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AN EXPLORATION OF TEAM INTEGRATION IN DESIGN-BID-BUILD PROJECTS

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A recent large sample study of project delivery in the United States (U.S.) concluded that more integrated teams led both directly and indirectly to more successful construction projects. Concurrent with this U.S. study, construction projects in Spain were surveyed using the same data collection questionnaire. While the sample size of participating projects in Spain was not as large as the U.S. and targeted only design-bid-build (DBB) deliveries, there were notable differences in the levels of team integration between the two data sets. Comparable DBB projects in Spain had significantly fewer team members participating in high-quality, multidisciplinary interactions than their U.S. counterparts. However, they relied on greater use of qualifications and experience in selection. DBB projects from the U.S. and Spain data sets are compared, with respect to their use, and proportion, of the team participating in: design charrettes, joint goal-setting, building information modeling (BIM) and construction phase co-location. To further explore these differences, we also examine how DBB delivery is implemented in the U.S. and Spain. While it was discovered that Spanish DBB projects did use some tools to increase team integration, the findings of this comparison suggest that the Spanish industry could improve team integration by: (1) incorporating earlier construction team involvement; (2) promoting cost transparency with open book construction contracts that transition to a lump sum near the completion of the project, and (3) encouraging the designer and contractors to use BIM throughout the project.

Keywords: Construction, Project delivery, Owner, Success, Team, United States.

1 INTRODUCTION

The traditional form of project delivery, commonly named design-bid-build (DBB), is the most popular method worldwide. The owner grants responsibility for the design to an architect or engineer, generally a consulting engineering and architectural firm. When the design is completed in detail (including calculations, plans, specifications and budget) and it is approved, the owner awards the project to a construction company that builds the project as indicated in the design documents (Touran *et al.* 2009, Shrestha and Mani 2013, Pellicer *et al.* 2016). Seminal contributors (Nam and Tatum 1992, Latham 1994) already identified problems arising from the fragmentation of this approach, criticizing the challenging relationships that develop among the involved parties that result from the use of transactional contracts (Matthews and Howell 2005).

Despite these critiques, DBB is still the most common delivery method around the world. It is broadly used in the Unites States (Hale *et al.* 2009, Shrestha and Mani 2013), the European Union (Rocha de Gouveia 2002, Pellicer *et al.* 2016), and the United Kingdom (Ling *et al.* 2004), among others. In the U.S., implementing alternative delivery methods to DBB was difficult prior to 1996, due to state and federal regulations (Hale *et al.* 2009, Touran *et al.* 2009, Minchin *et al.* 2013). Even today, some states are restricted by laws requiring the use of DBB when public money is used for their construction (Rojas and Kell 2008, Touran *et al*. 2009). In Spain, DBB is most commonly found in the public sector, since the Spanish Procurement Act 3/2011 makes the use of alternative methods difficult for public agencies (De la Cruz *et al.* 2006).

However, not all implementations of DBB are equal and the specific procurement practices, payment terms, and other factors vary by country. For example, in Spain, best value procurement approaches are often used for DBB by the public sector (Ballesteros-Pérez *et al.* 2016, Pellicer *et al.* 2016), whereas, in the U.S., choosing the lowest bid most often makes public sector procurement or first cost (Chaovalitwongse *et al.* 2012) and best value approaches are scarcely used (Tran *et al.* 2016). Following this direction, this research aims to compare the performance of DBB implementations in the U.S. to those of Spain. The goal is to learn from differences in implementation to improve integration in the DBB delivery process. There is an opportunity to challenge how culture and regulations, among others factors, affect integration and performance, considering similar delivery procedures. Two sets of similar construction projects from U.S. and Spain are used as a sample for this analysis.

2 RESEARCH METHOD

This research was performed in four main phases: (1) questionnaire development; (2) data collection (from U.S. and Spain); (3) statistical analysis; and (4) comparison and discussion of results. These phases are explained further in the following sub-sections. For the purpose of this research, the unit of analysis is the building project.

2.1 Questionnaire Development

This research used a structured questionnaire in order to collect information on each building project. To this end, the owner and the general contractor of each project (unit of analysis) were surveyed. The questionnaire was first developed from an in-depth literature review that identified variables to be considered in the study. Later, an advisory board of industry experts filtered these variables and defined the performance metrics. The first two sections focus on the characterization of the building project. The next sections get data regarding costs, schedule and quality that are used to compute the performance metrics. Next, the procurement methods as well as the different contracts are described. The following two sections deal with team behavior and interaction among key stakeholders. Finally, the last section gathers the opinions of the participants in the survey regarding their general opinion about the project (whether it was successful or not), experience with the particular delivery method applied, and lessons learned.

2.2 Data Collection in the U.S.

The questionnaires were distributed by postal mail and e-mail to professional associations of architects, engineers and constructors in the U.S. the survey targeted public and private building projects. Responses from the owner and general contractor were combined into a single input in the database. In order to resolve any discrepancy between them, a protocol was established. The research team collected a total of 331 questionnaires. A project was removed from the study if any of these conditions were met: (a) project out of scope; (b) more than 30% of missing data; or (c) no input from the owner. The final database comprised 204 building projects finished between 2008 and 2013. For this paper, only the building projects that implemented a DBB delivery method were studied, which is 20.6% of the total sample, or 42 projects. The most frequent type of facility in the sample of DBB projects was educational (18 projects or 43% of the DBB sub-sample).

2.3 Data Collection in Spain

In Spain, the survey data was collected with structured interviews with owners and general contractors. As in the U.S. approach, responses from the owner and general contractor for the same project were combined into one input, following the same protocol as in the U.S. the Spanish data was also stored in the same database in order to ease later analysis. The survey team collected data from 35 building projects. Applying the same inclusion criteria as in the U.S., only 32 projects were carried forward and one additional project was discarded due to its outlying size and complexity (a 43-story building). Therefore, the sample of DBB projects from Spain was 31. Every project in this sample was residential in use and built from 2005 to 2013 by private owners.

2.4 Statistical Modeling Approach

Following the work of Franz *et al*. (2017), the concept of integration among the project's owner, architect and contractors was split into two latent constructs: team integration and group cohesion. Team integration represented how engaged the team was in inter-firm interactions and was reflected in the number of BIM uses, as well as the proportion of the team participating in design charrettes, goal-setting, BIM planning and construction phase co-location. Group cohesion described how successful the team was in developing a shared culture, unique to the project. It was reflected in the timeliness of communication, commitment to common goals and team chemistry reported by the team at the project's completion. Both team integration and group cohesion are shaped by the project delivery method and serve as strong predictors of project performance (Franz *et al.* 2017). A confirmatory factor analysis (CFA) was run on the Spain data and arrived at similar factor loadings to those reported by Franz *et al.* (2017) for the team integration and group cohesion constructs. Therefore, the Spain data was combined with the larger U.S. dataset and run as a structural model to obtain factor scores for all projects. These factor score were used to represent the relative magnitude of a project's team integration and group cohesion in later analyses.

3 DATA ANALYSIS AND RESULTS

3.1 Descriptive Statistics

The combined sample data set contained 73 DBB projects, 42 (58%) from the U.S. and 31 (42%) from Spain. Of the U.S. projects, 33 (79%) were publically funded. Of the projects originating in Spain, all (100%) were private funded. Facility sizes were similarly distributed for both countries, as shown in Figure 1. However, large and medium-sized projects, ranging from 150,000 ft^2 (13,935 m^2) to over 400,000 ft^2 (37,161 m^2), were twice as common in the U.S. data subset (29% of U.S. projects versus 13% of Spain projects within the same size range). Despite this apparent difference in distribution, there was no statistically significant difference in the mean facility size between projects sampled in the U.S. and Spain, $t_{(71)} = 1.128$, $p = 0.264$.

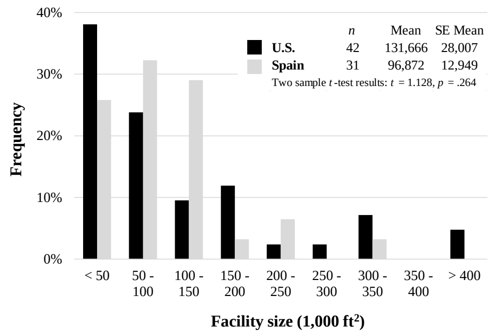

Figure 1. Facility size distribution and mean difference tests for U.S. and Spain projects.

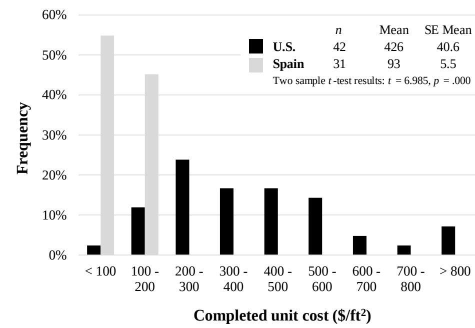

Figure 2. Completed unit cost distribution and mean difference tests for U.S. and Spain projects.

Completed project unit costs for facilities in the sample data set were adjusted for market fluctuations and regional differences in material and labor costs. For the U.S. projects, the *Engineering News Record's* (ENR) monthly reporting of the Building Cost Index (BCI) was used to control for price changes between each project's construction start date and the start of data analysis in June 2014. For the Spain projects, all costs were converted to U.S. dollars prior to analysis; market fluctuations were accounted for by the official consumer price index (IPC). The adjusted, completed project unit costs for the sample data set are shown in Figure 2. The mean unit cost for U.S. projects was significantly larger than the mean unit cost of projects in Spain ($t_{(71)}$ = 6.985, p = 0). The unit costs of U.S. projects had greater variance, ranging from less than \$100/ft^2 to over \$800/ft^2, but all of the Spain projects were completed for less than \$200/ft^2.

3.2 Project Performance Comparisons

As additional context for comparing the implementations of DBB delivery, differences in project performance by country of origin were examined. Multiple independent sample t-tests were conducted to compare the mean cost growth, schedule growth, intensity, delivery speed, team integration and group cohesion for projects in the U.S. and Spain. Of these performance measures, intensity and delivery speed were transformed using a base 10 logarithm to approximate a normal distribution. The statistical proof corresponds to a level of significance of 10% (p = 0.10). The results of these tests are summarized in Table 1. There was no significant difference in cost growth ($t_{(71)}$ = -0.90, p = 0.373) or delivery speed ($t_{(71)}$ = 0.14, p = 0.888). This suggests that, for DBB projects, these performance measures do not vary widely by country of origin. However, there was a significant difference in schedule growth ($t_{(71)}$ = -2.92, p = 0.005), intensity ($t_{(71)}$ = 12.13, p = 0) team integration ($t_{(71)}$ = 6.74, p = 0) and group cohesion ($t_{(71)}$ = -1.91, p = 0.060). Specifically, DBB projects in the U.S. have lower schedule growth (M = 3.64), higher intensity (M = 8.71) and higher team integration (M = 3.43) than DBB projects in Spain. On the other hand, DBB projects in Spain have higher group cohesion (M = 2.29).

3.3 DBB Implementation Comparisons

Adopting the project delivery characteristics of Franz and Leicht (2016), the differences in the organization, procurement and contract payment terms of projects from the U.S. and Spain were examined. Table 2 shows the percentage of projects with each characteristic, tabulated by country of origin. Commonalities between DBB in the U.S. and Spain were found in the timing of involvement of the builder and specialty trades, and in the builder's contract payment terms. In both countries, the owner held separate contracts for design and construction services (100%), hired the builder and trades after the schematic design (100% in the U.S., 100% in Spain) and commonly preferred closed book, lump sum payment terms with the builder (83.3% in the U.S., 93.4% in Spain). Differences in DBB implementation were found in the procurement of the builder and specialty trades. In the U.S., the owner used prequalification and open bid of the builder and specialty trades in nearly equal proportion (54.8% and 46.1%, respectively). However, owners in Spain always prequalify the builder (100%) and highly favored trade prequalification (83.9%). Once the proposals are submitted, the owners of U.S. projects made the final selections based on cost-of-work, either accepting the lowest bid or making a best value assessment. These selection criteria were used for 97.6% of the builders and 97.4% of the specialty trades in the U.S. sample. Conversely, owners of Spain projects only used cost-of-work criteria to select 61.3% of the builders and 90.3% of the specialty trades in the sample.

Table 1. Performance measurements U.S. vs. Spain.

Performance Measure	*t*	*df*	Sig.	**Mean** U.S.	**Mean** Spain	Interpretation
Cost growth	-.90	71	.373	4.38	6.00	U.S. = Spain
Schedule growth	-2.92	71	.005	3.64	12.58	Spain > U.S.
Intensity (Log)	12.13	71	.000	.94	.35	U.S. > Spain
Delivery speed (Log)	.14	71	.888	3.26	3.24	U.S. = Spain
Team integration	6.74	71	.000	3.43	2.73	U.S. > Spain
Group cohesion	-1.91	71	.060	1.96	2.29	U.S. < Spain

Table 2. Project delivery characteristics.

Project Delivery Characteristics	U.S. (%)	Spain (%)
Builder was prequalified	54.8	100.0
Specialty trades were prequalified	46.1	83.9
Builder was selected on strictly qualification-based criteria	2.4	38.7
Specialty trades were selected on strictly qualification-based criteria	2.6	9.7
Builder held an open book contract with the owner	16.7	6.5

4 DISCUSSION

DBB construction projects analyzed in Spain where less reliable in their schedule performance and had less integrated teams, when compared to their counterparts in the U.S. Team integration, as defined in this study, is measurable by the team's participation in inter-firm, collaborative practices. These practices include jointly setting project goals, using (BIM) and planning for its implementation, meeting during the design phase (e.g., charrettes) and sharing a common, co-located space. In Spain, these types of collaborative practices are not used on DBB projects. The project goals are set mainly by the owner and are later communicated to the contractor and specialty subcontractors. Additionally, most teams do not use BIM and are not co-located. By comparison, most projects in the U.S. use BIM for at least the architectural design and leverage the designer's expertise to assist with establishing realistic project goals. Together, these two, small practices give DBB projects in the U.S. a significant edge in team integration over their Spain counterparts. As demonstrated by Franz *et al*. (2017), higher values of team integration are associated with lower average schedule growth, meaning that the difference in team integration between countries is a likely explanation for the difference in schedule reliability.

On the other hand, in Spain, teams were more cohesive and developed generally stronger relationships. This may be partially attributable to differences in the selection processes favored by Spanish owners. These owners more frequently chose team members based on factors other than price, relying more on previous experiences and qualifications. Conversely, in the U.S., team selection was based mainly on a competitively bid price of work, which discourages cooperation and makes no effort to align goal commitment among team members. Thus, a selection process that not only guarantees qualification and capacity, but also aligns goals, was important to the development of a cohesive team. The findings of this comparison suggest that the Spanish industry could improve team integration by: (1) incorporating earlier construction team involvement; (2) promoting cost transparency with open book construction contracts that transition to a lump sum near the completion of the project, and (3) encouraging the designer and contractors to use BIM throughout the project.

References

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.

De la Cruz, M. P., del Caño, A., and de la Cruz, E., Downside risks in construction projects developed by the civil service: the case of Spain, *Journal of Construction Engineering and Management*, 132(8), 844–852, 2006.

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.

Hale, D. R., Shrestha, P. P., Gibson, G. E, and Migliaccio, G. C., Empirical comparison of design/build and design/bid/build project delivery methods, *Journal of Construction Engineering and Management*, 135(7), 579-587, 2009.

Latham, M., *Constructing the Team*, HMSO, London, 1994.

Ling, F. Y., Chan, S. L., Chong, E., and Ee, L. P., Predicting performance of design-build and design-bid-build projects, Journal of Construction Engineering and Management, 130(1), 75-83, 2004.

Matthews, O., and Howell, G. A., Integrated project delivery an example of relational contracting, *Lean Construction Journal*, 2(1), 46-61, 2005.

Minchin Jr., R. E., Li, X., Issa, R. R., and Vargas, G. G., Comparison of cost and time performance of design-build and design-bid-build delivery systems in Florida. *Journal of Construction Engineering and Management*, 139(10), 04013007, 2013.

Nam, C. H. and Tatum, B. C., Non contractual methods of integration on construction projects, *Journal of Construction Engineering and Management*, 118(2), 385-398, 1992.

Pellicer, E., Sanz, M. A., Esmaeili, B., andMolenaar, K. R., Exploration of team integration in Spanish multi-family residential building construction, *Journal of Management in Engineering*, 32 (5), 05016012, 2016.

Rocha de Gouveia, M., The price factor in EC public tenders, *Public Contract Law Journal*, 31(4), 679-693, 2002.

Shrestha, P. P. and Mani, N., Impact of design cost on project performance of design-bid-build road projects, *Journal of Management in Engineering*, 30(3), 04014007, 2013.

Touran, A., Gransberg, D. D., Molenaar, K. R., Ghavamifar, K., Mason, D. J., and Fithia, L. A., TCRP 131 - A Guidebook for the Evaluation of Project Delivery Methods, Transportation Research Board, Washington, D.C., 2009.

Tran, D., Molenaar, K. R., and Gransberg, D. D., Implementing best-value procurement for design–bid–build highway projects, Transportation Research Record: *Journal of the Transportation Research Board*, (2573), 26-33, 2016.