. The data for these BEQ MILCON projects were exported from FIS into a spreadsheet.

The majority of data collected is from this spreadsheet; however, a few notable gaps in the data existed. Design start dates and total project costs were obtained from eProjects, which is web-based project management software that enables the user to input data as well as to view data in a simple to use format that is tailored for project specific details.

The data from FIS and eProjects did not provide a detailed description of each project (Hale 2005). Project descriptions, cost estimate information and other information were collected from a NAVFAC website or from reference copies of DD Form 1391 located at NAVFAC Headquarters at the Washington Navy Yard. Any information that could not be gathered from these sources was collected through interviews.

Identifying the Data Sample

One hundred twenty-nine BEQ projects were found in FIS that were authorized between 1995 and 2004. During the analysis of the data, 52 projects were not considered as outlined below. Thirteen projects were open bay barracks. These barracks were not considered since the interiors of these buildings are vastly different from the other barracks. Unlike the barracks used in the analyzed sample, open bay barracks have a centralized location of the bathroom/shower facility, a significantly higher density of beds, and heating and cooling systems requirements are significantly different since an open bay must be temperature controlled versus numerous smaller rooms. Fourteen projects were renovations to existing buildings. The cost for renovation is significantly different since the building shell already exists. Therefore, these projects were not considered. Eight projects would not finish in time for analysis in this study and were not considered. Two projects were built for the Air Force. Since the Air Force has different standards for their barracks, these projects were not considered. Two projects had duplicate entries. The same projects for barracks in Port Hueneme, California and Great Lakes, Illinois were listed in two different fiscal years. Thirteen projects were located overseas. Due to such differentiating factors as foreign currency fluctuations, differing costs for labor, and varying availability of materials, these projects were not considered (Hale 2005).

After all these projects were removed, 77 projects remained. These projects were divided into two samples based upon the project delivery method chosen. The DBB sample contained 39 projects. The DB sample contained 38 projects.

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Table 2. Test Results of Homogeneity of Variance

Metrics	Levene statistic	Significance
Cost per bed with other costs	0.747	0.390
Cost per bed without other costs	0.036	0.850
Cost growth	3.775	0.056
Total project duration	15.388	0.001
Fiscal year duration	1.889	0.173
Project start duration	0.965	0.329
Project duration per bed	17.301	0.001
Fiscal year duration per bed	2.263	0.137
Project start duration per bed	2.566	0.113
Time growth	4.515	0.037

Table 3. Data Attributes

Data attributes	Statistics	Design/build	Design/bid/build
Project duration (days)	Minimum	404	655
	Maximum	1,078	3,160
	Mean	667	1,398
Number of beds (days)	Minimum	40	72
	Maximum	820	744
	Mean	329	275
Final project cost (USD)	Minimum	\$3,706,719	\$4,733,558
	Maximum	\$37,564,468	\$26,805,417
	Mean	\$14,453,298	\$13,156,670

Statistical Analysis

Statistical analyses were used to compare the samples and determine if one project delivery method is better than the other. In addition to standard descriptive statistics, a single factor analysis of variance (ANOVA) was used for most comparisons to determine if differences were statistically significant. The confidence level selected for the analysis was set at 95%, because the statistical analysis done within this range is considered to be acceptable in the construction industry. The ANOVA assumed a null hypothesis that the means of the DB and DBB samples were equal ($\mu_{DB}=\mu_{DBB}$). For the null hypothesis to be false, the p-value must be less than or equal to 0.05. Given that the null hypothesis is true, the p-value represents the probability of observing a random sample that is at least as large as the observed sample. If the p-value is below 0.05, the difference in the means is considered to be statistically significant (Weinstein 2007).

There are four underlying assumptions in ANOVA testing. They are: (1) the dependent variables are interval or ratio scaled; (2) the samples are randomly selected from the population; (3) the dependent variables for all the groups are normally distributed; and (4) the variances of population distribution for all the groups are equal. The first and second assumptions were found to hold true in this sample. The histogram of dependent variables for all groups shows that the data were normally distributed per assumption 3. Levene's test was conducted to test if the samples had equal variances per assumption 4. The null hypothesis for this test is that the samples have equal variances. The null hypothesis will be rejected if the significance level of this test is less than 0.05. The test results show that only total project duration, project duration per bed, and time growth metrics had significance levels less than .05 (Table 2). The test rejects the null hypothesis of equal variance across the two groups for these metrics. Therefore, all the metrics except these three metrics had equal variances. The results of ANOVA test will not be affected because F statistic is quite robust against violations of this assumption, if there are an equal number of samples in each group and, if the scores in the population are normally distributed, which were found to hold true in this sample. (Hill and Lewicki 2006).

Data Description

The analysis of the attributes of the DBB and DB samples presented in Table 3 shows that the number of projects in each sample was evenly distributed with 39 DBB projects and 38 DB projects. For the DBB projects, the minimum and maximum project duration was 675 days and 3160 days, respectively. For DB projects, the minimum and maximum project durations were 404 days and 1078 days respectively. The average numbers of beds in DB and DBB project were 329 and 275, respectively. For DBB projects, the final project cost varied between \$4,733,558 and \$26,805,417. For DB projects, the final project cost varied between \$3,706,719 and \$37,564,468. The projects were built in 18 different States and the District of Columbia.

Out of the 77 projects, 40 were 2+0 configurations used for Marine Corps bases and the other 37 were 1+1 configuration used for Navy bases. The distribution of projects by Navy Regions was uneven when comparing the two samples. The disproportionate number of DB projects was executed in Navy Region Southwest and some regions that executed several DBB projects did not construct any DB projects.

Adjustments for Time and Location

Because the 77 projects were delivered between FY95 and FY04, a time adjustment was needed. Escalation tables based on office of management and budget (OMB) inflation forecasts and provided in the historical *Air Force Construction Cost Handbook* (Air Force 2005) were used to calculate the rate of inflation. For each project, the index corresponding to the midpoint of construction was identified with the midpoint of construction determined by figuring the total construction time and dividing by 2. Therefore, each final project cost was adjusted to the latest midpoint of construction (i.e., September 2004). The total adjusted barracks project cost was obtained by multiplying the total barracks project cost by the September 2004 index and then dividing by the respective midpoint of construction index. This value was divided by the total number of beds to obtain the cost per bed.

Similarly, because the 77 projects were delivered in different locations, a location adjustment was needed. For this purpose, the authors used the area cost factor (ACF) index developed by the department of defense. This index compares construction costs in a specific location to the national average as ACF equals 1. According to the *Air Force Cost Handbook*, ACF indexes "are used by department of defense services to adjust average historical facility cost to a specific project location" (Air Force 2005, p. 54). According to same source, "the area cost factor index takes into consideration the cost of construction material, labor and equipment, and other factors such as weather, climate, seismic conditions, mobilization, overhead and profit, labor availability, and labor productivity for each area" (Air Force 2005 p. 54). After identifying locations of each military project, the authors adjusted them using the ACF listing dated February 2005.

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Table 4. Mean and Median Values of Cost Metrics by Project Delivery Methods

		Metrics		
Project delivery methods	Statistics	Cost/bed with other cost $K/bed	Cost/bed $K/bed	Cost growth %
Design/build	Mean	56.0	53.1	2.0
	Median	43.8	43.5	1.2
	Standard deviation	28.0	24.3	2.2
Design/bid/build	Mean	58.0	56.4	4.0
	Median	50.8	49.2	3.6
	Standard deviation	27.3	26.7	4.3

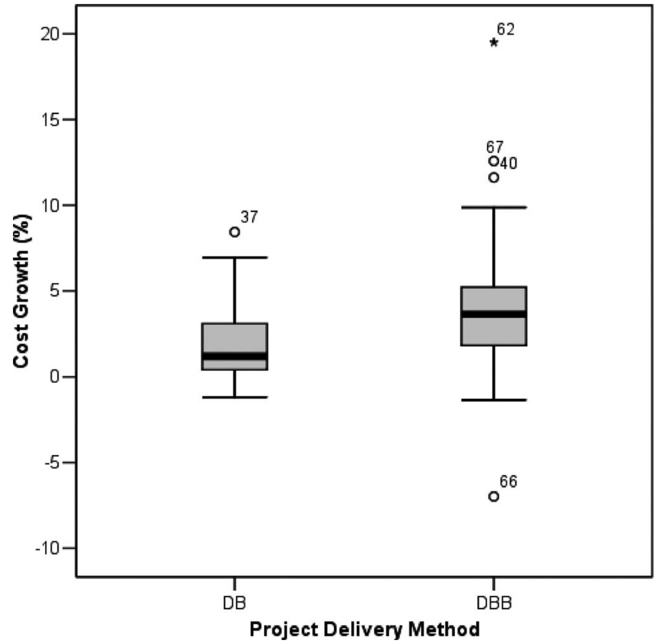

Fig. 2. Box plot for cost growth

Findings

Cost-Related Performance Metrics Results

Cost/bed with other costs, cost/bed, and total project cost growth for the two samples were analyzed. Since cost is always a consideration when determining which project delivery method to use, the cost/bed with other costs and cost/bed are important metrics to consider. Since both samples have a wide range in number of beds, the cost/bed metrics were used to normalize the data in order to see if one method was more cost efficient than the other. This data is equivalent to analyzing the cost per square foot since project total square footage is based upon the number of beds in the facility. The findings of the analysis are described below.

Cost/Bed with Other Costs

Cost/bed with other costs includes the cost of the BEQ construction along with other types of work included in the project. These costs were broken down into two groups: demolition and "other costs." Demolition costs were included in 50 of these projects. The projects included demolition of anywhere from 1 to 11 buildings. "Other costs" included a variety of unusual costs that needed to be removed to accurately obtain a cost per bed. This category included costs for construction of separate facilities such as mess halls, gymnasiums, and parking structures. Other examples include environmental mitigation, special architectural features to match surrounding buildings, and dewatering. Four projects had "other costs," but no demolition costs. Five of the 50 demolition projects had both demolition and "other costs."

Table 4 shows the mean and median for cost/bed with other costs. The average value for DB is $2,000 less than DBB (about 3% less). The median value shows a little more disparity. The median value for DB projects is about $7,000 less than the median value for DBB projects or about 14%. The standard deviations for both samples are similar.

Cost/Bed

For 54 of the 77 projects, the total project cost also included costs that did not directly relate to the construction of the BEQ. These costs were removed to accurately compare project with nonconstruction costs to projects without these extra costs.

As discussed above, numerous "other costs" may have had an impact on the cost/bed since each project has varying values of "other costs." Project costs were reduced by eliminating these values to obtain the cost/bed. Table 4 shows the median, mean, and standard deviation for the cost/bed metric. The difference between the mean ($3,000 per bed) and the median ($6,000 per bed) are similar to the difference shown in the cost/bed with other costs statistics. The means for DB and DBB were about $3,000 per bed and $2,000 per bed lower for this cost/bed metric respectively. However, median values remained the same for DB but reduced by about $2,000 for DBB. For DB projects, standard deviations for the cost/bed metric were 13% smaller of the analogous cost/bed with other costs while, for the DBB projects, this metric was only slightly smaller of the cost/bed with other costs.

Cost Growth

Inevitably, a construction contract will have change orders and minimizing the impacts of these changes on the overall cost of the project is important. The percentage of change in terms of total contract cost was evaluated. Table 4 shows that the mean cost growth for DB is about one half the cost growth for DBB. The DB median cost growth is less than about one third the median cost growth for DBB. The DB standard deviation is almost one half the DBB standard deviation. Figure 2 shows representative box plots for cost growth metric by delivery methods. This figure is a good example of the variation evident within each sample. Horizontal lines within each box represent median cost growth metric values presented in Table 4. The outlier data points can be seen in this plot. In DB sample there is one outlier project, whereas in DBB sample there are four outlier projects. An outlier is characterized as being more than 1.5 times the interquartile range above the third quartile or below the first quartile (Weinstein 2007).

Project Duration-Related Performance Metrics Results

The length of time to complete a project is an important element of project performance and was compared for each delivery method. The total project duration will be calculated as the difference between the dates of the first contract action and the project completion.

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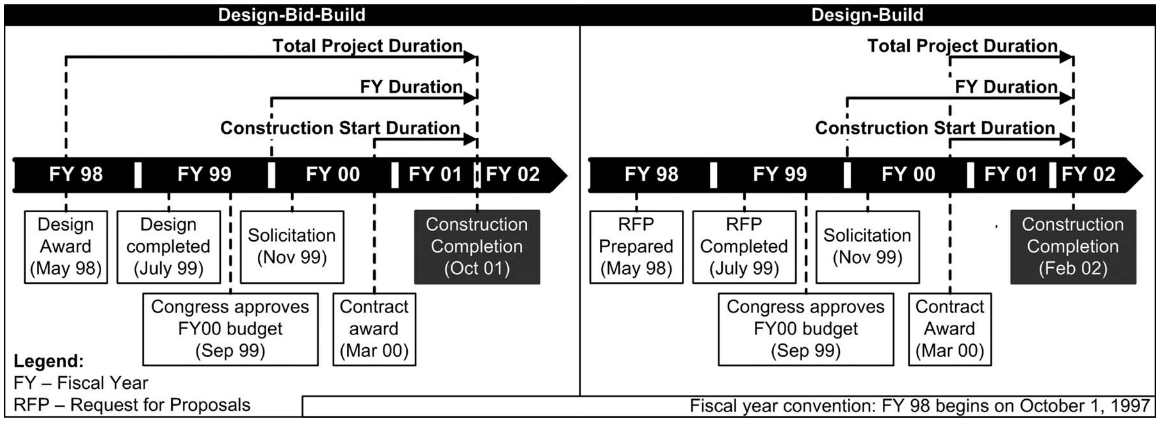

Fig. 3. Timeline for DBB-29 and DB-17

Total Project Duration

The first contract action for DBB is the award of the contract for design. Therefore, the total project duration for DBB projects includes the duration of the design contract, the duration of the solicitation for construction proposals, the award of the construction contract, and the duration of the construction contract until completion. Figure 3 shows the timelines of two actual projects, one from each subsample. These timelines are provided as examples of a typical timelines for a project and to graphically show the various project durations. The first contract action for the DB projects is the project contract award date. Therefore, the total project duration includes the duration of the contract for the design and construction of the project until contract completion.

As shown in Table 5, the data analysis of total project duration shows that the mean DB project duration is less than half of the mean DBB duration (667 days versus 1398 days). The median of the DB data is near its mean duration (671 days versus 667 days). The median for the DBB data is lower than its mean due to the high number of projects that are significantly higher than the mean (1398 days versus 1233 days) thus skewing the sample. DB projects seem to be more consistent as shown by the lower standard deviation.

Fiscal Year Duration

One may argue that the difference as given previously may be attributable to fiscal constraints. A DBB project's design may be completed well before Congress authorizes and approves the funding for the appropriate fiscal year, thereby increasing the project duration. Since a DBB construction contract and DB project contract can not start until after the fiscal year begins, a second project duration was calculated. "fiscal year duration" or "FY duration" was calculated as the difference between the contract completion date and the beginning of the FY authorized (i.e. October 1, 1999 for FY2000 projects). Figure 3 graphically shows these durations.

The FY Duration means and medians for the two samples are much closer to the same value, as shown in Table 5. The difference in the means and medians is around 150 calendar days (864 days to 1026 days), which is about four times lower than the same difference in total project duration.

Table 5. Mean and Median Values of Project Duration by Project Delivery Methods

Project delivery methods	Statistics	Metrics: Project duration days	Fiscal year duration days	Construction start duration days
Design/build	Mean	667	864	667
	Median	671	855	671
	Standard deviation	173	216	173
Design/bid/build	Mean	1,398	1,026	771
	Median	1,233	980	733
	Standard deviation	584	286	215

Project/Construction Start Duration

Congress does not always approve and authorize the MILCON projects on or before the beginning of the fiscal year. So using the start of the fiscal year might skew the results since the number of projects in each sample is not the same in each fiscal year. Another project duration value was therefore calculated. This duration value starts at the first contract action after the beginning of the fiscal year. Therefore, DB sample duration includes both the time for design and construction, whereas the DBB sample only includes the time required for construction. This duration will be referred to as project/construction or P/C start duration. Fig. 3 graphically shows these durations.

The means and medians project/construction start duration for these two samples are similar as shown in Table 5. The means are only different by 90 days (667 days to 771 days) and the median by 62 days (671 days to 733 days). The samples still appear to have some variation, but are more similar than the previous two sets of samples. However, it should be noted that these comparisons appear to show that the time to both design and build a BEQ using DB is less that the construction-only time for DBB BEQ projects.

Time/Bed

Each BEQ project had a unique number of beds. The above durations only take into account the total duration irrespective of the size of projects. A potentially more accurate comparison of total time may be to compare average project time per bed for each sample.

Days/Bed Using Total Project Duration

The data analysis of days/bed using total project duration shows that the mean, median, and standard deviation for the DBB

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Table 6. Mean and Median Values of Days per Bed by Project Delivery Methods

Project delivery methods	Statistics	Metrics: Project duration per bed days	Fiscal year duration per bed days	Construction start duration per bed days	Time growth days
Design/build	Mean	2.6	3.6	2.6	76.4
	Median	2.2	2.6	2.2	42.5
	Standard deviation	1.9	3.0	1.9	114.6
Design-bid-build	Mean	7.0	5.1	3.7	193.8
	Median	5.1	4.2	3.2	155.0
	Standard deviation	5.6	3.4	2.3	189.2

sample are much larger than the corresponding values for DB (Table 6). For instance, the mean days per bed for DB project were 2.6 versus 7.0 for DBB projects.

Days/Bed Using Fiscal Year Duration

A similar analysis of days/bed using FY duration was conducted. Table 6 shows the mean and median for days/bed using FY duration. The difference between the two samples' means and medians for days/bed is actually greater (3.6 versus 5.1 days/bed), on a percentage basis, than the difference between them for actual calendar day duration. This indicates that the difference between these metrics is greater when the projects are normalized for the number of beds in the projects.

Days/Bed Using Project/Construction Start Duration

An analysis of days/bed using P/C start duration was conducted and presented in Table 6. The table shows that the mean, median, and standard deviation. Again, the means (2.6 versus 3.7 days/bed) and medians (2.2 versus 3.2 days/bed) of the samples are less for DB projects, even though the DB projects include both design and construction.

Time Growth

All construction contracts have targeted completion dates. Establishing time growth for projects based on project delivery method is important to both parties. Due to the great variation in average duration between the two samples, the number of days of time growth was evaluated instead of time growth as a percentage of project duration.

The statistics of time growth show a similar disparity between the two samples as shown in Table 6. The mean for DBB is more than double the mean for DB (approximately 76 calendar days versus approximately 194 calendar days). The median for DBB is more than triple the median for DB. The box plot of time growth shows that there are four outlier projects in both DB and DBB samples (Fig. 4).

Univariate ANOVA of Cost and Schedule Results

An analysis of variance (ANOVA) was conducted to determine if the cost and schedule-related performance metric means of the two samples were the same. If the *p*-value is larger than 0.05, which is typically the standard for determining statistical significance, we cannot statistically conclude that the samples' means are statistically different. Table 7 shows the mean values of cost and schedule metrics for DB and DBB with their *F*-value, *p*-value, and *F*-critical value.

The means of cost/bed with other costs and cost/bed for DB and DBB projects are statistically not different. The *p*-value for these two cost metrics is larger than 0.05. We cannot statistically conclude that the sample means are not the same; evidence tends to indicate that the cost/bed with other costs and cost/bed for DB projects is lower than for DBB projects for this sample.

The significance test conducted on cost growth shows that the *p*-value is about 0.01. Therefore, we can reject the null hypothesis with statistical certainty, confirming the difference in sample means. We can conclude that the cost growth for a DB project is lower than the cost growth for a DBB project in this sample.

All of the schedule-related performance metric mean differences for the sample DB and DBB projects were statistically significant. Since all the *p*-values are less than 0.05 we can reject the null hypothesis with an almost statistical certainty, which confirm the difference in sample means. We can conclude that the project duration, fiscal year duration, construction start duration, project duration per bed, fiscal year duration per bed, construction start duration per bed, and time growth for a DB project are lower than for a DBB project, based on this sample.

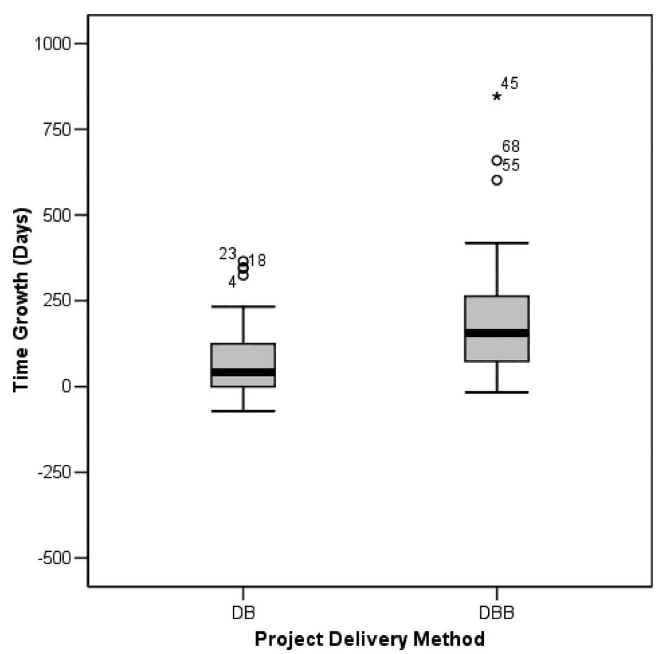

Fig. 4. Box plot for time growth

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Table 7. Single Factor ANOVA for Cost and Schedule Performance Metrics

Metric	Unit	DB mean	DBB mean	*F*-value	*p*-value	*F*-critical
Cost per bed with other costs	$K/bed	56.0	58.0	0.097	0.756	3.968
Cost per bed	$K/bed	53.1	56.4	0.317	0.575	3.968
Cost growth	%	2.0	4.0	6.738	0.011[a]	3.968
Project duration	Days	667	1398	55.650	<.001[a]	3.968
Fiscal Year duration	Days	864	1026	8.801	0.004[a]	3.968
Construction start duration	Days	667	771	5.779	0.019[a]	3.968
Project duration/bed	Days	2.6	7.0	20.726	<.001[a]	3.968
Fiscal Year duration per bed	Days	3.6	5.1	4.375	0.040[a]	3.968
Construction start duration per bed	Days	2.6	3.7	4.711	0.033[a]	3.968
Time growth	Days	76.4	193.8	11.450	0.001[a]	3.968

[a]Statistically significant at alpha level 0.05.

Summary and Conclusions

This study has collected data and analyzed two relatively homogeneous samples of DB and DBB projects. All of the projects consisted of new BEQs that had prescribed dimensions for each living quarters. All projects were administered by the same organization (NAVFAC) with an adequate geographical dispersion throughout the United States. Both samples were similar in size and large enough (38 DB projects and 39 DBB projects) to conduct ANOVA tests.

While this sample is unique to NAVFAC, the results point out that the DB method is superior to DBB when used on building projects. The sample data show that DB projects will take less time to complete and have less time and cost growth. In addition, while statistical significance was not found, the data also seem to indicate that DB projects may be less expensive to build. Whereas care should be taken when extending the results of this study to other types of projects and organizations because of the homogeneity of the samples, since NAVFAC is a public sector organization and many public sector organizations operate in similar fashion, the conclusion could be made that the benefits of DB will transcend just NAVFAC projects. Therefore, the public sector should strongly consider using DB to take advantage of time and potential cost benefits. The data are so convincing that the private sector should also strongly consider DB if it is not already taking advantage of this method.

Relevance to Industry Practitioners and Researchers

The findings of this study have significant implications for practitioners and policy makers building public facilities. Although the results in this study are focused on one agency and one type of facility, the findings are compelling when added to the body of research and understanding underlying project delivery methods. The fact that in this sample, the time required to perform a DB project was significantly less than the construction duration of a DBB project tells an important story. This study could be expanded to detect additional potential benefits of DB and DBB project delivery. Also, it did not take into account quality of the final product and that benefits of DB could potentially be at the expense of quality. An additional study could also be completed to see if the likelihood of claims is linked to project delivery method.

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