Revisiting Project Delivery Performance

Final Report

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Summary

This report presents the results of a study to examine and compare the performance of design-bid-build (DBB), construction manager at risk (CMR) and design-build (DB) project delivery systems in the U.S. building construction industry. By leveraging data from 212 projects completed over the past ten years, we use a best subset analysis to explain the variance in five measures of performance: unit cost, cost growth, schedule growth, construction speed and delivery speed. From these regression models, we calculate the average expected performance of each project delivery system. The results clearly show that the DB projects were delivered faster and with lower cost and schedule growth than the CMR and DBB projects in the data set. In addition, the completed unit cost of DB projects was comparable to DBB and slightly less than CMR projects. Our results are generally consistent with findings from the Construction Industry Institute's seminal report from 1998 that compares performance across delivery systems. However, our modeling does indicate that, with the exception of delivery speed, the gap in performance between DBB, CMR and DB has narrowed over time. We then interviewed owners and project participants from the best and worst performing projects within the data set. Across the best performing projects, interviewees frequently cited the owner's emphasis on a relational project culture and having previously contracted with the same architect or contractor as being vital to project success. Across the worst performing projects, interviewees identified consistent challenges, including a lack of experience with the project delivery system, poor communication between the owner and contractor, and understaffing or turnover within the project team. These interviews validated our regression models, as well as provided insight into how to improve the likelihood of a successful project, regardless of the project delivery system.

1. Purpose

Twenty years ago, the Construction Industry Institute (CII) published a report titled, "A Comparison of U.S. Project Delivery Systems,"[1] which benchmarked the performance of design-bid-build (DBB),

[1] Sanvido, V. and Konchar, M. (1998). "Project delivery systems: CM at risk, design-build, design-bid-build." The Construction Industry Institute, RT-133.

construction manager at risk (CMR) and design-build (DB) projects. The report examined data from 351 projects of varying size, sector, complexity, and location that were completed between 1984 and 1998. The analysis revealed that DB projects outperformed both DBB and CMR in terms of unit cost, cost and schedule growth, and all metrics relating to the speed of delivery.

These results had a profound impact on how public and private owners decided to deliver projects in the construction industry. The value of non-residential construction projects in the U.S. undertaken using a DB delivery system increased from an estimated 24% in 1996[2] to 38% in 2014[3]. By 2021, DB delivery is expected to encompass 44% of construction spending, with the greatest increases being seen in the manufacturing, highway and education construction sectors[4]. This growth has been primarily customer-driven, in that more owners are becoming aware of and choosing alternative forms of delivery for their projects because of their reported performance advantage.

Now, in the nearly two decades since this seminal report, there has been considerable interest in updating these performance benchmarks. *The purpose of our research effort was to provide new benchmarks for DBB, CMR and DB performance by repeating the same methodology employed by the authors of the 1998 CII report with a data set of contemporary projects.*

2. Background

There is a wide array of project delivery systems in the U.S. building construction industry. However, the most common project delivery systems continue to be DBB, CMR, and DB. The distinction between these systems has blurred somewhat, yet there is general agreement in the characteristics that define them: (1) the number of contractual relationships with project stakeholders; and (2) the timing of involvement of those stakeholders. Recent research has also identified patterns in (3) the contract payment terms and (4) stakeholder selection criteria that are commonly used in each delivery system[5]. Figure 1 provides a graphical comparison of the contractual relationships within each delivery system.

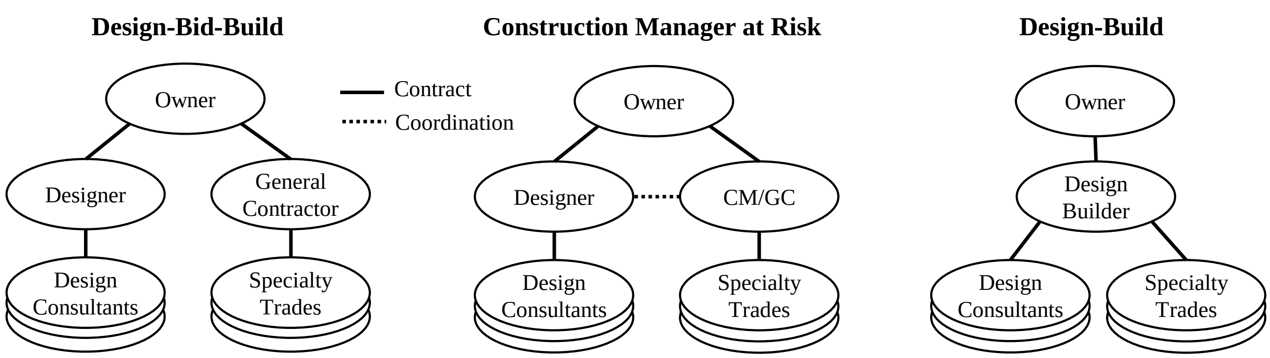

Figure 1. Project delivery systems

[2] Tarricone, P. (1996). Design-build it, and they will come. *Facility Design and Management*, September, 60-63.
[3] Duggan, T. and Patel, D. (2014). *Design-build project delivery market share and market size report*. Design-Build Institute of America and RS Means Reed Construction Data Market Intelligence, Norwell, MA.
[4] FMI. (2018). *Design-build utilization: Combined market study*. Design-Build Institute of America.
[5] Franz, B. and Leicht, R. (2016). An alternative classification of project delivery methods in the United States building construction industry. *Construction Management and Economics*, 34(3).

Under DBB, an owner first contracts with a designer, and with the design to nearing 100% completion, contracts with a general contractor (GC) to build the project. The GC is typically selected on the basis of their competitive bid price, which becomes their lump sum contract amount. The designer represents the owner's interests throughout the construction phase, exercising oversight of the GC.

Under CMR, an owner first contracts with a designer and then with a GC or CM once the design is between 20 to 60% complete. Since the scope is still being defined at that time, the owner selects the GC or CM based on a combination of their qualifications, plan for the work and fee. The GC or CM's contract may begin as a cost reimbursable, but is often converted to a guaranteed maximum price (GMP) or lump sum later in the project. Because of their early involvement, the GC or CM is expected to coordinate closely with the designer to provide constructability guidance, estimating and scheduling services.

Under DB, an owner has a single contract with a design-builder, who may be a firm offering in-house design, engineering and construction services, or teamed design and contracting firms. The owner commonly selects the design-builder based solely on their qualifications or through a combination of cost and technical proposal (i.e., best-value procurement). The design-builder may be contracted when the design is between 0 to approximately 20% complete. Depending on the level of design completion at selection, the design-builder's contract may be either lump sum or cost plus a fee with or without a GMP.

In the 20 years since the seminal 1998 CII study, additional studies have continued to explore the performance of these three project delivery systems. Most confirm that DB projects outperform CMR and DBB in the public infrastructure sector[6], as well as on sustainable projects[7] and healthcare projects[8]. However, there are a few studies that report only minor or no difference between delivery systems in terms of productivity[9] and cost growth[10]. Most recently, the intermediate factors of *team integration* and *group cohesion* were studied as an explanation for why certain delivery systems perform better than others[11]. Team integration was defined as the degree to which the owner, designer and builder engage in collaborative activities, while group cohesion was the degree to which those same stakeholders developed a sense of shared task commitment and interpersonal alignment with one another. The authors concluded that both team integration and group cohesion are important to project success, regardless of the project delivery system. Specifically, the project delivery system provides the framework or "potential" for success, while the project team is critical determinant in reaching that potential. To complement these research efforts, new performance benchmarks for DBB, CMR and DB are needed.

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[6] Molenaar, K., Songer, A. and Barash, M. (1999). Public-sector design/build evolution and performance. *Journal of Construction Engineering and Management*, 15(2).
[7] Korkmaz, S., Riley, D. and Horman, M. (2010). Piloting evaluation metrics for sustainable high-performance building project delivery. *Journal of Construction Engineering and Management*, 136(8)
[8] El Asmar, M., Hanna, A. and Loh, W. (2013). Quantifying performance for the integrated project delivery system as compared to established delivery systems. *Journal of Construction Engineering and Management*, 139(11).
[9] Ibbs, C., Kwak, Y., Ng, T. and Odabasi, A. (2003). Project delivery systems and project change: Quantitative analysis. *Journal of Construction Engineering and Management*, 129(4).
[10] Thomas, S., Macken, C., Chung, T. and Kim, I. (2002). Measuring the impacts of the delivery system on project performance: Design-build and design-bid-build, NIST, Austin, TX.

3. Methods

This research leverages an existing data set from a previous study[11], wherein a large sampling of projects (204 projects) were collected via survey questionnaire and extensively verified via conversations with the owners of each project. The projects within this data set were distributed across the U.S. (see Figure 2) and all completed after 2008. The distribution of project delivery systems used on these projects was 42 for DBB, 78 for CMR, 81 for DB and 3 classified as integrated project delivery (IPD). The 3 IPD cases were removed from the data set prior to our analysis. To increase the sample of DBB projects to be more consistent with the number of CMR and DB projects, we supplemented the existing data set with 11 additional DBB projects that met the same inclusion criteria as the previous study.

The final data set for our analysis contained 212 projects, 53 of which were DBB, 78 were CMR and 81 were DB. The projects ranged in size from about 10,000-square feet at the smallest to over 550,000-square feet at the largest, with 57% falling below 150,000-square feet. Of these projects, 62% were publically-funded, either through federal, state or local municipalities.

To remain consistent with the 1998 CII study methodology, we classified each facility by their use into families that closely align with project complexity. In order of increasing complexity, 9% of projects in the data set were considered light industrial, 13% as multi-story dwelling, 45% as simple office, 12% as complex office, 5% as heavy industrial and 16% as high-technology. A complete descriptive summary of the data set by project delivery system is provided in Appendix A.

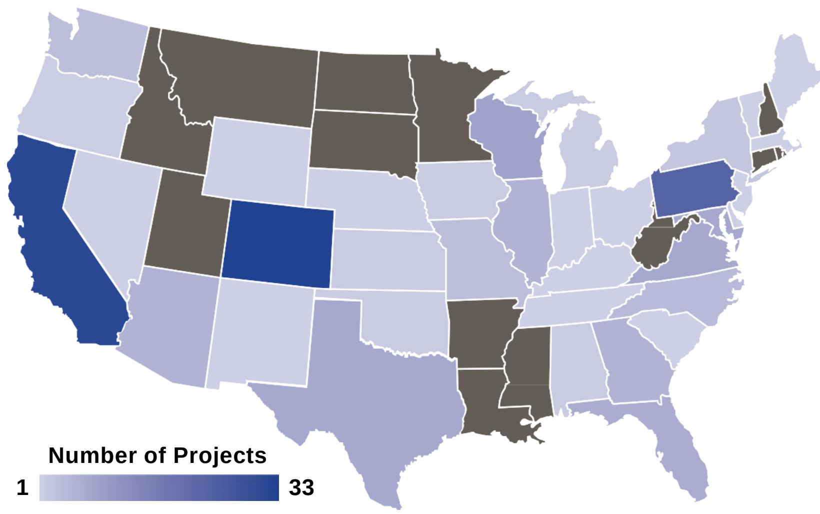

Figure 2. Geographic distribution of projects in data set

To compare the project delivery system performance, we repeated the same methods used in the 1998 CII study. From the 212 projects, a best subset regression analysis was performed for each measure of performance: unit cost, cost growth, schedule growth, construction speed and delivery speed. This analysis identified sets of variables that explained the greatest amount of variation in each measure. Table 1 summarizes the variables included in the analysis. Indicator coding was used for categorical variables and one level was removed to avoid multicollinearity in the regression models. Replicating the 1998 CII study procedure, several interaction terms were also created to account for moderating effects of facility type and contract terms. When specifying the best subset procedure, the project delivery systems

[11] Franz, B., Leicht, R., Molenaar, K., and Messner, J. (2017). Impact of team integration and group cohesion on project delivery performance. *Journal of Construction Engineering and Management*, 143(1).

(DBB, CMR and DB) and facility types (e.g., light industrial) were included in every model. The set of variables resulting in the highest adjusted R-squared and lowest Mallow's C_p was selected for each performance measure. An ordinary least square (OLS) regression was performed using each set of variables to predict the corresponding performance measure and derive coefficients of the regression equation. Projects with a high Cook's distance ($D > 1$), indicating a disproportionate effect on model fit, were removed and the OLS regression was re-run if necessary. These equations were then used to calculate the average performance for projects delivered under each project delivery system, when all other variables are held constant.

Table 1. Summary of predictor variables used in the best subsets regression procedure

Predictor Variable	**Coding**
Project Delivery System	
CM at Risk	1=Yes, 0=No
Design-Build	1=Yes, 0=No
Timing of Builder Involvement	Percent of design completed when the builder was hired, 0 to 100
Negotiated Builder Selection	1=Yes, 0=No
Facility Type	
Light Industrial	1=Yes, 0=No
Multi-Story Dwelling	1=Yes, 0=No
Simple Office	1=Yes, 0=No
Complex Office	1=Yes, 0=No
High Tech	1=Yes, 0=No
Project Characteristics	
1 / Area (Log10)	Inverse Log10 transform of the gross building area
Initial Unit Cost (Log10)	Log10 transform of the project's contracted unit cost
Deep Foundation System	1=Yes, 0=No
LEED Certification Goal	1=Yes, 0=No
High Complexity	1=Yes, 0=No
Average Complexity	1=Yes, 0=No
Percentage New Construction	Percent of project that was new construction, 0 to 100
Team Characteristics	
Public Owner	1=Yes, 0=No
High Administrative Burden	1=Yes, 0=No
Participation in Goal Setting	Proportion of project team that participated in goal setting, 0 to 1
Participation in BIM Planning	Proportion of project team that participated in BIM planning, 0 to 1
Excellent Team Chemistry	1=Yes, 0=No
Excellent Communication	1=Yes, 0=No
Interactions	
CMR*Light Industrial	Project was both CMR and Light Industrial: 1=Yes, 0=No
CMR*Multi-Story Dwelling	Project was both CMR and Multi-Story Dwelling: 1=Yes, 0=No
CMR*Simple Office	Project was both CMR and Simple Office: 1=Yes, 0=No
CMR*Complex Office	Project was both CMR and Complex Office: 1=Yes, 0=No
CMR*High Tech	Project was both CMR and High Tech: 1=Yes, 0=No
DB*Cost Plus	Project was both DB and Cost Plus: 1=Yes, 0=No
DB*GMP	Project was both DB and GMP: 1=Yes, 0=No

To provide validation for the regression analysis and offer additional insights into performance, we also conducted interviews with a sample of respondents from the best and worst performing projects. These projects were identified by considering the upper and lower quartiles of the performance measures in the data set (see Figure 3). The best performing projects were those found in at least three of the following ranges: the lower quartile for cost growth, the lower for schedule growth, the upper quartile for construction speed and the upper quartile for delivery speed. The worst performing projects were those appearing in at least three ranges at the opposite end of the distributions: the upper quartile for cost growth, the upper for schedule growth, the lower quartile for construction speed and the lower quartile for delivery speed. Unit price was not considered in this classification because of its strong dependence on facility type.

Using these criteria, we classified 24 projects as "best" performing and 16 projects as "worst" performing. Each of these projects was contacted and, of the best performers, 9 respondents (38%) agreed to a follow-on interview. Seven of the respondents (44%) on the worst performers agreed to participate. We performed semi-structured interviews over phone or video conference with each of the respondents, using a guiding list of questions (see Appendix C). Notes taken during the interview were entered into a spreadsheet. Afterwards, the projects were cross-compared with one another to identify commonalities both within and between the best and worst performing project groups.

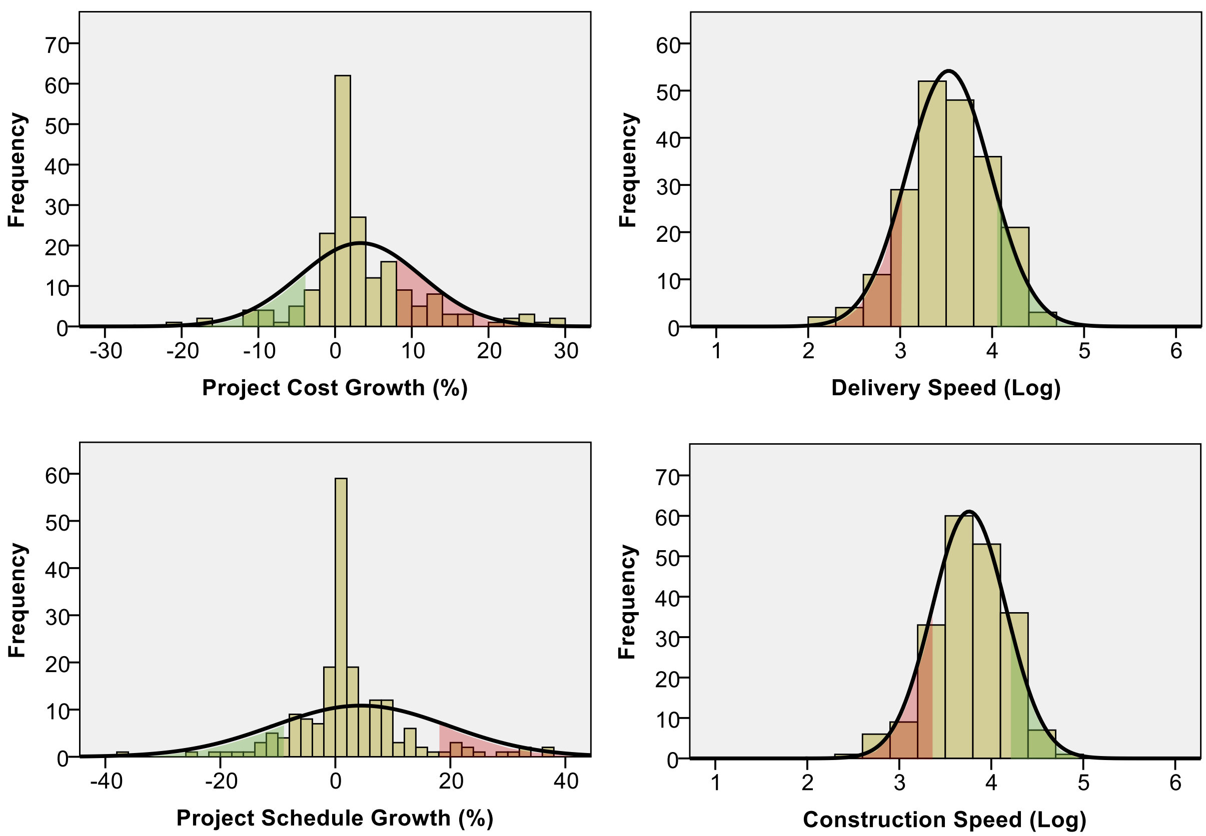

Figure 3. Best performing (green shaded areas) and worst performing (red) quartiles by performance measure

4. Results

Descriptive statistics. Prior to the regression analysis, a simple comparison of the median and mean project performance measures was prepared. Table 2 summarizes this comparison, both overall and by delivery system. The standard deviation (Std. Dev.) is a measure of the variation or dispersion of the measure, where a larger standard deviation suggests that the data is spread over a wider range of values. Because of the relatively large standard deviations of these measures, we caution against drawing conclusions based on this summary alone. The best subsets regression results offer a more accurate comparison because they consider and control for differences in all project characteristics, while holding the impact of the project delivery system constant.

Table 2. Median and mean performance by project delivery system

Performance Measure	n	Median	Mean	Std. Dev.
Unit Cost ($\$/ft^2$)	204	387	422	239
DBB	52	431	448	245
CMR	73	427	442	227
DB	79	327	388	243
Cost Growth (%)	203	1.15	3.34	7.9
DBB	53	1.90	3.23	8.6
CMR	72	0.91	3.99	8.5
DB	78	0.85	2.81	7.2
Schedule Growth (%)	212	0.00	4.38	15.2
DBB	53	2.49	6.29	13.2
CMR	78	0.22	5.41	16.8
DB	81	0.00	2.16	14.7
Construction Speed (ft^2/mo.)	211	5,844	8,845	8,443
DBB	52	3,893	5,562	4,698
CMR	78	6,825	10,626	9,614
DB	81	6,292	9,237	8,592
Delivery Speed (ft^2/mo.)	211	3,634	5,777	6,175
DBB	52	1,721	3,214	3,419
CMR	78	3,655	6,270	6,377
DB	81	4,704	6,915	6,175

Best subset regression analysis. The best subsets procedure allowed us to identify the combination of variables that best explained the variance in each performance measure. Regressing those variables on each performance measure resulted in equations (see Appendix B) that may be used to predict and compare project success.

Cost results. Table 3 represents a comparison, in the form of a percent difference, of the average cost performance for projects delivered under each project delivery system, as predicted by their regression models. With respect to unit cost and cost growth, DB has the best performance (see Table 3) on average. When all other variables were held constant, projects using DB are expected to cost 1.9% less per square-foot when compared to CMR, and 0.3% less when compared to DBB. Similarly, projects using DB are expected to average 2.4% less cost growth than a similarly scoped project using CMR and 3.8% less cost growth than a project using DBB. When compared to DBB, CMR is expected to cost 1.6% more per square-foot and have 1.4% less cost growth on average. The coefficient of determination (R^2) represents the amount of variation in each performance measure being explained by its regression equation. In the case of unit cost, we are able to explain 99% of the variation in unit costs across projects in the data set. This indicates a high level of certainty in the model and we can be more confident in the results shown. The lower R^2 value for cost growth (22%) indicates that we were not able to fully explain a large portion of the variation in that measure with the variables available in our data set.

Table 3: Predicted cost performance comparison

Performance Measure	**DB vs. CMR** (%)	**CMR vs. DBB** (%)	**DB vs. DBB** (%)	R^2
Unit Cost	1.9 less	1.6 more	0.3 less	99
Cost Growth	2.4 less	1.4 less	3.8 less	22

The standardized regression coefficients (β) can be used to compare the relative influence of predictors in the model on the performance measure. For unit cost, the most influential predictors of performance were the initial contracted unit cost (β = 0.267), team chemistry (β = -0.006), contract payment terms (β = -0.006) and facility type (β = 0.006). Given the direction of the relationships and variable coding, this means that a lower cost per square foot was found on projects with:

- Lower initial contracted unit cost at the start of the project
- Excellent team chemistry among the owner, designer and builder (GC, CM or design-builder)
- Open book contracting terms, such as a cost plus a fee or GMP
- Lower project complexity

For cost growth, the most influential predictors were the project delivery system (β = -1.85), facility type (β = -1.72), contract payment terms (β = -1.67), timing of builder involvement (β = -1.48) and team chemistry (β = -1.31). In other words, reduced cost growth was more likely to be found on projects with:

- A DB project delivery system
- Lower project complexity
- Open book contacting terms, such as a cost plus a fee or GMP
- Earlier timing of builder involvement
- Excellent team chemistry among the owner, designer and builder (GC, CM or design-builder)

Schedule results. Design-Build was the best performing project delivery system in terms of schedule growth, delivery speed and construction speed (see Table 4) on average. This table summarizes the percent difference in average schedule performance for projects delivered under each project delivery system, as predicted by their regression models. When all other variables were held constant, projects using DB are expected to have 3.9% less schedule growth than a comparable project using CMR and 1.7% less schedule growth than a project using DBB. On average, DB projects are delivered 13% faster during construction and 61% faster from design through final completion when compared to CMR projects. DB projects are also delivered 36% faster during construction than DBB and 102% faster over the entire project duration. Similar to the cost results, the R^2 values suggest greater certainty in the regression models that produced the construction speed (88%) and delivery speed (89%) results. There is still a large proportion of the variation in schedule growth, approximately 79%, that could not be explained by the variables in our analysis.

Table 4: Predicted schedule performance comparison

Performance Measure	**DB vs. CMR** (%)	**CMR vs. DBB** (%)	**DB vs. DBB** (%)	R^2
Schedule Growth	3.9 less	2.2 more	1.7 less	21
Construction Speed	13 faster	20 faster	36 faster	88
Delivery Speed	61 faster	25 faster	102 faster	89

In order of decreasing influence, schedule growth was predicted by the participation in goal setting (β = -4.31), timing of builder involvement (β = -2.74), facility type (β = -2.30), owner type (β = -2.16) and foundation system (β = 1.86). Allowing for the direction of the relationships and variable coding, this means that reduced schedule growth was found on projects with:

- Participation of the designer and builder (GC, CM or design-builder) in project goal-setting
- Earlier timing of builder involvement
- Lower project complexity
- Public funding source
- Simpler foundation systems, such as slab-on-grade

For construction speed, facility size was most influential (β = -0.383), followed by the project delivery system (β = 0.149) and initial contracted unit cost (β = -0.092). In other words, the rate of completion of the construction scope, from notice to proceed to final completion was faster on projects with:

- Larger gross square footage
- Higher initial contracted unit cost at the start of the project
- A design-build or CM at risk project delivery system

For delivery speed, the same predictors were also influential, but in a different order. Facility size (β = -0.355), initial contracted unit cost (β = -0.081) and project delivery system (β = 0.064) had the most impact on delivery speed. Therefore, the rate of completion of the entire project, from design initiation to final completion was faster on projects with:

- Larger gross square footage
- A design-build or CM at risk project delivery system
- Higher initial contracted unit cost at the start of the project

Case study comparisons. A total of 16 semi-structured interviews were performed with respondents, 9 of which were owners or builders on a project that we classified as a best performer within the data set and 7 that we classified as a worst performer. A brief summary of each interview is provided in Appendix D. Beyond simply confirming the influential variables from the regression analysis, the interviews also explored additional factors leading to the success or failure of the project.

Best performers. Across the most successful projects, there were four factors that appeared with regularity (see Figure 4): early team formation, relational culture, clear expectations and repeat clients. A description of these factors and several examples from projects are summarized below.

Early team formation meant that the designer and builder (GC, CM or design-builder) were both procured and collaborating by the design development phase of the project. Of the best performing projects, 78% described this factor, compared to only 29% of the worst performing projects. Most of the respondents we interviewed described the primary benefit of early team formation as the ability to engage in rigorous pre-planning for the construction phase.

A *relational culture* was present when the attitudes and values of project participants aligned with concepts of cooperation and collaboration. The owner placing a strong emphasis on creating a relational culture was referenced in 78% of the best performing projects, compared to only 14% on the worst performing projects. Each owner had a different approach to shaping their project's culture. One owner, in particular, made their expectations clear during the first meeting. They challenged each member of the design and contractor's teams to not tolerate arguments or unprofessionalism, be willing to express their opinion and to treat each other fairly. Another owner described a constant drive for greater accountability and one project successfully implemented periods of co-location that began during the schematic design phase. Regardless of how it was achieved, the culture on these projects emphasized the project's success over the success of any single firm or organization.

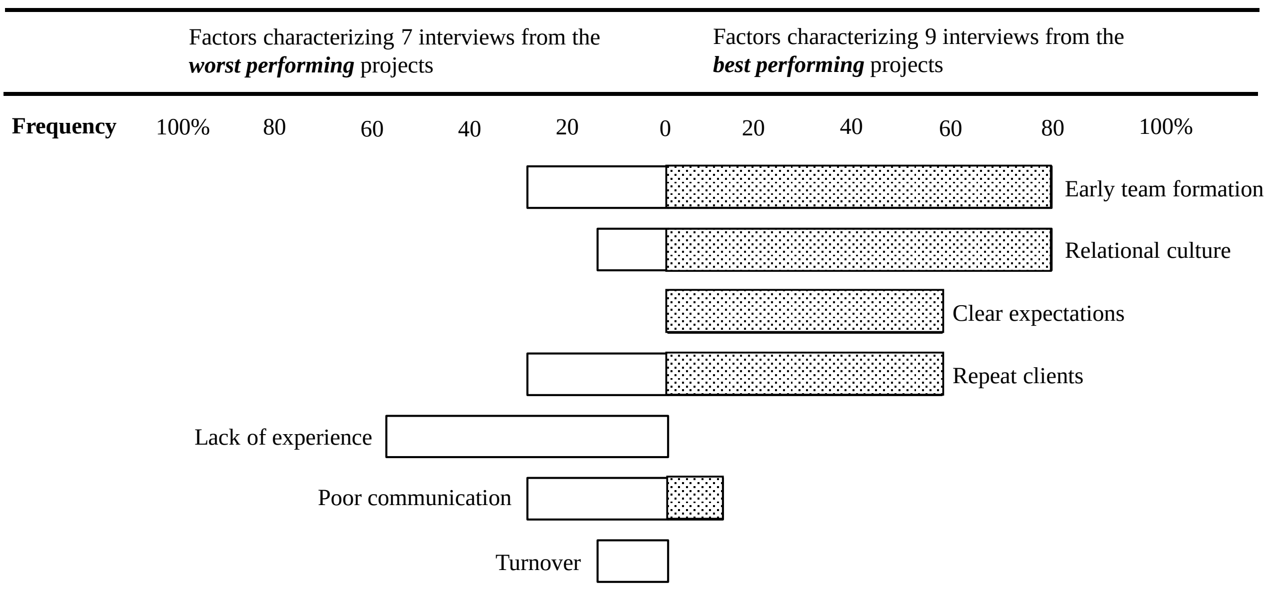

Figure 4. Comparison of factors characterizing the best and worst performing projects

Clear expectations meant that the owner, designer and builder had an unambiguous understanding of what will or should be done to have a successful project. This factor appeared only in the best performing projects and was discussed in over half (56%) of our interviews. On one project, having clear expectation was cited as a reason that the team was able to recover quickly from a delay due to poor soil conditions. The team was aware of what the owner expected of the project and were able to respond more quickly. This factor was closely linked having the owner as a repeat client, since an understanding of owner's expectations could be obtained on a previous project and carried forward to the current project to shortcut a learning period within the team.

Repeat clients meant that the owner had worked alongside either the designer or the builder, or both, on prior projects. The majority (56%) of the best performing projects and a few (29%) of the worst performing described having this factor. Because of these prior working relationships, the owner and builders that we interviewed were more comfortable communicating and, specifically, more willing to share challenges or problems encountered on the jobsite with other team members.

Worst performers. There was less agreement across the least successful projects; however, there were three factors nearly unique to this set of projects (see Figure 2): lack of experience, poor communication and turnover within the team. A description of these factors and several examples from projects are summarized below.

A *lack of experience* with either the project delivery system or project management in general was found to be factor common to most of the worst performing projects. Inexperience was cited on 57% of the worst performing projects as the underlying cause of poor planning and inconsistent quality of installed work. In one case, the inexperience originated with owner’s project manager who lacked experience with the DB project delivery system and was unsure of their role in the process, which led to delayed decisions and poorly conveyed expectations. In another, the project manager for the contractor was new to the company and assigned to a project with tight deadlines. He had limited experience and, as a result, managed reactively to current problems, losing sight of the overall schedule.

Poor communication meant that communication among the owner, design and builder was lacking in either frequency or quality, or both. This deficiency was cited on 29% of the worst performing projects and only 11% of the best performing projects. The causes of poor communication cited in our interviews varied, although there was often a “trigger” event, such as an unexpected condition or conflict that led one team member to retreat from the team. In one case, poor communication was more simply attributed to having an international owner. This case presented language, cultural and time zone barriers that the team was not entirely able to overcome.

Turnover meant that key project team members were transitioned away from the project, either because of a career move or staffing change within the owner, designer or builder’s firm. Turnover and the resulting periods of understaffing was a challenge on 14% of the worst performing projects. On one case, frequent turnover meant that few team members retained a complete understanding of the project. This placed a heavy workload on members of the project team and forced long hours. The result was increased stress and animosity among the owner, designer and builder.

5. Discussion

This study compared the performance of DB, CMR and DBB delivery systems for a data set of contemporary projects, using the same methodology as the seminal 1998 CII study. The best subset procedure allowed us to identify the sets of variables that explained the most variation in five measures of project performance: unit cost, cost growth, schedule growth, construction speed and delivery speed. Five separate regression models were built from these subsets of variables. We use these models to calculate the average expected performance for each project delivery system in Table 5. A direct comparison to the 1998 CII study results is also shown in Table 5. We were able to obtain similar levels of certainty (R^2) in our regression models as the 1998 CII study. While DB is the best performing delivery system in both studies, we found that the performance gap in unit cost, cost growth and schedule growth has narrowed somewhat over the past 20 years. On the other hand, the gap in construction speed and delivery speed between DB and CMR and DBB has widened significantly.

Table 5: Comparison of results between 1998 CII study and this study

	1998 CII Study				**This Study**			
Performance Measure	**DB vs. CMR** (%)	**CMR vs. DBB** (%)	**DB vs. DBB** (%)	R^2	**DB vs. CMR** (%)	**CMR vs. DBB** (%)	**DB vs. DBB** (%)	R^2
Unit Cost	4.5 less	1.5 less	6 less	99	1.9 less	1.6 more	0.3 less	99
Cost Growth	12.6 less	7.8 more	5.2 less	24	2.4 less	1.4 less	3.8 less	22
Schedule Growth	2.2 less	9.2 less	11.4 less	24	3.9 less	2.2 more	1.7 less	21
Construction Speed	7 faster	6 faster	12 faster	89	13 faster	20 faster	36 faster	88
Delivery Speed	23 faster	13 faster	33 faster	87	61 faster	25 faster	102 faster	89

Through a more detailed examination of the best and worst performing projects, we also identified several common factors. The following are recommendations derived from those factors that can be applied, regardless of the project delivery system, to improve the likelihood of a successful project.

- **Bring the team together early:** Owners who seek early involvement, not only of the primary builder, but also of key DB or design-assist specialty contractors, realize more successful projects. Engaging the core project team members in the design process, before advancing beyond the schematic design phase, is critical to garner the full value of construction input and to begin building a cohesive project team.

- **Develop a relational project culture:** Owners who create a culture of trust within a project team have a higher probability of success. They can begin building relationships of trust through qualifications-based procurement and open book contracting. The use of the same designer and builder on multiple projects, as opposed to low-bid selection on a project-by-project basis, can jump start a project culture by carrying forward existing relationships.

- **Communicate expectations:** Early team involvement and a relational project culture provide an opportunity for exceptional communication. The most successful projects use this opportunity to set clear expectations at the onset. Treating project goal-setting as a team activity with the owner, designer, builder and key specialty trades ensures team alignment. Similarly, co-location is an essential tool on complex projects to facilitate communication and manage expectations throughout the process.

- **Engage in succession planning:** The least successful projects in this study experienced disruptive turnover in key team members from the owner, designer and/or builder's organizations. While some level of turnover is unavoidable, the teams that employ qualified project managers and actively plan for departures have a higher likelihood of success. This means developing a deep understanding of the roles and responsibilities of each other team member.

6. Conclusions

This report provides an empirical investigation into the performance of the three most common project delivery systems. The results of best subsets regression analysis clearly showed that, on average, DB projects were delivered faster and with lower cost and schedule growth than their CMR and DBB counterparts. The completed unit cost of DB projects was also comparable to DBB and slightly less than CMR projects. Our regression models ranged in their ability to explain the variance of these performance measures and we have greater certainty in the unit cost, construction speed and delivery speed comparisons. We then identified the best and worst performing projects in the data set and performed interviews with their project participants to identify common factors. Across the best performing projects, interviewees frequently cited the early team formation, the owner's emphasis on a relational project culture, setting clear expectations and having contracted with the same architect or contractor on a previous project as being vital to their success. Across the worst performing projects, interviewees mentioned factors that hindered performance, including a lack of experience with the project delivery system, poor communication between the owner and contractor, and understaffing or turnover within the project team. These interviews validated our regression models, as well as provided insight into how to improve the likelihood of a successful project, regardless of the project delivery system.

Acknowledgements

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Definitions

Construction Speed: The square-feet per month rate of completion for construction activities. It is calculated by dividing the gross square footage of the building by the actual construction duration in months.

Cost Growth: The percent change in project cost from design initiation to final completion. It is calculated by taking the final project cost, including both design and construction contract, less the initial contracted project cost and then dividing by the initial contracted project cost and multiplying by 100.

Delivery Speed: The square-feet per month rate of completion for both design and construction activities. It is calculated by dividing the gross square footage of the building by the actual project duration in months.

Schedule Growth: The percent change in project duration from design initiation to final completion. It is calculated by taking the final project duration, including both design and construction activities, less the initial contracted project duration and then dividing by the initial contracted project duration and multiplying by 100.

Unit Cost: The cost per square foot of the completed project. It is calculated by taking the final project cost, including both design and construction contracts, divided by the gross area of the building. All cost data was indexed by project location and to June 2014 prices prior to analysis to control for regional differences in prices.

Appendix A: Existing Data Set Variable Summary

	n	Median	Mean	Std. Dev.
Gross Area	211	116,400	188,710	230,710
DBB	52	68,488	129,813	168,265
CMR	78	155,000	254,880	278,654
DB	81	120,000	162,802	199,329
Gross Area				
Light Industrial	19	165,000	232,095	325,896
Multi-Story Dwelling	28	125,500	191,757	197,584
Simple Office	100	90,572	147,722	180,446
Complex Office	24	82,500	175,439	187,036
Heavy Industrial	11	195,000	145,240	126,684
High-Tech	29	116,888	326,157	340,504
Unit Cost				
Light Industrial	18	433	417	195
Multi-Story Dwelling	28	286	293	141
Simple Office	97	380	430	238
Complex Office	23	321	339	182
Heavy Industrial	11	355	495	419
High-Tech	27	542	573	209
Cost Growth				
Light Industrial	18	2.96	6.07	8.39
Multi-Story Dwelling	28	1.38	3.73	7.68
Simple Office	96	1.90	3.81	7.88
Complex Office	22	0.00	0.17	4.32
Heavy Industrial	11	2.86	3.49	5.37
High-Tech	28	0.00	1.97	10.58
Schedule Growth				
Light Industrial	19	0.00	-0.26	6.77
Multi-Story Dwelling	28	1.09	3.77	17.75
Simple Office	100	1.60	6.33	16.65
Complex Office	24	-0.07	0.60	10.24
Heavy Industrial	11	0.00	1.19	3.99
High-Tech	30	0.00	5.54	16.48

	n	Median	Mean	Std. Dev.
Construction Speed				
Light Industrial	19	9698	12507	12413
Multi-Story Dwelling	28	6707	10393	9198
Simple Office	100	4610	6562	6322
Complex Office	24	8094	9847	6979
Heavy Industrial	11	9534	9953	7536
High-Tech	29	8610	11571	10638
Delivery Speed				
Light Industrial	19	6676	8573	9253
Multi-Story Dwelling	28	5186	6184	4794
Simple Office	100	2447	4347	5205
Complex Office	24	4348	6031	4594
Heavy Industrial	11	6391	7029	5953
High-Tech	29	4880	7617	8104

Appendix B: Regression Model Results

	Performance Measure				
Predictor	Unit Cost (Log10)	Cost Growth	Schedule Growth	Construction Speed (Log10)	Delivery Speed (Log10)
Constant	**0.076	**32.50	***47.40	***7.762	***7.962
CMR	0.008	-1.32	2.85	0.055	-0.151
DB	-0.001	-3.77	-1.62	***0.132	***0.305
Light Industrial	0.004	0.73	-9.23	-0.033	-0.088
Multi-Story Dwelling	-0.014	-3.67	0.51	-0.030	-0.094
Simple Office	-0.007	-2.45	-0.93	-0.047	-0.095
Complex Office	*-0.019	*-5.74	-7.96	-0.045	-0.059
High Tech	0.007	1.38	-4.13	0.029`	0.067
Timing of Builder Involvement		-0.038	-0.077		
Public Owner			*-5.47	0.039	0.038
Percentage New Construction		-11.61	*-20.37	0.094	
Deep Foundation System			*4.87		0.042
CMR*Light Industrial				0.131	***0.428
CMR*Multi-Story Dwelling	0.024	7.13			*0.279
CMR*Simple Office					**0.257
CMR*Complex Office				**0.190	**0.332
CMR*High Tech	*-0.029	-6.57		-0.066	0.164
Negotiated Builder Selection					-0.027
DB*Cost Plus	*-0.021	-3.49			
DB*GMP	*-0.013	*-3.34	1.86		
Initial Unit Cost (Log10)	***0.981	*-4.81		***-0.307	***-0.342
1 / Area (Log10)				***-16.87	***-18.29
Administrative Burden		1.38			*-0.055
Participation in Goal Setting	0.019	4.43	***-23.10		
Participation in BIM Planning			-4.79		
Excellent Team Chemistry	**-0.015	*-3.04	-3.94		
Excellent Communication			3.00		
R^2	98.9	21.3	21.5	88.2	88.9
R^2-adjusted	98.9	12.5	14.2	87.2	87.8

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Appendix C: Sample Interview Questions

PROJECT **P**ERFORMANCE **I**NTERVIEW

Purpose of the research: To understand the performance differences of various project delivery methods and to identify the specific factors that owners see as contributing to the success of their projects.

What you will do in this research: If you decide to volunteer, you will be asked to participate in one interview. You will be asked several questions. Some of them will be about project performance. Others will be about the organizational factors and use of technology that contribute to performance. The research team will be taking notes during these interview, but you will not be recorded.

Time required: The interview will take approximately 30-60 minutes.

Benefits: This is a chance for you to tell your story about your experiences concerning a project that you recently completed. Taken together with other participants, your experiences will improve the confidence in statistical models that we develop to compare project delivery performance.

Confidentiality: Your responses to interview questions will be kept confidential. Your name and company affiliation will not be known outside of the research team and will not appear in any publications or presentations related to the findings of the research. Notes from the interview, without your name, will be kept until the research is complete.

Participation and withdrawal: Your participation in this study is completely voluntary, and you may refuse to participate or withdraw from the study at any time. You may withdraw by informing the research team that you no longer wish to participate. You may skip any question during the interview, but continue to participate in the rest of the study.

To Contact the Researcher: If you have questions or concerns about this research, please contact:
Dr. Bryan Franz, School of Construction Management, University of Florida, 573 Newell Drive, Gainesville, FL 32611; *Email:* bfranz@ufl.edu; *Phone:* (352) 273-1161.

Agreement:
The nature and purpose of this research have been sufficiently explained and I agree to participate in this study. I understand that I am free to withdraw at any time.

Signature: ______________________________________ Date: __________________

Name (print): ____

Q1. Why did you choose the project delivery system used on this project?

Q2. How did you decide when to hire the designer and builder?

Q3. How overlapped were design and construction activities?

Q4. Did you run into any unexpected challenges on the project?

Q5. How and when were project goals established? Do you feel those goals were shared by the designer and builder?

Q6. How was the chemistry between yourself, the designer and the builder? Did you do anything special create or foster strong relationships within the team? When, if ever, do you feel the team "clicked?"

Q7. What do you believe most strongly influenced the performance of this project?

Appendix D: Interview Summaries

Best Performing Projects

[1] This project was a 7-story apartment building of approximately 500,000 square feet. The project was built using a DBB project delivery method and the interview was conducted with the owner's representative. This delivery method was chosen because the owner was comfortable with its execution and gained familiarity by delivering multiple prior projects in the same way. The owner was very involved in their role and maintained control of the project, but was very open to the team they worked with and open to creative design solutions. This project brought project team members together very early, during pre-construction and felt that early pre-construction services were critical to project success. The project did have a major problem with unexpected site conditions that had the opportunity to increase costs well outside of the budget, but with cooperation and teamwork the project was able to recover from these unexpected costs and was completed under budget. Having the designer and builder together early and knowing their expectations was a significant factor in becoming a team, upholding their commitments, and the ultimate success of the project.

[2] This project was a 23-story, 1,250,000 square foot, medical facility built to meet LEED standards. The project was completed using a CMR delivery method and the interview was conducted with a member of the construction management team. This method of delivery was chosen because the project team members felt that it best allowed for pre-planning. The designer and CM were brought in early and co-located, as well as empowered to make critical decisions. This project had an aggressive overlap in design, planning, and construction, but with a large management team located at the site, the project moved at a rapid pace. The project ran into unexpected site conditions due to inadequate fill, but the overwhelming amount of pre-planning performed by the project team minimized the disruption. The project used a real-time punch list method that assisted in keeping the project on schedule. Because of the size of the project, the amount of planning, and the co-location of the project team, there was an early development of high team chemistry that made reaching the project goals seem "like a forgone conclusion."

[3] This project was a 12-story office building of roughly 310,000 square foot that was built to LEED standards. The project was completed using the DB delivery method and the interview was conducted with the owner. They chose this delivery method because of familiarity. The designer, builder and select specialty trades were all hired early in the delivery process. This project was designed and then place on-hold before construction due to the recession. This project had a very strong relational culture and the expectation of the owner was a high level of success. The interviewee described making a "charge" to the project team during their first meeting, where they challenged each member of the design-builder's team to not tolerate arguments or unprofessionalism, be willing to express their opinion and to treat each other fairly. The interviewee stated that the penalty for non-compliance was being black listed from future projects.

[4] This project was a 275,000 square foot, 2 story athletic building. The project was constructed using the DBB delivery method and the interview was conducted with the owner. This method was chosen due to funding issues, which required the design to be completed and then more funds to be raised prior to construction. Project team members worked very well together and

the general contractor was motived by the hope of future work with the owners, which led to higher performance at the most advantageous price to the owners. The project did have issues with needing to import structural fill and dealing with some groundwater infiltration, as well as having a subcontractor go bankrupt, but with strong leadership and sense of commitment the project overcame these obstacles. The interviewee stated the there was a previous relationship with the designer and that, with the motivation of future business for the contractor, the team came together and worked well toward common goals. The interviewee felt that the high visibility of the project in the community helped to create a positive “can do” attitude that assisted in making this project successful.

[5] This project was a 6 story, 335,000 square foot, laboratory-research building that was built to LEED standards. The project was completed using a CMR delivery method and the interview was conducted with the owner’s representative. This delivery method was the owner’s preferred method for larger scale, higher cost projects. The project had little to no overlap of design and construction activities. The project ran into issues regarding under funding, which was overcome by creative planning, some team members agreeing to lower their fee, and cost savings using lean construction methods. The project team worked very well with each other and had strong relationships even outside of the project. The interviewee felt that this contributed to the flexibility of the team and assisted them in overcoming the projects funding challenges.

[6] This project was a 165,000 square foot, 2-story office building. The project was completed using a CMR delivery method and the interview was conducted with a member of the construction management firm. This delivery method was chosen because the owner had a prior relationship with the CM. The interviewee felt that the project was better described as a hybrid of CM and DB. Critical path trades were brought on early in design-assist roles to help plan the project. However, the project was delayed on construction activities until a completed design was submitted due to permitting. The interviewee felt that the largest issue this project faced was delays and difficulties with the glass and glazing work. The project also suffered from weather delays, but these were overcome by modifications to the schedule, which allowed the project to come in with a faster than estimated construction time. The interviewee felt that the project greatly benefited from the familiarity of the owner, designer and CM team, as this was the 15^{th} project they had completed together.

[7] This project was a 1-story manufacturing facility of approximately 126,000 square feet. The project was completed using a DB delivery method and the interview was conducted with a member of the design-build team. This delivery method was chosen based on the owner’s preference for this delivery method and a previous relationship with the design-build firm. This project brought the whole construction team together prior to the submission of the proposal. The design and construction process was aggressively overlapped and described by the interviewee as a “rolling” process. The project suffered only minor unexpected drainage issues, but otherwise was described as a good project. The project goals were set early and the team understood the importance of not just meeting these goals, but of exceeding them. The interviewee mentioned that the project team worked extremely well because they were an existing team that the design-builder had used on many projects before.

[8] This project was a 1- story, 343,000 square foot, manufacturing facility that was built to LEED standards. The project was completed using a DB delivery method and the interview was conducted with a member of the design-build team. This method was chosen due to a long standing prior relationship between the owner and design-build firm. Much of the construction participants were "valued partners" of the design-build firm and thus had an established relationship. These participants were involved early in the process. The design for this project was completed during months of construction stoppage due to weather conditions. The biggest challenge for this project was meeting the owners design requirements for portions of the building to that meet "food grade" standards. The design-build firm benefits from being able to partner project managers and architects from project to project, over many years, this allows for strong teamwork and efficiency. The project team was large and thus allowed for many minds and hands to address problems in a quick and timely manner, never really allowing the project to fall behind.

[9] This project was a 195,000 square foot, 5- story medical building. The project was completed using a DB delivery method and the interview was conducted with a member of the design-build firm. This method was chosen due to the owner's need to get the building to market fast. The interviewee felt that DB allowed the building process to move quickly and not become "bogged down." The project moved at a record pace in the interviewee's experiences, which was assisted by having participants brought on to the project without the need for bidding. The project's only issue involved the owners wanting to install medical equipment prior to full completion of the building and thus causing "traffic jams." The interviewee described using a white board schedule method on site, with each trade contractor having their own board, to keep them on task and on time. This goal-setting method, combined with $500 fines for missing weekly progress meetings, allowed for the project to come in 3/5th quicker than similar projects. The project benefited from the owner, design-builder and trades all having prior experiences working together and the owner empowering the design-build team to pick the best, not the cheapest, trades.

Worst Performing Projects

[10] This project was a 35,000 square foot, 1-story educational building built to LEED standards. The project was completed using the DBB delivery method and the interview was conducted with the owner. This delivery method was chosen because of the downward market, which the owner felt would provide greater competition from contractors and eventual cost savings. The builder was hired at 75% CD to assist with value engineering and guide the project's scope based on costs. The project had issues with site conditions, requiring large amounts of structural fill to be imported before construction could begin. The team had meetings prior to construction to establish goals and the interviewee felt that their approach of openness and understanding assisting in the team having good chemistry.

[11] This project was a 1-story recreational building of approximately 8,000 square foot that was built to LEED standards. The project was completed using CMR as a delivery method and the interview was conducted with the owner. This delivery method was chosen for familiarity and because they felt that the level of quality and service were much higher than traditional delivery. This project was a smaller, new construction portion of a larger residential remodel project. Because of this the designer and CM had been working to together previously on the other buildings prior to the start of this new construction. Some members of the project team

had little experience, this being their first project in a leadership position. The project had some setbacks due to design flaws, which required large amounts of repairs and rework after discovery of the issues. The interviewee felt that the CM's project management team was not properly staffed and spread thin with contributed to the projects issues.

[12] This project was a 10,000-square foot, 1-story recreational building that was built to LEED standards. The project was completed using a DB delivery method and the interview was conducted with the owner's representative. This project suffered from being outside of the normal procedure for this owner due to funding constraints. The interviewee was not able to provide much information about the project due to being placed in an observation position in preparation for the transfer of ownership to his firm once the project was completed. The interviewee did opine that it was "the worst project" of their career.

[13] This project was a 4-story, 50,000 square foot remodel of a medical building into a multi-unit residential building. The project was completed as DBB delivery method and the interview was conducted with the owner. They chose this delivery method because they felt it gave them the best price and allowed for the most competition during procurement. Project team members were brought on early to assist in pre-construction and assist with current market information. This project had difficulties with overlapping design and construction activities due to funding restrictions. The projects biggest challenge was not carrying enough contingency funds and thus the project was over on budget and time. This was the owner's first renovation project and they had little experience with this process and with the other team members. This interviewee felt that many lessons of how not to conduct a project were learned and that it was important to financially tie the designer and builder into the project using the contract to develop a level of ownership in the project success.

[14] This project was a 35,000 square foot, 2-story recreational building that was built to LEED standards. The project was completed using a CMR delivery method and the interview was conducted with the owner. This delivery method was chosen because allowed the project to progress faster and was allowed by the project funding requirements. The CM firm was able to hire trades that they had prior relationships with, as long as the owner could review their proposal. Construction activities started while the design was progressing, which assisted in addressing one of the project's main challenge, preexisting utility structures that had to be worked around. This was the interviewee's first time using this delivery method. The interviewee felt that many lessons were learned from the mistakes made in this project's delivery and that, as they have continued to use the CMR delivery method over the following projects, it has become a much smoother and more successful delivery method for them.

[15] This project was a 1-story, 4,300 square foot, office building. The project was completed using a CMR delivery method and the interview was conducted with owner's representative. This method was chosen because the owner prefers to have separation between the designer and builder and prefers some conflict between members, which they feel keeps members more accountable. There was no construction and design overlap in the completion of this project. The project used different materials from other projects which slowed the projects delivery.

[16] This project was a 25,000 square foot, 1-story commercial building built to LEED standards. The project was completed using a DBB delivery method and the interview was

conducted with a member of the general contracting firm. This delivery method was chosen due to a previous relationship between the builder and the owner in the past, where they had used this method before. The interviewee stated that there were no unexpected or significant challenges faced by the project. The interviewee thought this was a well performing and delivered project, contrary to what the data showed.