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PREDICTING PERFORMANCE IN DESIGN-BID-BUILD PROJECTS

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Design-bid-build (DBB) is the most common delivery method for public and private construction projects in Spain, and is also widely used in the United States (U.S.). While the execution of DBB projects in Spain and the U.S. is similar in many ways, owners in Spain approach the procurement of the general contractor and subcontractors differently. There is a greater emphasis on selecting firms that provide the "best value" of cost, quality and expertise. Comparatively, U.S. owners leading a DBB delivery are more concerned with achieving the lowest first cost. Using data from 67 completed DBB projects in Spain and the U.S., a best subsets regression analysis was performed to develop five models, each predicting a key performance outcome of DBB projects: cost growth, schedule growth, unit cost, delivery speed and intensity. These models separated the effects of the country of origin from other explanatory variables that effect performance. These other explanatory variables include differences in the procurement process, payment terms, the initial unit cost, size of the project, and measures of the project team's integration and cohesion. The findings of this study show that, while owners in Spain opt for a more robust procurement process, DBB projects in the U.S. have comparable unit cost and are delivered faster and with a greater intensity when all other variables are held constant. This suggests that factors unique to the country of origin, not directly related to the execution of DBB projects, have a distinct effect on their performance.

Keywords: Construction, Project delivery, Regression, Spain, United States.

1 INTRODUCTION

Although design-bid-build (DBB) is the most common form of project delivery worldwide, there are some differences in how the process is implemented. Objectively, there are two main characteristics that all DBB deliveries must have: (1) the owner holds separate contracts for design and construction services; and (2) the design itself, including drawings and specifications, are completed or nearly completed before hiring the builder, who is typically a general contractor (Franz and Leicht 2016). While these two characteristics commonly lead owners to pursue a bidding strategy for procurement, there are variations possible in how the builder is ultimately selected. Similarly, while lump sum contract terms are commonly paired with DBB, there is nothing precluding owners from using reimbursable contracts, such as guaranteed maximum price (GMP) or unit price.

These differences in implementation are particularly evident when comparing DBB delivery across countries. For example, many public sector owners in the United States (U.S.) are required by law to select the lowest, responsive bidder, making cost the sole determinant of contract award (Potoski 2008, Chaovalitwongse *et al.* 2012). For comparison, in Spain, public sector owners are permitted to use "best value" selection to choose the bidder with the best combination of cost, quality, and expertise (Ballesteros-Pérez *et al.* 2016).

Despite being common, these types of differences are rarely highlighted in literature. Empirical studies on project delivery performance frequently make between-group comparisons by examining cost, schedule, and quality outcomes across multiple project delivery methods. Few consider the within-group variation found in the implementation of a single delivery method, such as DBB. Thus, the goal of this study is to compare the performance of DBB delivery on projects in the U.S. and Spain. Using a data set of similar construction projects from both countries, we performed a best subsets regression analysis to develop models that predict performance on DBB projects. We then used these models to isolate the effects of country of origin from other explanatory variables that effect performance. The result is a within-group comparison of DBB implementation in the U.S. and Spain, which provides several key lessons for improving the delivery process in both countries.

2 RESEARCH METHOD

2.1 Survey Questionnaire

A survey questionnaire was developed to collect detailed information on completed building projects. Questions included on the survey were informed by a combination of literature review and advice by a panel of industry experts. The survey covers a wide range of topics, not all of which are presented in this paper. Respondents were asked to complete the survey for a project they recently completed, providing basic information on the project itself (e.g. area, number of stories, location), as well as the delivery process and performance data on cost and schedule.

2.2 Data Collection

In the U.S., the survey was distributed by postal mail and e-mail to members of professional organizations, with the intention of reaching owners, architects, and builders in both the public and private sectors. In total, we collected 331 questionnaires that resulted in 204 usable projects completed between 2008 and 2013. Many survey responses included projects that were outside the scope of study or were missing over 30% of the requested information. These were not usable in our analysis. A more detailed discussion of the data verification and handling procedures for this data is provided by Franz *et al*. (2017). For this paper, only projects that using a DBB delivery method were studied. Thus 36 projects, or 17.6% of the usable sample, were isolated and combined with the Spanish data set.

In Spain, the data was collected directly from owners and general contractors via structured interview that asked the same questions as the U.S. survey. This effort collected data on 35 projects from the private sector, only 31 of which were usable by the criteria established by the U.S. research team. When combined with the U.S. data set, 67 DBB projects were studied.

2.3 Best Subsets Modeling Approach

To model differences in implementation, this study used characteristics identified by Franz and Leicht (2016) in their classification of project delivery methods. These characteristics are a series of dichotomies that were found to be strong differentiators among project delivery methods.

Since the presence of split contracts for design and construction, as well as late involvement of the builder are common to all DBB deliveries, these two specific characteristics were not included in the analysis. However, the prequalification process, selection criteria and payment terms of the builder and trades were characteristics that we included as predictors. Following the work of Franz *et al*. (2017), this study also considered the concept of "integration" among the project's owner, architect and contractors as predictors of performance. The factor scores represented integration from two latent constructs: team integration and group cohesion. The combined U.S. and Spain data set of DBB projects was run through the same confirmatory factor analysis reported by Franz *et al.* (2017) to obtain factor scores for both constructs to use as predictors. Lastly, the remaining predictor variables, used primarily as controls, were the country of origin, facility size (in square-feet) and project unit cost (in dollars per square-foot) at contract signing.

Performance metrics were selected based on trends in prior project delivery research. Schedule growth, cost growth, unit cost, delivery speed and intensity are the most commonly cited metrics in literature. A summary of both the predictor and performance variables used in the analysis are provided in Table 1.

Table 1. Summary of study variables.

Predictors (Independent)	**Performance Metrics (Dependent)**
• Country of origin: U.S. or Spain • Facility size in square-feet (SF) • Contracted unit cost in dollars per square-foot ($/SF) • Was the builder prequalified? • Were the trades prequalified? • Was the builder selected based on qualifications only? • Were the trades selected based on qualifications only? • Did the builder have a cost plus fee or GMP contract? • Team integration: Factor score • Group cohesion: Factor score	• ***Schedule growth*** as percent change (%) between planned and actual project durations • ***Cost growth*** as percent change (%) between initial and final contract values for design and construction • ***Unit cost*** in dollars per square-foot ($/SF) • ***Delivery speed*** in square-feet per month (SF/Month) • ***Intensity*** in dollars per square-foot per month ($/SF/Month)

For each project delivery performance metric, a separate best subsets regression analysis was performed with the list of predictor variables in Table 1. The subset of predictors that resulted in the model with highest adjusted R^2 among competing models was then selected. Thus, a total of five regression models were selected (one for each metric) that offer the greatest explanatory value for the variance observed in each metric.

Next, each of these five regression models was used to compare the performance differences in DBB between the U.S. and Spain. This was done by setting the country of origin in all 67 projects in the data set to "U.S.", holding all other predictors constant and taking the mean of the resulting prediction for each metric. The same calculations were performed with the country of origin set to "Spain". Therefore, for each metric, two predicted mean performance values were obtained: one that presumes all projects were delivered in the U.S. and another that presumes all projects were delivered in Spain. This methodology was adapted from Konchar and Sanvido's (1998) seminal comparison of performance across project delivery methods. However, instead of using project delivery methods, we are comparing performance by country of origin.

3 RESULTS

The selected regression models for each performance metric and the coefficients of their best subset predictors are summarized in Table 2. To ensure homoscedasticity during regression, three metrics and two predictors were transformed with a base 10 logarithm prior to the best subsets analysis: facility size, contract unit cost, unit cost, delivery speed and intensity. There was no missing data within the data set; so all-67 projects from both the U.S. and Spain were included in each regression model. Using these models, further analysis was able to separate the effects of country of origin from other predictor variables. In this manner, the performance differences in DBB projects from the U.S. and Spain were explored, while controlling for regional differences in their implementation.

Table 2. Best subsets regression models.

	Project Delivery Performance Metric				
Coefficients in Best Subsets Regression	*Schedule Growth*	*Cost Growth*	*Unit Cost*[1]	*Delivery Speed*[1]	*Intensity*[1]
Constant	-6.444	-27.498	-0.098	-0.168	-0.533
Country of origin (1=U.S., 2=Spain)	15.863	7.249	-0.033	-0.257	-0.260
Facility size (Log10)	-7.542		0.011	0.957	
Contract unit cost (Log10)	12.461	11.888	1.038	-0.367	0.701
Builder prequalified (0=No, 1=Yes)	-5.419	-5.495	-0.022	0.044	0.031
Trades prequalified (0=No, 1=Yes)	5.475	5.604	0.028		
Builder qualification-based selection (0=No, 1=Yes)		3.641	0.013	0.062	0.077
Trades qualification-based selection (0=No, 1=Yes)		-12.703	-0.047		
Builder CPF/GMP contract (0=No, 1=Yes)		4.674	0.016	-0.013	
Team integration				-0.031	-0.026
Group cohesion		-2.344		0.018	0.015
Adjusted R^2	**17.50%**	**13.20%**	**99.20%**	**92.00%**	**84.80%**
Number of projects	67	67	67	67	67

[1]Log10 transformed

3.1 Schedule Growth

The best subsets analysis identified five predictor variables that together explained 17.5% of the variance in schedule growth across all projects in the data set. While this low adjusted R^2 suggests the presence of additional exogenous variables that influence schedule growth, three predictor variables accounted for a large proportion of the explained variance. In order of importance, they were: country of origin, contract unit cost and facility size. This means that schedule growth was found to be lower on DBB projects that were delivered in the U.S., had a lower unit cost at contract signing and had a larger building area. When all other variables were held constant, the effect of country of origin predicted that DBB projects from the U.S. would be delivered with 15.9% less schedule growth, on average, than DBB projects from Spain.

3.2 Cost Growth

Eight predictor variables were identified in the best subsets analysis for cost growth; however, taken together, they only explained 13.2% of the variance. The top three most influential predictors, in order of importance, were: contracted unit cost, country of origin and builder prequalification. For DBB projects, this means that cost growth was lower when starting with a lower unit cost at contract signing, when being delivered in the U.S. and when the builder is prequalified prior to selection. When all other variables were held constant, the effect of country of origin predicted that DBB projects from the U.S. would be delivered with 7.3% less cost growth, on average, than DBB projects from Spain.

3.3 Unit Growth

The best subsets analysis identified eight predictor variables that together explained 99.2% of the variance in unit cost. Compared to cost and schedule growth, this model has a high degree of predictive certainty. The largest proportion of explained variance is accounted for by the initial unit cost, followed very distantly by the country of origin and facility size. Perhaps unsurprisingly, this suggests that, for DBB delivery, the unit cost of the facility at contract signing is the best predictor of the final unit cost at project completion. When all other variables were held constant, the effect of country of origin predicted that DBB projects from the U.S. would be delivered with 7.9% greater unit cost, on average, than DBB projects from Spain.

3.4 Delivery Speed

Eight predictor variables were identified in the best subsets analysis for delivery speed and together explained 92% of the variance in delivery speed. The top three most influential predictors, in order of importance, were: facility size, contracted unit cost and country of origin. Delivery speed for DBB projects was greater for larger facilities and those with lower unit cost at contract signing. When all other variables were held constant, the effect of country of origin predicted that DBB projects from the U.S. would be delivered 80.1% faster, on average, than DBB projects from Spain.

3.5 Intensity

The best subsets analysis identified six predictor variables that together explained 84.8% of the variance in intensity. The largest proportion of variance in the model is explained by the contracted unit cost, followed by country of origin and more distantly the selection of a builder based solely on their qualifications, rather than cost-of-work. This means that DBB project with a larger unit cost at contract signing were more intense, perhaps due to an increase in complexity. When all other variables were held constant, the effect of country of origin predicted that DBB projects from the U.S. would be delivered with 82.0% greater intensity, on average, than DBB projects from Spain.

4 DISCUSSION

A best subsets regression analysis provided a method of comparing the performance of DBB delivery between the U.S. and Spain. We built five models, one for each performance metric, which allowed us to vary the country of origin, while keeping all other variables constant. The models predicted unit cost, delivery speed and intensity with a high level of certainty ($R^2 > 80\%$). Cost and schedule growth were also predicted, but with a much lower level of certainty ($R^2 < 20\%$). Using these predictive models, we performed a within group analysis of DBB projects, comparing differences in implementation, as well as their country of origin. A summary of our findings is provided in Table 3.

Table 3. Comparison of performance by country of origin.

	Mean Predicted Values		
	U.S.	*Spain*	***U.S. vs. Spain***
Schedule growth (%)	0.17	16.04	15.9% less
Cost growth (%)	1.87	9.11	7.3% less
Unit cost ($/SF)	185	171	7.9% more
Delivery speed (SF/Month)	4,377	2,422	80.1% faster
Intensity ($/SF/Month)	5.99	3.29	82.0% more

Recent research shows that Spain's approach to DBB should produce better performance, since it is more selective and qualifications-driven (Pellicer *et al.* 2016, Franz *et al.* 2017). However, this was not the case in our analysis. The country of origin predictor variable was both statistically significant and explained a large proportion of variance in all best subset models. When delivered in the U.S., our analysis suggests that projects using DBB are expected to perform better across most metrics, despite being less likely to prequalify builders and more likely to make selections based strictly on cost-of-work. The one exception is unit cost, where facilities delivered in the U.S. appear to be more expensive per square foot when compared to their delivery in Spain. Therefore, we are left to conclude that the "country of origin" variable is representing either cultural or management differences that are not being captured in the other predictor variables that represent the delivery process. In other words, the differences in implementation of DBB between the U.S. and Spain do not adequately explain their noted gap in performance. Thus, there is a need for additional research into the delivery process itself, potentially to examine the supply chain and day-to-day management practices, which contribute to project performance.

References

Ballesteros-Pérez, P., Skitmore, M., Pellicer, E., and W Zhang, R., Scoring Rules and Competitive Behavior in Best Value Construction Auctions, *Journal of Construction Engineering and Management*, 142(9), 2016.

Chaovalitwongse, W. A., Wang, W., Williams, T. P., and Chaovalitwongse, P., Data Mining Framework to Optimize the Bid Selection Policy for Competitively Bid Highway Construction Projects, *Journal of Construction Engineering and Management*, 138(2), 277–286, 2012.

Franz, B. and Leicht, R., An Alternative Classification System for Project Delivery Methods Used in the U.S. Building Construction Industry, *Construction Management and Economics*, 34(3): 160-173, 2016.

Franz, B., Leicht, R., Molenaar, K., and Messner, J, Impact of Team Integration and Group Cohesion on Project Delivery Performance, *Journal of Construction Engineering and Management*, 143(1): 04016088, 2017.

Konchar, M. and Sanvido, V. Comparison of U.S. Project Delivery Systems, *Journal of Construction Engineering and Management*, 124(6): 435-444, 1998.

Pellicer, E., Sanz, M. A., Esmaeili, B., and Molenaar, K. R., Exploration of Team Integration in Spanish Multi-Family Residential Building Construction, *Journal of Management in Engineering*, 32 (5), 05016012, 2016.

Potoski, M., State and Local Government Procurement and the Winter Commission, *Public Administration Review*, *68*(s1), S58-S69, 2008.