COMPARATIVE ANALYSIS OF INTEGRATED PROJECT DELIVERY (IPD) COST AND QUALITY PERFORMANCE

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ABSTRACT

Integrated project delivery (IPD) is an emerging construction project delivery system that aligns different stakeholders' interests and objectives, while collaboratively involving key participants very early in the project timeline. It is distinguished by a multiparty contractual agreement that incentivizes collaboration and allows risks and rewards to be shared among the parties of the contract. IPD is becoming increasingly popular with various organizations expressing interest in its benefits to the construction industry. However, no research studies have shown statistically significant performance differences between IPD and more established delivery systems.

This study fills that missing gap by (1) evaluating the performance of IPD projects compared to projects delivered using the more traditional design-bid-build (DBB), design-build (DB), and construction management at-risk systems (CMR); and (2) showing statistically significant performance differences between IPD and these systems. Project delivery performance literature was analyzed, as well as recent IPD literature, to identify performance metrics to be studied. A data-collection survey was developed and used to gather quantitative and qualitative performance data from the industry. Then a univariate data analysis was performed to develop benchmarks for IPD project performance.

Results indicate that IPD achieves major improvements in building quality metrics. These findings are statistically significant, and provide a more comprehensive understanding of IPD performance by specifically identifying performance areas that are positively affected by this emerging delivery system. Furthermore, the results can be used by the Architecture / Engineering / Construction (AEC) industry to improve its performance in both private and public sector projects.

Keywords: Integrated Project Delivery, Project Performance, Mann-Whitney-Wilcoxon Test

1. INTRODUCTION

1.1 Background

IPD is the subject of great interest in the AEC industry today. Major organizations, such as the Construction Industry Institute (CII) and the American Institute of Architects (AIA), have weighed in on the topic, as evidenced by the several reports and publications dedicated to IPD or closely related subjects (e.g. CII 2011; AIA 2011). Additionally, construction magazines, such as *Engineering News Record* (ENR) and *Tradeline*, have featured projects that have used IPD (ENR 2011; Tradeline 2007). Articles in several journals, including the ASCE *Journal of Construction Engineering and Management*, the *Construction Lawyer*, and the *Lean Construction Journal* (LCJ) have commented on the experiences and potential benefits of IPD, such as reduction of project costs and increased cooperation in the construction process (Matthews and Howell, 2005). In 2011, LCJ dedicated an entire issue to IPD, discussing its implementation, illustrating barriers to industry integration, and suggesting positive outcomes from the use of IPD. This paper examines the claims of superior performance by quantitatively studying the performance of IPD.

1.2 Problem Statement

There are major problems in the AEC industry today, including wasted resources (Hanna 2010), decreasing productivity (Teicholz 2004), and lack of schedule and budget compliance (NCHRP 2007). Collaboration achieved through IPD seems to be a potential solution, as expressed by CURT (2004 and 2007), UKOGC (2007), and AIA (2010).

A survey of the literature to date shows no comprehensive studies that have statistically compared and quantified the benefits of IPD projects relative to non-IPD projects based on all relevant metrics. Despite the references to several sources discussing IPD benefits, the UKOGC report gives mere estimates, and the AIA report only discusses data from individual case study perspectives.

Aside from a few case studies and anecdotal examples, no significant literature exists to support the claim of superior IPD performance. In fact, the only research study that investigates this claim using statistical methods found no significant performance differences for IPD (Cho and Ballard 2011). The hypothesis that the implementation of IPD would improve project performance is not supported by their statistical analysis. Since no solid statistical inference can be made based on the findings, data collection and analysis are still necessary to validate the relationship between IPD and project performance.

1.3 Research Methodology

The research plan for this study encompasses three distinct stages. The first stage is an assessment of the literature and industry practices that will lay the ground for the rest of the study. This stage consists of two steps: the first step reviews the current state of knowledge regarding IPD, project delivery comparisons, and project performance metrics. The second step identifies key variables that need to be gathered and analyzed in order to answer the research questions.

The completion of the first stage serves as a solid basis for the second stage of this research – data collection. Three steps were completed for this stage: survey development; pilot testing of the survey; and full-scale data collection.

Upon completion of the second research stage, the resulting project data was verified and readied for the analysis. The third and last stage of this research builds on the previous two and consists of analyzing the data collected and developing benchmarks for IPD project performance.

2. LITERATURE REVIEW

This section consists of a survey of the literature to understand the current state of knowledge in the AEC field. The focus will be on three aspects: (1) IPD literature, (2) major project delivery systems comparisons, and (3) key project performance metrics.

2.1 Integrated Project Delivery

There is no single definition for IPD. In fact, numerous definitions can be found throughout published studies and reports. As shown later in this section, some of the definitions continue to evolve. Mathews and Howell (2005) define IPD as "*a relational contracting approach that aligns project objectives with the interests of key participants.*" Mossman et al. (2010) compared traditional and integrated delivery timelines, and summarized some of the key differences between IPD and the traditional DBB delivery system, mainly the early involvement of project stakeholders in IPD which results in a much earlier common understanding of the project as well as a reduction in clashes and a shorter project schedule.

The AIA literature on IPD (e.g. AIA 2010, 2011) can be summarized in two key points. First, their IPD definition is clearly evolving. Most of their early IPD *Principles* are being carried forward, gaining a clearer definition with time. However, their IPD requirements appear to be loosening to accommodate what is available in the industry today; the most noticeable example is considering multiparty contracts to be optional and not a required IPD characteristic. The second point is that their reports discuss case studies on an individual basis, and no statistical comparative analyses were performed to draw strong conclusions regarding IPD performance.

A joint effort of the National Association of State Facilities Administrators (NASFA) and other national organizations culminated in a report on IPD that discusses the different levels of collaboration in project delivery: the lower level uses IPD as a philosophy with a CMR or DB delivery approach; the middle “IPD-ish” hybrid level employs some IPD characteristics, without a multiparty contract; and the higher level uses IPD as a delivery system with a multiparty contract (NASFA 2010). This NASFA IPD definition emphasizes the grouping structure for the project stakeholders; at the heart of the project is the project leadership team (or core group) that handles day-to-day decision making. Projects can have two other team levels: a higher-level executive team for circumstances where consensus is not reached by the core group, and lower-level project implementation clusters responsible for designing, detailing and constructing specific aspects of the project. The report states that adopting IPD drives waste out of the project, reduces or eliminates changes, improves schedules, and results in avoiding conflicts through resolving disputes by the core group. However, no analysis was completed using actual project data. This paper adopts a version of the NASFA definition of contractual IPD, as discussed in *Section 2.4*.

To summarize this first section of the literature review, one can see there are different definitions of IPD, some more stringent than others. However, none of the previously listed definitions are perfect because they are not consistent with the two key elements of a project delivery system definition: relationships and timing of engagement of the key stakeholders. Summarizing the explanations found in the literature, and based on the project data collected, this paper develops its own definition of IPD, discussed in *Section 2.4*. The literature also reveals a myriad of benefits stemming from the use of IPD, but the claims are often not rigorously supported or only based on a limited number of case studies.

2.2 Delivery Systems Comparisons

There are numerous project delivery systems being used to deliver buildings around the world. However, Branca (1987) identified the three delivery systems most commonly employed in the U.S. construction industry: traditional DBB, CMR, and DB. There is an abundance of construction delivery literature comparing DBB, CMR, and DB. The studies differ based on specifics, such as the types of projects and performance metrics used. Extensive literature review was conducted on comparisons of project delivery systems. This section will provide a small sample of the surveyed literature.

In the CII study conducted by Sanvido and Konchar (1998), DB showed a superior performance over CMR, which in turn performed greater than DBB. The authors studied 351 projects in the following U.S. general building market sectors: light-industrial, multi-story dwelling, simple and complex office, heavy industrial and high technology. The metrics studied for which the results were statistically significant were unit cost, construction speed and delivery speed. Other metrics had less statistical significance, including cost growth, schedule growth, turnover quality and systems quality.

Ibbs et al. (2003) also studied DB and DBB using data from 67 CII projects by comparing cost growth, schedule growth and productivity as the performance metrics. Schedule growth results confirmed previous findings (e.g. Molenaar et al. 1999) on the superiority of DB compared to DBB. However, DB was not found superior to DBB when looking at cost growth and productivity.

More recently, Korkmaz et al. (2010) studied the influence of project delivery methods on achieving sustainable high performance buildings. Looking at 12 in-depth case studies covering DBB, DB and CMB, the study investigated the effects of project delivery attributes on project performance at construction completion. Korkmaz et al. found that CMR and DB outperform DBB projects overall; one specific result suggests that projects adopting the DBB method display higher cost growth. The Korkmaz et al. study revealed that the level of integration in the delivery process affects final project outcomes. Interestingly, the results showed that project delivery attributes, such as owner commitment and timing of participant involvement, affect the level of integration more than the characteristics of the project delivery method selected.

One of the latest studies comparing delivery systems contrasted IPD to other delivery systems. Cho and Ballard (2011) studied whether the Last Planner System (a production planning technique) improves project performance, and also whether IPD projects show different project performance than non-IPD projects. While it was shown that the Last Planner System improves performance, the authors were not able to find significant differences in performance between IPD and non-IPD projects. They performed t-tests on data from 49 projects, but the paper does not provide information about the dataset (e.g. project types, sizes, and locations). The authors' definition of project performance is restricted to reductions in time and cost. However, additional metrics need to be evaluated to complement these results, specifically quality performance, since owners often reinvest the savings into the project to add value to their facility.

To summarize this section, most studies provide some evidence for more collaborative delivery systems being superior to less collaborative systems. The statistical significance of the results was stronger in some cases, depending on the type of construction and the scope of the studies performed. However, there is little literature showing significant performance differences for the emerging IPD system.

2.3 Key Performance Metrics

Performance metrics are the dependent variables which are after-the-fact measures of project success, such as unit cost and schedule growth. Previous comparative studies, including some of those discussed above, included several performance metrics in their analyses. There also is an abundant body of literature related to project success factors and key performance indicators. Important project performance metrics used in the literature were compiled, and after a detailed examination an interesting occurrence was evident: many studies focus heavily on schedule and cost performance metrics, while largely disregarding other identified performance metrics, such as: safety, quality, and sustainability. It is only recently that authors stressed the importance of comprehensively measuring performance using several complementary variables.

Initially, the plan was to collect data for each of the metrics identified. However, the long list of performance metrics was modified after receiving feedback from the study's industry panel regarding which metrics will be accessible in a reasonable amount of time and effort. Furthermore, after the data was collected, some metrics needed to be removed because of missing data across several projects. This paper focuses solely on cost and quality performance; the other metrics studied in this research are discussed in *Section 3.4*.

2.4 Research Opportunities, Objectives, and Scope

Conducting a review of the relevant literature was beneficial in understanding what has been previously accomplished in the area of project delivery systems. It also helped uncover gaps and reveal two main research opportunities: (1) there is no consistent IPD definition; and (2) there is a lack of studies showing performance differences for IPD.

First, the finding that there is no consistent definition of IPD presents an opportunity to unify and standardize a definition for IPD, based on the literature as well as the data collected from IPD projects. The lack of a consistent definition is not unique to IPD. As with any new concept, different definitions can exist depending on the source. For example, long before IPD, the definition of DB also was changing. As for IPD, the literature shows several definitions, including some definitions that vary and evolve within the same organization. The definition of IPD, like all new systems, needs to be standardized in order to provide a comparable baseline that others also can use.

There are several existing definitions of "project delivery systems." Cho et al. (2010) have tried to summarize the different definitions under three components: commercial terms, organizational structure, and management system. However, two elements are consistently found in the majority of delivery systems definitions: (1) relationships of stakeholders, and (2) timing of engagement. Therefore, this paper defines a project delivery system as *a system that determines the relationships between the different project stakeholders and their timing of engagement to provide a facility*.

In accordance with the two features of this definition, this paper simply defines IPD as *a delivery system distinguished by a multiparty agreement and the very early involvement of the key participants.* The IPD data shows that “very early involvement” can be quantified as “before 10% of the design is complete”. This definition is similar in essence to the NASFA (2010) definition of contractual IPD, and also has a format consistent with the definition of a project delivery system. Additionally, the term *IPD-ish*, as introduced by NASFA (2010), will be used to describe projects that incorporate some IPD attributes but should not be referred to as IPD because they do not include all the necessary characteristics of a true IPD project, namely a multiparty contract.

Second, there is an obvious lack of studies showing significant performance differences for the emerging IPD system. Other delivery systems that have been around for a longer period of time have enjoyed several studies that compared their performance depending on the type of projects and the various performance metrics of interest. The lack of studies targeting IPD is most likely due to the newness of IPD. Because IPD is a recent development, there is only a small number of IPD projects completed. The only study that attempted to compare IPD and non-IPD projects based on cost and time shows no significant differences. This paper fills the void by studying performance differences across several metrics to provide a more comprehensive understanding of IPD performance through a thorough comparison of IPD and non-IPD projects.

The scope of this study is shaped by the data collected. Few public sector IPD projects are available, since special legislation is typically needed to deviate from the traditional procurement method of picking the lowest bidder. Therefore, as anticipated, most data was received from progressive private owners; however, universities were a noticeable exception as use of private funds may give them some flexibility in project delivery methods.

Vertical construction was targeted, as opposed to horizontal construction. Based on the current use of IPD, the most common types of buildings are large-scale high complexity institutional facilities, such as hospitals and research laboratories. These tend to be large complex projects, justifying the relatively intense initial effort required to carry out IPD. Therefore, hospitals and research laboratories were some of the first types of buildings on which IPD was applied.

Data was collected from projects that were completed within only the last five years, due to IPD being a recent system, and to provide a fair comparison with the non-IPD projects. For research efficiency purposes, most of the data for IPD and non-IPD projects was collected from the construction manager or general contractor (CM/GC), because the CM/GC typically has access to most of the key project information. This study specifically focuses on metrics related to the delivery phase from the CM/GC’s perspective.

3. UNIVARIATE ANALYSIS AND RESULTS

This section uses the collected data to compare IPD to other project delivery systems, and investigates the effect of IPD on all identified performance metrics for which data was available. IPD and non-IPD projects are compared for each performance metric individually. This univariate analysis allows for a clear performance comparison of IPD and non-IPD projects.

Generous industry collaborators granted the researcher access to 35 projects. The left side of *Figure 1* shows how the projects are distributed across several delivery systems, to provide a basis of comparison for the performance of IPD projects. The right side of the *Figure 1* shows the data distribution by project size. One can see that all major delivery systems are represented, and project sizes varied from less than 20 million Dollars to more than 200 million Dollars.

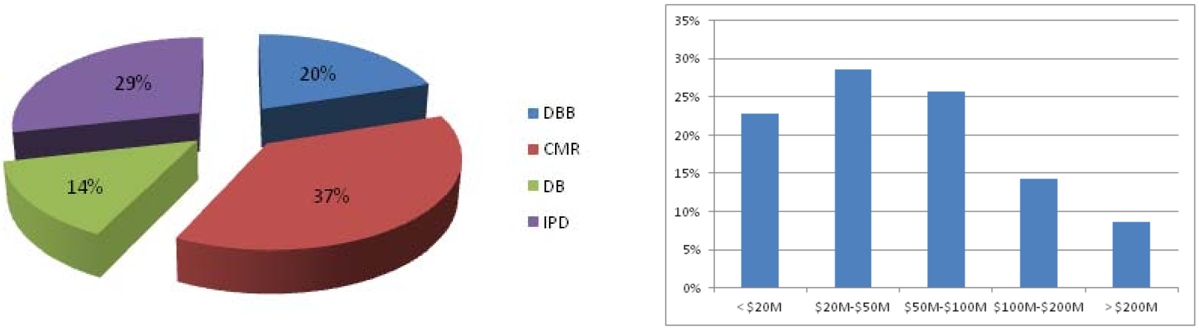

Figure 1: Distribution of the Data by Project Delivery System (left) and Project Size in U.S. Dollars (right)

3.1 Statistical Methods

Two statistical tests were used throughout for each performance metric to provide a more comprehensive look at the comparisons. The two types of statistical hypothesis testing used for this part of the study are t-tests and Mann-Whitney-Wilcoxon (MWW) tests. In general terms, a t-test is optimal when each population in the dataset is normally distributed, whereas MWW is a non-parametric test used when the data cannot be assumed to be normally distributed. In fact, when the data is normally distributed, the MWW test has 86% of the power of the t-test; however, when the data is not normally distributed, the MWW test has a much larger power (up to infinity). It is more conservative to interpret the results of the MWW test because the normality assumption is not needed, and therefore it is less likely to draw the wrong conclusions. Overall, most of the results were identical whether t-tests or MWW tests were used. Therefore, only MWW results are presented in this paper. A discussion of univariate results for individual performance areas follows.

3.2 Cost Performance Metrics

Data for two standard cost performance metrics were available for most of the projects: (1) unit cost, and (2) construction cost growth. Unit cost is measured in dollars per square foot. Construction cost growth is measured in percentage terms by comparing the final actual construction costs to the original estimated construction costs.

Project costs were adjusted to account for location and time. RS Means City Cost Indexes were used to adjust costs based on location. Unit costs were divided by the index to reduce effect of location and provide a fair comparison of construction costs across the United States. Additionally, the ENR Construction Cost Index, available from 1908 to today, was used to adjust the unit costs based on the time of each project. For consistency, the date for substantial completion (month and year) was used for each project.

After adjusting the cost data, IPD and non-IPD projects were compared. Before discussing the results of the statistical analysis, boxplots of the data are presented. Boxplots give a visual representation of the dataset and provide insights as to the distribution of the data. A boxplot is a non-parametric graphical summary of data, displaying the sample minimum, lower quartile, median, upper quartile, and maximum. The median value is represented by a thick black line, dividing the dataset in half, and the box represents the 50% of the data around the median, while the remaining 50% of the data are divided equally above and below the box.

The boxplots on the left side of *Figure 2* show the construction unit cost data in dollars per square foot. The x-axis separates the IPD projects in green and non-IPD projects in red, while the *"IPD-ish"* projects that did not use a multiparty contract are plotted in yellow in the middle.

The vertical axis corresponds to construction unit cost, and the boxplots show that IPD projects (in green) seem to have a median unit cost slightly higher than the non-IPD projects (in red); the values for the medians are represented by the thick horizontal line around the middle of each boxplot. However, these findings are only based on plots of the raw cost data, and any visual differences need to be tested for statistical significance.

The boxplots on the right side of *Figure 2* represent the data for construction cost growth in percentage of the initial cost estimates. One cannot see major differences in medians here, but again the differences need to be tested for statistical significance.

Next, MWW tests are used to determine whether there are any statistically significant differences in cost performance between IPD and non-IPD projects. Both two-sided and one-sided tests were conducted to compare construction unit cost and construction cost growth for the IPD and the non-IPD samples.

The tests result in p-values that can be interpreted as follows: for each individual test, the smaller the p-value, the more significant the performance differences are between IPD and non-IPD projects. The threshold used is a p-value of 0.05 below which the performance differences are considered statistically significant. The null hypothesis used for these tests is that the performance metric is equal for both the IPD and the non-IPD samples. The alternative hypothesis for two-sided tests is that the IPD and non-IPD samples have a dissimilar performance. When the tests do not reject the null hypothesis, it can be assumed there are no significant differences in performance between IPD and non-IPD. When the tests reject the null hypothesis, the alternative hypothesis is true and IPD has a dissimilar performance for the studied metric. In the four tests conducted, all the p-values were larger than 0.05 denoting no significant differences in cost performance. The results for the two-sided tests are shown in *Table 1*. However, the discussion of project costs is incomplete without considering project quality, as will be discussed in the next section.

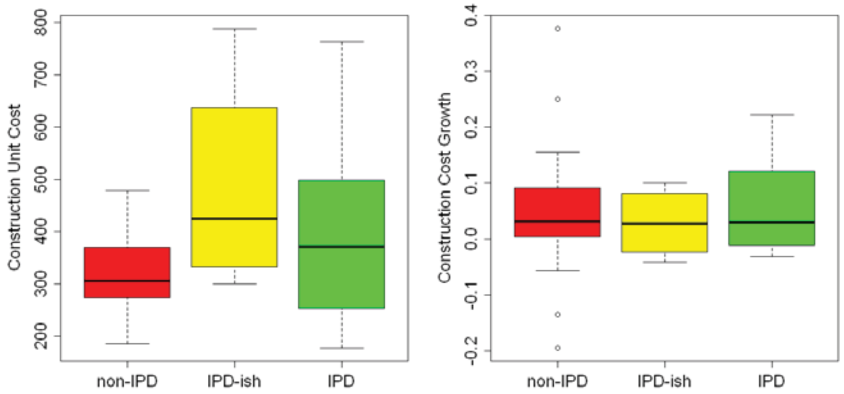

Figure 2: Boxplots for Cost Performance Metrics

Table 1: Hypothesis Testing for Cost Performance Metrics

Hypothesis Test Number	Hypothesis	p-value	Outcome at 95% level
1	IPD projects result in a different unit cost than non-IPD projects	0.659	Fail
2	IPD projects experience a different cost growth than non-IPD projects	0.941	Fail

3.3 Quality Performance Metrics

The previous section showed there are no statistically significant differences in cost performance between IPD and non-IPD projects. However, as mentioned earlier, the cost discussion is incomplete without considering project quality in order to make a more comprehensive comparison. Since quality is hard to measure, both qualitative and quantitative performance metrics were evaluated to provide a good understanding of quality performance. The quality performance metrics include: (1) the quality of major building systems; (2) the number of deficiency issues; (3) the number and cost of punchlist items; and (4) the cost of warranty and latent defects.

The eleven major building systems surveyed include structure, mechanical systems, and finishes. Respondents were asked to provide the quality of each system on a scale of 1 to 5, representing Economy, Standard, High Quality, Premium, or High Efficiency Premium. Deficiency issues are issues that arise during the course of construction, and can be related to numerous reasons, such as failed field inspections and jurisdiction problems. Punchlist items are the uncompleted or unsatisfactory items remaining after the substantial completion of a project, such as damaged building components or problems with the installation of building materials. Warranty costs are measured in the first year of occupation. Latent defect costs are measured after the end of the one-year warranty period.

All of the above items serve as indicators of the building quality. In order for these items to be compared across a number of projects of different sizes, their values were normalized. For example, the number of deficiency issues per million dollars was obtained by dividing the total number of deficiency issues for a project by the total project cost. The number of punchlist items per million dollars was calculated in a similar manner. The relative cost of punchlist items in percentage of the total project cost also was obtained. The cost of warranty and latent defects was obtained in percentage of the total project costs.

The upper left corner of *Figure 3* shows the boxplots for overall project quality combining all major building systems. There is a clear difference in quality between the non-IPD projects in red and the IPD projects in green. The upper right corner shows the boxplots for the number of deficiency issues per million dollars. Even before performing any statistical analyses, one can see that IPD projects experience much less deficiency issues than their non-IPD counterparts. Additionally, IPD projects in this sample have considerably fewer punchlist items than non-IPD projects, as shown in the lower left corner of the figure. Finally, the interpretation of the warranty costs and latent defects is not very obvious and will need statistical testing. As discussed earlier, these findings are only based on plots of the raw cost data, and any visual differences need to be tested for statistical significance.

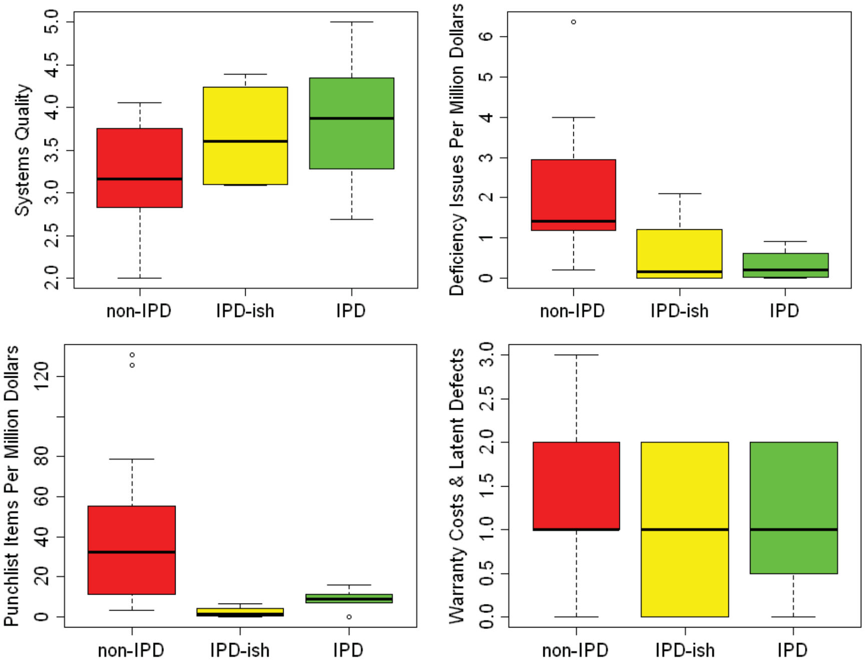

Figure 3: Boxplots for Quality Performance Metrics

Both two-sided and one-sided MWW tests were conducted to statistically verify the significance of the differences observed when comparing quality metrics for the IPD and non-IPD samples. Most tests showed significant differences; the one-sided test for systems quality showed a p-value of 0.032 indicating IPD projects have significantly superior quality over non-IPD projects. This result is significant at the 0.05 level and demonstrates that IPD projects have a higher quality than their non-IPD counterparts.

Similarly, both two-sided and one-sided MWW tests were conducted for deficiency issues, and both tests showed significant differences between IPD and non-IPD projects. The one-sided test provided a p-value of 0.001 indicating IPD projects have significantly less deficiency issues than non-IPD projects.

This result is significant at the 0.05 level and the more conservative 0.01 level. In fact, the median value for non-IPD projects is 1.4 deficiency issues per million dollars versus 0.2 deficiency issues for the IPD projects. The point estimate for the difference is 1.4 issues per million dollars with a 95% confidence interval ranging between 0.5 and 3.0 issues.

Additionally, both two-sided and one-sided MWW tests were conducted for the two metrics measuring punchlist items: the number of punchlist items per million dollars, and the cost of punchlist items in percentage of total construction cost. All four tests show significant differences between IPD and non-IPD projects. The one-sided test for number of items per million dollars shows a p-value of 0.013 indicating IPD projects have significantly fewer punchlist items than non-IPD projects. This result is significant at the 0.05 level, and the median value for non-IPD projects is 32.39 items versus 8.98 for the IPD projects. The point estimate for the difference is 23.05 items per million dollars, with a 95% confidence interval for the difference ranging between 2.82 and 48.18 items. The width of the confidence interval is a function of the sample size and the variance of the data.

While the tests conducted for the latent defects do not show significant differences between IPD and non-IPD projects, the tests for warranty costs show differences in performance. The one-sided test shows a p-value of 0.040 indicating IPD projects have lower warranty costs than non-IPD projects, and this result is significant at the 0.95 level. The results for the one-sided tests are shown in *Table 2*.

Table 2: Hypothesis Testing for Quality Performance Metrics

Hypothesis Test Number	Hypothesis	p-value	Outcome at 95% level
1	IPD projects result in a higher systems quality than non-IPD projects	0.032	Pass
2	IPD projects result in fewer deficiency issues than non-IPD projects	0.001	Pass
3a	IPD projects result in fewer punchlist items than non-IPD projects	0.013	Pass
3b	IPD projects result in lower punchlist costs than non-IPD projects	0.003	Pass
4a	IPD projects result in lower warranty costs than non-IPD projects	0.040	Pass
4b	IPD projects result in lower latent defects costs than non-IPD projects	0.442	Fail

This section provides the first quantitative proof that the IPD system has superior quality performance as compared to traditional delivery systems. Combined with the previous section on cost performance, it provides a better understanding of IPD project performance by demonstrating that IPD delivery systems result in higher quality projects at no significant cost premiums. The next section overviews additional key performance metrics.

3.4 Additional Key Performance Metrics

Several additional metrics have been investigated but will not be covered in this paper. Data for four schedule performance metrics were studied: construction speed, delivery speed, construction schedule growth, and schedule intensity. Three safety metrics also were measured: the number of OSHA recordables, the number of lost-time-injuries, and the number of fatalities. Three types of project change performance metrics were targeted: total percent of change in the project, reason for the changes, and average change order processing time. Communication performance included direct means of communication as well as process inefficiencies and work that needed to be redone. The research focused on requests for information, rework and resubmittals. Three labor performance metrics were available for data collection: (1) extent to which additional labor is used, in terms of overtime, second shift work, and over-manning; (2) trend of Percent Plan Complete (PPC), a measure of work flow reliability; and (3) labor factor, measured as a ratio of the total cost of work divided by the labor cost of work. Material waste metrics included: total value of material waste, percentage of waste recycled, and percentage of waste sent to landfills. Business performance metrics included overhead and profit, and the effect of the project on the company image and potential for return business.

The most significant differences in performance were found for quality metrics, project change metrics, team communication metrics, and business or financial metrics. These were followed by improvements that were less significant for schedule, safety, and material recycling metrics. Cost performance and labor performance did not show any differences between IPD and non-IPD projects.

4. CONCLUSIONS AND RELATED WORK

This paper presented the first statistical proof that IPD offers a superior performance compared to other delivery systems when used on large high-complexity projects. The analysis demonstrated that IPD can deliver higher quality projects at no significant cost premiums.

The paper only discussed two of the nine performance areas studied in this research as mentioned in the previous section. The results of the remaining seven performance areas provide additional insights to stakeholders embarking on new projects. A comprehensive understanding of the comparative performance can assist owners in choosing the adequate delivery system for their project. Given that initial design and construction costs are often a small fraction of the facility lifecycle costs, AEC project stakeholders such as owners, occupants, and facility managers, should consider the benefits IPD has to offer when choosing a project delivery system.

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