A COMPARISON OF US AND UK PROJECT DELIVERY SYSTEMS

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Abstract
Construction management at risk, design-build and design-bid-build are three principal project delivery systems used in the United States today. This paper empirically compares cost, schedule and quality performance of these three project delivery systems, using project specific data collected from 351 US building projects. Metrics included unit costs ($/m^2), cost growth (%), construction speed (m^2/month), total project speed including design and construction time (m^2/month), schedule growth (%), and intensity ($/m^2)/month. Seven quality metrics were also measured.

The study included collecting, checking and validating industry data, significance testing of univariate comparisons and the statistical development of multivariate linear regression models for predicting average project performance. A non-response study verified statistically that collected data was appropriate for analysis and representative of the industry from which it was drawn.

US results are compared to a similar study of 332 projects conducted by the Reading Design and Build Forum in the United Kingdom. The UK project delivery systems included traditional design-bid-build, management contracting and several forms of design build. Performance results are compared and contrasted and salient differences are identified. An application of these results and the impact of project delivery systems on the international building community are offered.

Key Words

Project delivery system, Performance metrics, Construction management, Design-build, Design-bid-build, Construction management at risk, Project data, Regression

1 Objective

The objective of this paper is to measure the time, cost and quality differences between the major project delivery systems used in the building construction industry in the United States and to compare those results to a similar study recently completed in the United Kingdom. The paper first defines each major delivery system, then describes the research methods, the data collected and the findings for each study. The final section of the paper compares the results and the factors found to be significant on successful projects. It then draws implications from this study for other countries and markets.

2 Comparison of US Project Delivery Systems

Construction management at risk, design-build and design-bid-build are three principal project delivery systems used in the United States today. Konchar and Sanvido [1] empirically compared cost, schedule and quality performance of these three project delivery systems, using project specific data from 351 US building projects. This research was conducted by the authors as part of

a task force of twelve industry practitioners, selected by the principal research sponsor, The Construction Industry Institute (CII). The results of this research are reported in this paper and are later compared to the results of a study performed in the UK

2.1 Definitions

The following project delivery system definitions were used in this research:

Construction Management at Risk is a project delivery system where the owner contracts separately with a designer and a contractor. The owner contracts with a design company to provide a facility design. The owner selects a contractor to perform construction management services and construction work, in accordance with the plans and specifications, for a fee. The contractor usually has significant input in the design process.

Design-Build is a project delivery system where the owner contracts with a single entity to perform both design and construction under a single design-build contract. Contractually, design-build offers the owner a single point of responsibility for design and construction services. Portions or all of the design and construction may be performed by a single design-build entity or selected specialty work or in some cases, all may be subcontracted to other companies.

Design-Bid-Build is the traditional project delivery system in the US construction industry where the owner contracts separately with a designer and a constructor. The owner normally contracts with a design company to provide "complete" design documents. The owner or owner agent then usually solicits fixed price bids from construction contractors to perform the work. One contractor is usually selected and enters into an agreement with the owner to construct a facility in accordance with the plans and specifications.

2.2 Performance Metrics

Project performance was measured using seven cost, schedule and quality metrics. The unit cost was measured using base building costs. Cost and schedule growth metrics allowed for the comparison between as planned and as built cost and time figures. The speed at which each facility was designed and built was measured using construction speed and delivery speed values. Finally, the quality of a facility was ranked by the facility owner in three areas: the difficulty experienced during the turnover process (the process of handing a facility over to an owner), the ability of specific systems to meet quality expectations and the quality of specific process equipment inside the facility. Each metric was calculated and analyzed separately using multivariate regression models to measure the impact that a particular project delivery system was having on project performance.

2.3 Research Methods

The purpose of this research was to empirically compare construction management at risk, design-build and design-bid-build project delivery systems on projects. General building projects studied were completed within the past five years in the United States. The study was divided into four distinct phases. The first phase developed and pilot tested an instrument to collect and analyze project data in an objective manner. The data collection instrument included quantitative cost, schedule and quality performance data, nineteen characteristics of the project team environment, building system characteristics, success criteria and lessons learned. The performance metrics were restricted to installed costs, schedule and quality of projects. Other costs, outside that of the base building, such as all property costs, owner costs, costs of installed process or manufacturing equipment, furnishings, and fittings were not addressed by this research effort. Quality was limited to asking facility owners to measure the difficulty of the turnover process and the actual versus expected performance of each principal facility system.

Next, the researchers used the data collection instrument to collect extensive project data from the US construction industry. During the data collection phase, nearly 300 facility owners were interviewed directly to obtain objective quality data. The remaining owners responded in written form.

Phase three used several critical data checking techniques such as respondent interviews to verify project data. These greatly improved the consistency and accuracy of project data. Of particular importance, a non-response study, never before conducted in the US construction research community, was administered to verify the appropriateness of collected data. By gaining additional project specific data from a sample of the industry who did not respond during the initial data collection effort, the researchers were able to validate the fact that collected data was representative of the industry from which it was drawn.

Finally, the fourth phase tested several hypotheses to distinguish significant differences in delivery performance. Significance testing and multivariate comparisons used nearly 100 explanatory and interacting variables to explain project cost, schedule and quality performance.

2.4 Project Types

The researchers were able to collect data on 351 projects. Of these projects surveyed, 23% were delivered using construction management at risk, 44% used design-build and 33% used design-bid-build. Six facility types were classified as light industrial (28%), multi-story dwelling (8%), simple office (24%), complex office (18%), heavy industrial (5%) and high technology (17%). Fifty seven percent of the 351 projects surveyed were privately owned and 43% were owned publicly.

Projects ranged in size from 500 square meters to over 200,000 square meters. Twenty eight percent were less than 5,000 square meters, 33% from 5,000 to 15,000 square meters, 25% from 15,000 to 35,000 square meters and 13% were larger than 35,000 square meters in size.

Twenty two percent of all projects had unit costs less than $600/square meter, 26% ranged from $600 to $1000/square meter, 19% from $1000 to $1,400/square meter, 13% from $1,400 to $1,800/square meter and 19% were over $1,800/square meter. High technology projects, 17% of the entire sample, accounted for the majority of the high project unit costs while light industrial facilities accounted for most of the low unit cost facilities.

Of the 351 projects submitted, 32% were received from private and public owners, 28% from design-build entities, 8% from designers and 32% were submitted by general contracting or construction management firms.

2.5 Summary of Main Findings

Table 1 indicates average differences between each project delivery system, regardless of facility type, for the listed performance metrics. Table 1 indicates that on average, in the area of unit cost, design-build is at least 4.5% less than construction management at risk and at least 6% less than design-bid-build. Therefore, on average, an owner can expect these differences on their particular project, whether they are building a light industrial plant or a complex office.

The level of certainty is a statistical measure used to express the ability of a particular regression model to explain differences in each performance metric. The higher the level of certainty the more confident one can be about the results shown. The level of certainty (R^2 or the coefficient of determination) is listed in the fifth column of Table 1. In the case of unit cost, the level of certainty indicates that results explain 99% of the variation in unit cost and can isolate the effect of the project delivery system used on the project. Low values for cost and schedule growth (24%) indicate that results cannot explain or target those factors affecting a significant portion of cost and schedule growth variation, namely the remaining 76%.

Table 1. Summaries of average differences between project delivery systems.

Metric	DB vs. CMR (%)	CMR vs. DBB (%)	DB vs. DBB (%)	Level of Certainty (%)
Unit Cost	4.5 less	1.5 less	6 less	99
Construction Speed	7.0 faster	6.0 faster	12 faster	89
Delivery Speed	23 faster	13 faster	33 faster	87
Cost Growth	13 less	7.8 more	5.2 less	24
Schedule Growth	2.2 less	9.2 less	11 less	24

(DB = design-build, CMR = construction management at risk, DBB = design-bid-build.)

3 Comparison of UK Project Delivery Systems

The University of Reading Design and Build Forum's recent study (referred to as 'The Forum' in this paper) [2] analyzed cost, schedule and quality data taken from design-build and design-bid-build projects recently built in the United Kingdom. The study recognized three distinct variations of design-build and compared them to design-bid-build jobs and projects procured using a management contracting approach.

3.1 Definitions

Several distinct types of delivery system are used in the United Kingdom. The first two are design-bid-build and design and manage. Three variations of design-build are also encountered. The following descriptions define each project delivery system.

Design-bid-build in the UK represents the common, sequential approach to project delivery where design is completed before engaging the construction contractor. This system and **design and manage**, where the manager holds no construction contracts, is also used in the US. The Forum excluded design and manage from the study since the contractor does not assume any risk for the ultimate performance of the facility.

Traditional design-build was used for approximately twenty percent of new design-build projects. Here, an owner would approach a contractor for early design assistance then negotiate with that contractor for design and construction responsibility. The design-build firm would then acquire outside design assistance or utilize in-house capabilities.

Consultant novation arrangements were used for approximately fifty percent of all new design-build work in the UK. Here, an owner sought independent design advice during the briefing stage from one or more design consultants. Design consultants advanced design to a stage when a contractor was engaged into the process. From this point forward the consultants employment was 'novated' or assigned to the contractor, thus shifting design and construction risk to the selected contractor for the remainder of the project.

Develop and construct accounted for twenty percent of the design-build market. This organizational arrangement differs from traditional design-build only in the extent to which the owner develops design before engaging the construction contractor. Projects varied from owners who had only outline specifications to those having detailed requirements. The owner would then utilize an in-house design staff or appoint a design consultant to further develop these varying levels of design.

Newer approaches to delivering design-build in the UK were using a fee-based management approach. This approach involved a management firm early in the delivery process, who then agreed to a guaranteed maximum price at an appropriate stage.

3.2 Research methods

Because of the similarity between the efforts completed by The Forum and this study, a meeting was held between The Forum team and the researchers to exchange ideas, discuss procedural techniques and review analysis methods before starting the US study.

The Forum mailed a comprehensive survey to a select sample of owner agents to collect performance data in terms of cost, schedule and quality. Areas of qualitative data describing the project client, management approach, building functions, construction type, size and project location were also collected. The Forum conducted 150 interviews with clients and project team members on a select group of 35 projects. These interviews were conducted to evaluate the accuracy of collected data and to identify differences in project performance. The Forum did not conduct a non-response study to verify the appropriateness of project specific data. The Forum analyzed 332 projects. One hundred sixty six used design-build approaches, 156 used traditional design-bid-build and 10 used a management approach.

In addition to basic univariate comparisons, the Forum conducted multivariate regression analyses to identify variables affecting the performance of certain metrics. To investigate the speed and cost differences between design-build and design-bid-build, three regression models were developed. *Construction speed* was defined as gross building area divided by the construction time period. *Total speed of delivery*, was defined as gross building area divided by design and construction time periods. *Unit cost* was defined as project cost per square meter. Each model was based on a reduced sample of project data and explained uneven levels of variation around set response variables. The study did not attempt to develop models for other critical metrics such as cost growth, schedule growth or quality. Therefore, results describing these metrics were based only on univariate comparisons.

3.3 Summary of Main Findings

Due to the limited number of projects procured using the management approach, the Forum did not attempt to offer conclusions regarding this arrangement. Therefore, comparisons were limited to project data taken from design-build and design-bid-build jobs. Data showed that design-build projects resulted in:

- a 12% improvement in construction speed,
- a 30% improvement in project delivery speed,
- a 13% reduction in unit cost,
- more certainty in finishing on time,
- a greater chance of finishing within 5% of budget, and
- a higher possibility of achieving specified quality.

4 Comparison of US and UK multivariate regression models

A direct comparison of the results between the US and UK studies is possible in the areas of unit cost, construction speed and delivery speed. The results of these specific performance metrics represent the most significant findings and are the areas where extensive multivariate analyses were successfully performed. In particular, both studies were able to explain various levels of certainty surrounding each of the performance metrics. Through the use of multivariate regression models, significant indicators of project performance were identified.

4.1 Results

A direct comparison with the Forum's main findings shows similar results. In their study, design-build on average outperformed design-bid-build by the same amount. In addition, several similar explanatory variables were used to build multivariate linear regression models in both studies, which can predict average performance based on input parameters.

The first three columns of Table 2 present results of this study by performance metric and project delivery system. Column four compares multivariate results of this study to results of a similar study done in the UK by the Forum. Values in Table 2 represent averages. For example, the unit cost of US design-build projects were on average, 4.5% less than the same projects completed using construction management at risk.

Table 2. Comparison of UK and US primary metrics.

	US DB vs. CMR	US CMR vs. DBB	US DB vs. DBB	Reading Forum DB vs. DB vs. DBB
Unit Cost	4.5 less	1.5 less	6 less	13 less
Construction Speed	7 faster	6 faster	12 faster	12 faster
Delivery Speed	23 faster	13 faster	33 faster	30 faster

Note: the first three columns are identical to Table 1.

4.2 Explanatory variables

Table 3 orders several variables that exerted the greatest influence on construction speed, total speed and unit cost within both the US and UK research efforts. Numbers in the main table represent the rank order of influence of each explanatory variable. The table also indicates the number of projects used to build each regression model and the amount of variation explained by the model. Maximum explained variation, and thus the greatest certainty in results, is one hundred percent.

Regression results indicate that project size, unit cost and facility type are critical to explain speed and cost performance of projects. Delivery system, although critical to explaining project performance, was not ranked in the top three in all cases, therefore it was less important in determining project performance. These findings are important in two primary ways. First, both studies attempted to measure differences between delivery systems while considering a wide range of variables by using multivariate regression modeling. Second, while explaining only substantial levels of variation from a prediction standpoint, these results identified variables other than the chosen delivery method, which are critical to project success.

Table 3. Ordered influence of variables on metrics.

	Construction Speed		Delivery Speed		Unit Cost	
	US	UK	US	UK	US	UK
No. of Projects	344	223	328	176	316	240
Explained Variation	89%	90%	88%	80%	99%	51%
Contract unit cost	2	3	2	2	1	
Facility type		2	4	4	2	1
Project size	1	1	1	1	3	5
Delivery system	3	5	8	3	4	4
Design advancement	4		3			
Team communication	5		5			
Project complexity	6	4	7	6		2
Subcontractor experience			6			
Level of new construction			9			
Onerous contract clauses			10			
Technology		6		11		7
Innovation		7		5		8
Building structure		8		10		9
Existence of basements		9		9		10
Quality		10		8		6
Aesthetics		11		7		11

4.3 Success Factors

Both the US and UK research efforts identify factors other than the project delivery system as significant indicators of project performance. The US study describes the top five critical project delivery success factors for each system. These were determined from the largest difference between highly successful and unsuccessful projects within each project delivery system. They are the most critical factors to focus on when considering the successful use of each system. [3]

Construction Management at Risk Success Factors

1. High ability to restrain the contractor pool.
2. Excellent owner experience with the type of facility being built.
3. Few or no legal constraints affecting the project team or the project.
4. Owner - project team relationship that is repeat or has a partnering agreement.
5. Excellent A/E experience with construction management at risk project delivery.

Design-Build Success Factors

1. Low percent design complete (<20%) before engaging construction entity.
2. Excellent subcontractor experience with the type of facility being built.
3. Excellent subcontractor experience with design-build delivery.
4. Excellent contractor experience with the type of facility being built.
5. Excellent project team communication.

Design-Bid-Build Success Factors

1. Excellent project team communication
2. High ability to prequalify team.
3. Excellent subcontractor experience with the type of facility being built.
4. High ability to restrain the contractor pool.
5. Excellent contractor experience with the type of facility being built.

5.0 Implications and Conclusions

The impact of this project delivery research and comparative analysis is two fold. First, the international design and construction building community now has an empirically based reference by which to compare project delivery systems. In this regard, it seems that both US and UK research have identified striking similarities in their core results, thus indicating that the performance of procurement methods within these two countries is fairly consistent. It seems likely that similar differences may exist in countries that use similar project delivery systems.

Second, each study focused not only on describing the measurable difference between defined systems, but strived to explain the reasons for such significant performance variations. In particular, it indicates to the design and construction community that critical factors other than the project delivery system of choice can greatly impact project performance. Furthermore, it is evident that by focusing on these few critical success factors, a project can achieve success regardless of the project delivery system employed.

This paper has explained differences in the cost and schedule performance of the design-bid-build (traditional) and the design-build project delivery systems in the US and UK. It may be possible to extend these findings to countries with similar procurement methods. The comparison in the paper offers a performance-based, empirical investigation of the three principal delivery systems used in the US and UK construction industries today. It is hoped that an effort will be made to use this research as a benchmark from which worldwide comparisons between project delivery systems are made in the future.

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